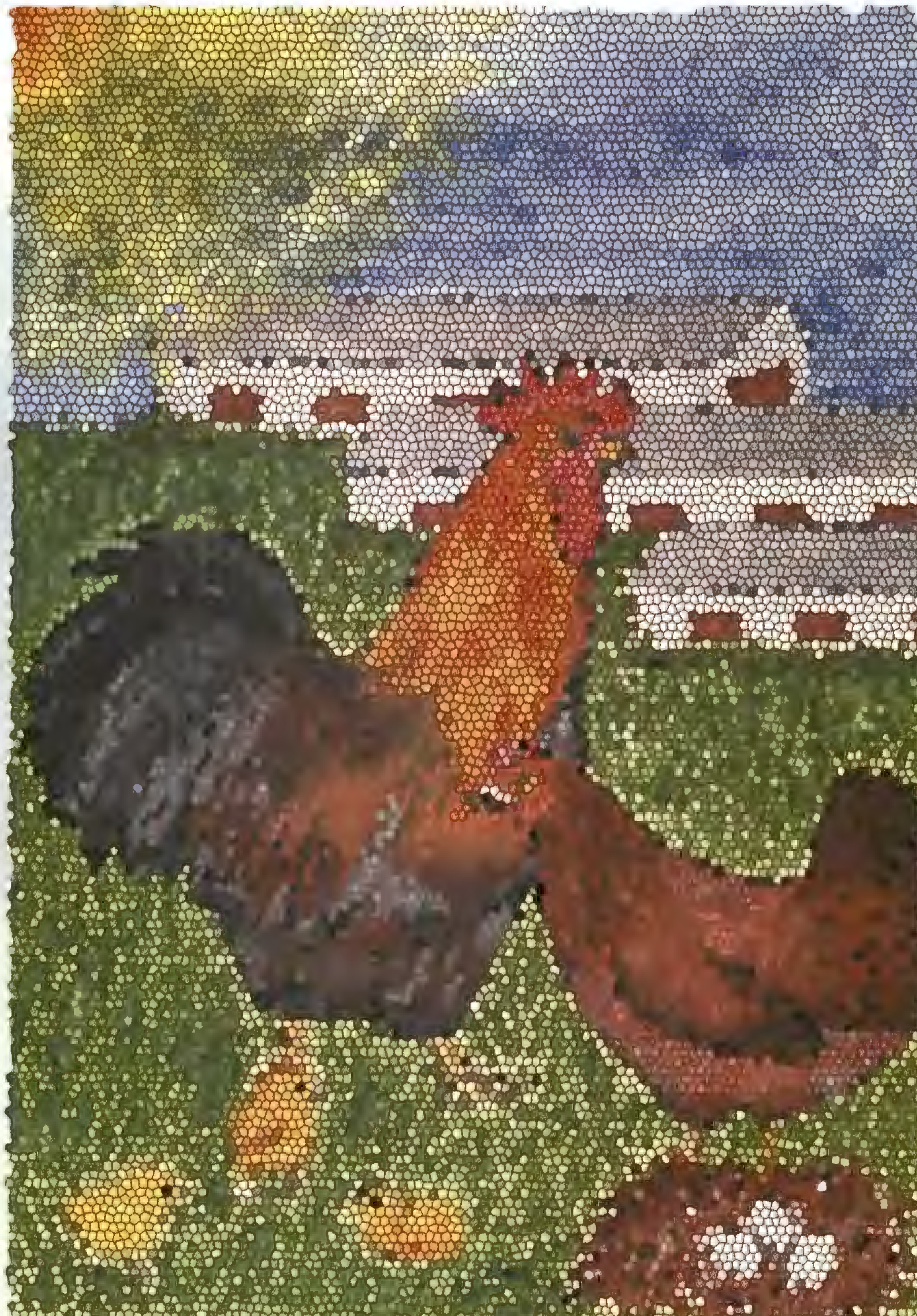
PROCEEDINGS

2000 National Poultry Waste Management Symposium



Edited by J.P. Blake and P. H. Patterson

Proceedings

2000 NATIONAL POULTRY WASTE MANAGEMENT SYMPOSIUM

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Proceedings and Meeting Are Dedicated to the Memory of

Dr. Charles J. Wabeck
Extension Specialist – Poultry Processing and Products
1938-2000

Dr. Charles J. Wabeck, 62, also known as "Chuck" or "Charlie" to many of his friends and colleagues, died on August 7, 2000 in Salisbury, Maryland. Born in Montague, Massachusetts on July 16, 1938, he was the son of Laura Samorajski Wabeck and the late John David Wabeck.

Dr. Wabeck graduated from the University of Massachusetts in 1962 with a bachelor of science degree in poultry science, from the University of New Hampshire in 1964 with a master of science degree in poultry science, and from Purdue University in 1966 with a doctor of philosophy in food science. He retired in 1999 as a professor at the University of Maryland at College Park after 30 years of service. As Professor Emeritus, he continued to serve the University of Maryland and provided assistance to various government and private organizations on poultry processing and food safety until his untimely death. He was a co-founder of the National Poultry Waste Management Symposium in 1987 and was an active member of many professional and civic associations such as the Institute of Food Technologies, Poultry Science Association, Poultry and Egg Institute Research Council, National Poultry Improvement Plan, National Chicken Council, National 4-H Poultry and Egg Council, International Meat and Poultry HACCP Alliance, Delmarva Poultry Industry Inc., Mid-Atlantic Cooperative Extension Poultry Health and Management Unit (MACE), Maryland Extension Specialists Association, Epsilon Sigma Phi and Gamma Sigma Delta. He was a member of the St. Francis de Sales Catholic Church and the Knights of Columbus in Salisbury. In addition, he was state director for the American Poultry Association and served on the Judges Licensing Committee and was a member of the American Bantam Association. Dr. Wabeck received many awards, published more than 200 professional papers, and gave more than 100 professional presentations during his lifetime.

In addition to his mother, he is survived by his wife of 36 years, Sandra Borowski Wabeck of Salisbury; a son and a daughter-in-law, John E. and Shoko Wabeck of Napa, California; a daughter, Karen M. Wabeck of Miami, Florida; and two foster children and their families. Most importantly, according to Dr. Wabeck's family, Chuck was a beloved husband, father, and son with many special friends.

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Patricia Curtis
Food Science Department
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POSTER PRESENTATIONS

2000 National Poultry Waste Management Symposium

Dates: October 16 - 18, 2000

Location:

Sheraton Fontainebleau Hotel
Ocean City, MD

Preface

Since 1988, six National Symposia have been held biennially to communicate the latest technology and information regarding poultry waste management. Today, environmental concerns for the quality of air we breath, water we drink and the environment we habitate are on the minds of most Americans. The majority of the people in the poultry industry share the same concerns and goals for a better environment. With this Seventh National Symposium and Proceedings, the Program Committee hopes to further the understanding of waste management issues and to provide some solutions to the betterment of our national environmental resources.

The 2000 National Poultry Waste Management Symposium is targeted to meet current and future needs of the poultry industries when responsibly dealing with environmental issues and challenges. The program begins with a General Session covering broad topics related to poultry by-products, social and regulatory concerns, air quality concepts, and nutrient utilization. Concurrent sessions devoted to Production and Processing topics follow with additional research and technologies presented in posters and commercial exhibits. The final day is devoted to tours of production and processing facilities. The Proceedings serves to disseminate this wealth of information to others that were unable to attend.

The Audience focus continues to be mid-level managers, and decision makers at all levels in the poultry production system. We actively encourage participation by growers and independent producers. The Mission of the Symposium continue to provide cutting edge, timely, and hard-hitting presentations that address the need for comprehensive programs that assist members of the poultry production system to fulfill their individual and collective environmental protection responsibilities.

The Program Committee wishes to thank all persons, exhibitors, corporate and government sponsors that graciously helped to make this Symposium successful and well attended.

Editorial

The manuscripts presented herein were reviewed and subjected to minor revisions, as necessary, by the editors. The manuscripts were not evaluated by a peer review process. We wish to thank those authors who diligently prepared their manuscripts in a timely fashion to allow its dissemination at the Symposium.

Unless otherwise stated, mention of trade names in this Proceedings does not imply endorsement by the editors or symposium sponsors.

John P. Blake
Paul H. Patterson
Editors

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Acknowledgments

The organization and administration of a successful symposium requires the diligence and cooperation of many individuals and organizations. This symposium is no exception. The organizing committee recognizes the essential contributions of all committee and session chairs, committee members, organizations, and others who have participated in planning and implementing this innovative symposium. Cooperation among the committees and the dedication and perseverance by the committee chairs is greatly appreciated. A sincere thank you is extended to those involved in the planning and execution of this workshop.

Several other contributors to this Symposium have made in-kind and financial contributions
to this Symposium. Novus International provided direct speaker support for Alex Avery, Center for Global Food Issues. The Poultry Water Quality Consortium provided a financial contribution in support of this Symposium as well as participating in program planning functions.

The organizing committee would like to recognize Wanda Linker and the Alabama Poultry and Egg Association for their coordination of registration and other financial related activities. Their involvement has definitely contributed to the success of this symposium for many years.

The editors and organizing committee are indebted to Patricia Owen for her technical assistance and dedicated efforts in ensuring the quality and timeliness of the proceedings.

INTRODUCTION

Richard D. Reynnells
National Program Leader, Animal Production Systems
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Plant and Animal Systems
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Washington, DC 20250-2220

The first National Poultry Waste Management Symposium was held in 1988 through the local efforts of Ohio State University Poultry Science Department faculty, and based on the vision and cooperation of several poultry scientists at Land Grant Universities, industry, and in government. We first overcame the inertia of "business as usual" of 1986, then voted at the 1987 Poultry Science Association Annual meeting to hold the symposium. The team took significant financial risks, with no safety net. Through the cooperative efforts of several dedicated professionals, our biennial program has continued to address cutting edge issues and contributed to the stimulation of thought and action on several aspects of environmental protection throughout the poultry system. Numerous Land Grant University, industry, and other personnel have provided exceptional leadership in maintaining this program. Everyone knows their true contribution so there is no benefit to enumerating these personnel and their accomplishments. A matter of personal pride is that the symposium's planning and implementation has been characterized by a true team effort, total inclusiveness, and commitment to providing cutting edge information for the poultry system. The team has pulled together and taken up slack as was necessary and has produced outstanding programs and documentation through the proceedings.

As symposium coordinator, beginning with the failed attempt to generate interest in 1986, and the subsequent 1987 inception, I find it is now time to begin the process of transferring responsibility for the symposium to another generation of leaders. If the program is relevant and useful, someone will provide the respective overall and component leadership. Feedback from various sources indicates the need to continue this meeting, which has led the way for many current environmental protection programs. However, it is important to remember that similar meetings were held in the early 1960's. To paraphrase Charlie Sheppard's (retired poultry scientist from Michigan State University) observation *circa* 1975, "many ideas in poultry are not truly new, because every 25 or so years people recycle or rediscover management concepts that seem new at the time". We have merely carried on a long tradition of Extension and Land Grant University leadership in the area of environmental protection programs, based on best available science. The transition will start in 2002, and be in place by the end of the 2004 symposium. I will participate at some other level from that time until I leave this position.

A point we must recognize is that water has evolved from an abundant resource that was marginally if at all necessary to conserve ("the solution to pollution is dilution"), a cheap solvent (convenience and mandated meat or egg processing procedures), a nutrient, or a carrier of drugs or vitamins, to a commodity today. Water company stock is now traded by the public. Bottled water is sold in most grocery and convenience stores. Bottled or filtered tap water is provided for many offices and homes in urban and rural areas. International organizations proclaim the current and projected extent of potable water shortages. We have begun to treat potable water as the scarce resource that it has become. We have begun to more fully recognize the essential nature of water and our finite supply of this resource for human and animal consumption. Water quality and quantity (WQ2) issues will increase in importance in the future and will significantly affect the political interaction of nations. We must ask the questions: "Are we in time?", "Are we doing enough?", and "How can we put the politics of egocentrism, short term profits, or personal gains behind us to create win-win solutions to environmental challenges?".

In some countries, water is controlled by the government and allocated according to current policy. Agriculture may not be the first priority for water, particularly potable water. Urban needs and industrial needs may come before crop production, and crops may have priority over animal production. Justification for these statements regarding the severe and potentially severe shortage of potable water come from United Nations documents, international non-government organization estimates, and actual conditions in some countries as reported in the media.

We have for years attempted to reduce water use in our processing plants only to have government mandated procedures put in place to address food safety concerns, that increase water use. Recycled water, treated to potable standards, should be an option for processing plants to allow a reduction in water utilization. This has been reported to not be true in some states. There are some people who understand the protection of the quality and quantity of our potable water supplies is a societal concern, and believe we must take a comprehensive approach to achieve the best overall solution to environmental pollution given available and future resources. This would seem a worthy goal of government, industries and individuals, where actions should be compatible with that goal.

Environmental issues are a high priority with most industry people, not from a threat of regulation standpoint, but from the recognition of a need to protect the environment for their children and grandchildren. There is a great need for mutually respectful interaction, not manipulation, between regulators and the regulated community. If that situation does not exist, optimal progress in protecting our environment and supply of potable water will be a secondary priority to the evasion of inconsistent regulations, retaliation by regulators, and an emphasis on environmental politics. Regulators must abandon the policy of close cooperation with activist groups and mere lip service to cooperation with industry. Honest advice from all sources must be honored and evaluated objectively. Everyone in industry must reciprocate with valid and aggressive efforts in pollution prevention and publicize these efforts to the public and legislators.

The focus of pollution prevention must be on a comprehensive approach to environmental protection and a primary reliance on educational, voluntary programs while using regulations as a last resort for individuals that will not accept their responsibilities. These willful, habitual violators, or "bad actors", in industry must be prosecuted to the full extent of the law. "Bad actors" are perceived to be only farmers or industry personnel. However, "bad actors" in government must likewise be held accountable for their sins of commission or omission. This category must include the individuals in government and NGO's that sanctimoniously label industry as polluters, yet inhibit or prevent policy or other mechanisms that would solve or ameliorate environmental problems. Perhaps documentation of wrongdoing and exposure to the public and legislators would be a good first form of punishment. Responsibility is not a one-way street. Much more is at stake than ego fulfillment and the creation and maintenance of political or bureaucratic empires. Only by working together can we hope to create an environment that will provide sufficient potable water for future generations.

The "Poultry Dialogue" environmental protection meetings and products of a couple of years ago was a good first step for official cooperation with regulatory personnel, with the important result that industry has made formal commitments and put programs in place to follow through on Dialogue recommendations. The regulatory community should reciprocate and facilitate mechanisms that stimulate industry capacity to follow through, and not erect roadblocks. Henceforth, the entire industry must be fully proactive, not out of fear of punishment but out of fear of the future if they and everyone else in society are not successful in protecting our scarce resources. There is no more room for "bad actors", either here, or abroad.

Precious time is wasted, as are opportunities to build trust, when possibly inappropriate regulations are presented as a trial balloon---or the intended mandated solution. Regulatory agencies are not intended to be defenders of perceived social justice, or the mechanism of activist groups to achieve their goals, particularly when the root cause(s) of rural problems are complex and can not be addressed by what some people view as apparently vindictive regulations. For example, the co-permitting issue attempted to create ownership of manure by integrated poultry companies using an apparently all or none proposition with no obvious room to accommodate individual farm situations. Many growers were as opposed to these proposed solutions to a contractual and social issue as were animal production companies. This intended mandatory solution is now "on-hold". Would not a preferred solution be to create multiple opportunities to change behavior, even if it meant reauthorization of base legislation? Buy-in by the regulated community can not be achieved by the policies of polarization. Nor is it likely this approach will result in sustained progress in environmental protection. Polarization does have the effect of creating and maintaining a level of command and control, plus the continuation of government contracts with consultant companies and law firms.

Regulators prefer to avoid modifying base legislation that could be argued was not completely correct at the time, or soon after, it was passed. It seems apparent that much of our inability to fully use comprehensive procedures to address nutrient pollution of our environment is due to this inability to use up to date scientific and management data on which to make decisions. For example, animal units as defined by EPA do not appear consistent within or between species, a point which has not been debated by EPA over the last ten plus years. Basing regulations on the nutrient output of animals (thus possibly stimulating innovative nutritional and management modifications) such as is done successfully in Holland, is not considered an acceptable alternative to our system. Commercial fertilizer nutrients have not been addressed by current regulations, while there is some hope with the TMDL program. Regardless of reality, and because animal manures are regulated, with the effects of human wastes and commercial fertilizers not being fully addressed. Animal manure is generally presented to the public and legislators as the first and foremost culprit in nutrient pollution of ground or surface waters. As a taxpayer, it is unsettling that a major economic country such as the USA apparently lacks the intellectual and moral capacity to change base legislation to ensure the most up to date scientific data is used to create legislation and policy, but a developing country such as the People's Republic of China has "Sunset Provisions" on their environmental laws to achieve this goal. While logistical problems exist, long term and positive change is possible if there is a desire to do so.

Intensive animal agriculture of today has in part been created out of the need to spread compliance with government regulations over more units of production, out of society's demand for cheap food, out of the highly competitive nature of the poultry (agricultural) system, and somewhat by the desire to increase profits by having more control of inputs and products (scheduling, quality, quantity). Labor availability, cost issues, grocery store or distributor demands, and regulations also have driven out the small farmers who are idealized in commercials and stories. Perhaps they never existed. An individual farmer's business management skills and preferences have also led to the demise of this important component of society. Many excellent farmers did not have a sufficient level of these skills, interests, or personality to make the changes society required of them. Consumer demands were and are based on cheap food...the "best buy", along with convenience and quality. The only way to keep "small" farmers, or "family" farms, in business is to ensure sufficient income through higher costs to consumers. Even if society accepted this premise, the other factors mentioned previously could still shift production to larger size units.

One very simplistic and difficult to implement suggestion to addressing environmental, food safety, and social issues is to provide added income to growers, and to change the "set point" of their base pay by moving from the $0.04 to 0.05/lb in contracts to double that (or another value). This could be done voluntarily, and coordinated by industry and the Federal government. Anti-trust legislation prevents industry members from discussing prices, so such a coordinated effort would have to be in cooperation with the Federal government who would be required to make a temporary suspension of this law, or some other mechanism to avoid legal problems. This added money to grower's income could in

part be used to update facilities to address these various issues. These environmental and other costs could thus be internalized. Just as grower costs are now a part of total costs, the proposed increased total costs could be passed along to consumers.
Environmental issues are complex and will not be solved until we create win-win solutions that are comprehensive in nature. We must address environmental challenges in a holistic manner, using a team approach.

Speakers will discuss several aspects of regulations, related issues and their impacts. We must deal with issues proactively, so included are discussions of educational and grower programs, and value added alternatives. Air quality is of tremendous importance today and in the foreseeable future so a section is devoted to this topic, as is done for nutrient utilization questions.

The Production Session goes into more depth on residual utilization and marketing alternatives, and the measurement and utilization of phosphorus. One-half day is devoted to new technologies that will improve environmental protection.

Processing has always been a vital part of this program. Rendering continues to face numerous challenges so papers are offered in this area. Discussions of water reuse options may offer solutions to processing concerns. Air quality issues also plague processing plants, so part of the program discusses these type intervention strategies.

We are grateful to Novus International, Inc. for providing sponsorship of Mr. Alex Avery, our luncheon speaker on Monday. An Alternative Perspective on Environmental Protection will be provided by Dr. Tom Simpson at the Tuesday luncheon.

Of great significance to our program are the papers presented as part of the Poster Session. A summary of this information is included in the Proceedings, but for more details please be certain to visit with the authors.

We are also proud of the extensive commercial exhibit section, which is located in the reception and break area. New concepts and proven technologies are presented for your consideration. Educational exhibits highlight effective WQ2 programs at universities or government agencies.

As in previous years, the industry tour is an opportunity for personnel to share observations and potential solutions to common problems.

The primary purpose of this series of meetings is to address current and projected educational, research and other requirements of the poultry system (industry, university, government) in the area of poultry waste management. Therefore, it is very important that each participant fill out the evaluation form and provide feedback to the organizing committee regarding each aspect of the program. If at a later time you discover a topic or speaker you would like to see for the 2002 meeting, please contact the coordinator or any committee member.

If you would like to volunteer as a committee member for future programs, we welcome your participation.

We have tentatively selected Alabama as the site for the 2002 meeting. Let us know your opinion of this decision.

Participants at the symposium have been provided a copy of the proceedings. Additional copies are currently available for \$30.00, plus \$5.00 for postage and handling from:

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Please make the check payable to:

National Poultry Waste Management Symposium

We appreciate your active interest in addressing WQ2 issues and for taking the initiative to learn more about environmental protection, and poultry waste management topics covered in this symposium. We hope the next few days will add to your capacity to understand current problem areas, and your ability to address these and future environmental protection challenges.

CO-PERMITTING AND OTHER ISSUES: CONCERNS AND CONSEQUENCES

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I appreciate the opportunity to discuss the issues associated with Environmental Protection Agency's (EPA's) Animal Feeding Operation Strategy and the underlying statutory authority of "co-permitting." This proposed regulation has caused great concern throughout the agricultural community, in part because the regulation not only blurs the clear statutory distinction between the discharge of pollutants from a point source and pollution resulting from nonpoint source runoff, but also through an attempt to extend liability for compliance with water quality permits to certain persons or entities who contract with farmers and ranchers all across our nation. This aspect of the regulation is of particular importance to small farmers and ranchers who have been struggling to maintain the viability of their operations. Many small farmers have been able to stay on their farms because they have entered into contracts with large companies that sell agricultural products as food commodities. Such companies are generally referred to as "integrators." EPA's proposed regulation places this small farmer/integrator relationship in jeopardy and may ultimately lead to the demise of many family farm operations.

At the outset, it is important to note that the increased federal regulation of animal feeding operations (AFOs) envisaged by EPA in its recent *Unified National Strategy for Animal Feeding Operations* and *Draft Guidance Manual and Examples of National Pollutant Discharge Elimination System (NPDES) Permits for Concentrated Animal Feeding Operations (CAFOs)* and in the proposed revisions to the NPDES CAFO regulations is neither needed in order to fill a regulatory vacuum nor justified by water quality data. First, states throughout the country have instituted their own non-NPDES permitting schemes that address AFOs. The existence and success of these permitting schemes indicates that increased federal regulation of AFOs would result only in increased coordination costs for federal and state governments and unnecessary heightened regulatory burdens for producers. In addition to these financial and logistical problems, water quality data do not suggest the need for increased federal regulation of AFOs. For example, EPA's own data show that impact on watersheds by feedlots and agriculture in general is only a problem in a few localized areas in the United States. [*See* Baseline Description of the Confined Livestock Animal Feeding Industry (Draft Report), Office of Wastewater Management, U.S. Environmental Protection Agency, Sept. 2, 1999 (Figures 4-5 & 4-6)]. Such data do not suggest that the solution to such problems should be approached on a national level.

EPA's discretion in regulating AFOs is circumscribed by Congress' understanding at the time the Clean Water Act (CWA) was passed (1972). The legislative history of the CWA indicates that Congress was primarily concerned with direct, "end-of-pipe" discharges from large feedlots. While EPA does have the regulatory authority to require certain AFOs smaller than 1,000 animal units to obtain NPDES permits, this authority is limited to the very few AFOs that discharge pollutants from their confinement areas to waters of the United States. EPA's regulation of smaller operations should be based on factors that indicate that such operations have a similar polluting potential as larger operations. Many of these farms have not invested in elaborate waste management systems and estimates of implementation costs for the average "small" swine, poultry, beef and dairy farm range from $50,000 to $200,000.

The current NPDES CAFO definition includes only layer and broiler operations that use continuous overflow watering or liquid manure systems. I believe that this definition is not only consistent with EPA's statutory authority but also correctly recognizes the fact that these are the only type of poultry operations that could possibly result in a "discharge" of a pollutant, as that term is defined under the CWA. A related conclusion is that dry manure management systems — because of the absence of water or other liquids — do not result in pollutants that can be discharged through a discrete point source. Accordingly, I believe that EPA is currently without the authority to regulate poultry operations that use dry manure management systems.

CO-PERMITS

Co-permits will drastically affect the rights of those farmers and ranchers who grow agricultural commodities under contract for agricultural processors. Co-permits will sanction these farmers and ranchers and control how they can use their land by dictating where they locate their production operations and where, when and how they can apply animal waste to their fields. What co-permits mean for farmers, ranchers, integrators, agricultural processors and U.S. consumers is not yet clear. However, we can and should anticipate rational economic behavior. The following three scenarios are examples of what could happen to the domestic livestock, feedgrain and processing sectors.

Scenario #1 - <u>Co-permits could result in a massive structural reorganization of the domestic poultry industry:</u> Because of the joint and severe liability associated with ownership of birds, the integrators are likely to use implementation of CAFO regulations as an excuse to change contractual relationships by essentially transferring ownership, production risk and marketing risk back to the producer. We should anticipate a response by integrators where producers would be required to purchase/own the birds, purchase all inputs and then be responsible for sale and delivery of birds that met contractual specifications.

Scenario #2 – <u>Co-permits could result in significantly higher cost for individual farmers and ranchers:</u> It is likely that only the farm and ranch operator will incur the costs associated with implementing NPDES permit requirements. The farmers, not processors, will bear these costs involved in both developing and implementing pollution prevention plans. Generally, contracts with processors have indemnification clauses that place the financial burden of environmental compliance on the farmer/grower. Therefore, processors would bear little, if any, additional costs. On numerous occasions during a Small Business Regulatory Flexibility **Act panel, (January, 2000), EPA officials clarified that they could not, in any way whatsoever, require co-permittees through the "NPDES process" to bear the cost an operator would incur in implementing specific NPDES permit requirements. EPA repeatedly emphasized that there was no way for EPA to contractually bind the co-permittee for any other liability except the liability associated with an unlawful discharge.**

Scenario #3 – Co-permits could result in a shift in how and who produces agricultural products: Currently, independent small businesses contract their resources (facilities, management, labor, and services) to agricultural processors to grow consumer goods. Under the current structure, agricultural processors do not have a financial stake in the capital assets of these small businesses, nor do these small businesses have a financial stake in the capital assets of the agricultural processor. Co-permits and their joint and severe liability could, over a 10 to 15 year time period, force agricultural processors to invest in the resources (production facilities and labor) currently provided by these independent business which would effectively phase out the business opportunity for many small independent farmers and ranchers.

Scenario #4 – Co-permits could result in a shift in global production patterns: The potential impact of such a shift will directly impact the livestock sector, the feed grains sector and agribusiness. As we witness the effects of a global market place, agricultural investors and their capital will seek friendlier environments. Already we have seen growers abandon opportunities in proposed animal feeding/processing operations within the United States for a friendlier environmental atmosphere elsewhere. Countries like Mexico, Brazil and Argentina will welcome the investment and jobs it will bring. These countries stand to benefit from investment in the livestock production sector, in an agricultural processing sector and from increased investment in an existing feed grain production sector that has a huge transportation differential advantage. The United States on the other hand will be left to deal with the displacement associated with our loss of competitiveness as well as the resulting food security and food safety concerns.

COST OF COMPLIANCE

Complying with new NPDES regulations will be costly to many producers. These costs potentially will have a major effect on the future of many individual farms. Survival in this pricing environment means that farms must become more efficient and larger to provide an increasing standard of living that matches nonfarm businesses. Increasing efficiencies on the farm can be gained by purchasing larger quantities, specialization of the labor and management and utilizing larger, more efficient equipment. Since the farmer does not control the price of the products they sell, they must control the cost of production. As environmental regulations are placed on farms, this additional cost of production will stress our current farm structure and accelerate the need for larger, more efficient operations. Environmental issues include controlling contaminated runoff from the housing and feeding as well as spreading the collected runoff and manure produced by animals appropriately on crop fields. During certain times of the year, manure must be stored in order to avoid damaging crops or causing excessive risk to the environment.

Stored manure odors are worse than fresh manure. Increasing the size of storage systems only increases this problem. Much of the negative attention given to farms in rural areas comes from a reaction to the odors produced by farms trying to comply with water quality regulations. A hidden cost of the regulations will be the treatment of manure for odor control. The total cost of manure management systems that will be required to meet the proposed regulations and to control odors may be the largest new expense on farms. The implementation period may have as much of an effect on the farm during the next 15 years as integration has had over the last 30 years.

STATUTORY AUTHORITY TO DIRECT NPDES LIABILITY

EPA's proposal requires an integrator to be a co-permittee for a permit issued under the NPDES, and it imposes upon the integrator joint and several liability for violations of the farmer's NPDES permit. EPA's proposal conveys liability for permit conditions if an integrator and/or person fits one or more of the following three conditions: owns the animals; directs the manner in which the animals will be housed or fed; or controls the inputs or other material aspects of the concentrated animal feeding operation. EPA has no authority under federal law to impose liability as it is proposed in EPA's strategy/guidance documents.

The separation of powers provisions of the Constitution place recognized limits on what each branch of government can constitutionally undertake. Congress "may not delegate to another the power to enact a law, whether in form or effect". The power to make regulations is not the power to legislate in the true sense, and under the guise of regulation, legislation may not be enacted. Regulations are valid only as subordinate rules and when found to be within the framework of the policy which Congress has sufficiently defined. It is fundamental that administrative agencies are creatures of statute and must find within the statute warrant for the exercise of any authority which they claim. This means that EPA can neither add to the requirements established by Congress for the issuance of a NPDES permit nor can it exercise authority not vested in it. In order to successfully maintain that it has not acted in excess of it's authority in promulgating a rule that imposes joint and severe liability on both the owner of a CAFO and the individual/entity with whom he contracts to raise animals, EPA must demonstrate that it has express statutory authority to require the integrator to be a co-permittee - and to be jointly and strictly liable.

CO-PERMITS AND KENTUCKY'S IMPLEMENTATION

Kentucky, the first state to attempt co-permitting, cites statements contained in the USDA/USEPA Unified National Strategy for Animal Feeding Operation ("Strategy"), issued March 9, 1999, for its conclusion that the EPA believes that the owner of the animals is an "owner or operator" for purposes of the NPDES permitting system. Kentucky also cites the Draft Guidance Manual and Examples of NPDES Permits for Concentrated Animal Feeding Operations ("Guidance") issued August 6, 1999. Neither the strategy nor the Guidance states that under the CWA all integrators must be considered owners or operators for permitting and liability purposes. Rather, the Strategy and the Guidance both say that such entities may become operators if they "exercise substantial operational control" over a CAFO. The Strategy states as follows: "EPA believes that corporate entities that exercise substantial operational control over a CAFO should be co-permitted along with the CAFO owner/operator and will clarify this in CAFO permit guidance." In turn, the subsequent Guidance provides: Corporate entities that exercise substantial operational control over a CAFO should be co-permitted along with the CAFO operator. Corporate entities that exercise such operational control over a CAFO are considered "operators" of the CAFO under the CWA Guidance (Section 2.4.) The Guidance then discussed the three factors (ownership of the animals; directs the manner in which the animals will be housed or fed; or controls the inputs or other material aspects of the concentrated animal feeding operation) that Kentucky has placed in their regulation. However, the Guidance merely states that factors such as these three "would be relevant in determining where a corporate entity exercises substantial control over a CAFO." It further states that the determination "should be made on a case-by-case basis."

Kentucky's regulation goes much farther than the suggestions in the Guidance and makes each factor an irrebuttable presumption of "exercising substantial control over a CAFO" so there is no decision on a case-by-case basis. Thus, mere ownership of the animals that are being grown on a farm means that the animal owner who has entered into a contract with a small farmer in Kentucky to grow the animals is considered by the Cabinet to have total operational control of the farm so that the animal owner becomes an "operator" and must be jointly and severely liable for the actions of the farmer.

There is no basis for this extreme approach in the CWA which the Guidance purports to be pursuant to. Moreover, even if the Cabinet were correct when it states that "EPA believes that the owner of the animals is in fact an owner or operator of the CAFO" such a "belief" is not law. Indeed, the federal courts, including the United States Supreme Court, have rejected prior attempts to extend liability to parties who do not exercise substantial control over polluting activities by overextending the definition of "operator" in environmental statutes.

In United States v. Bestfoods, 524 U.S. 51 (1998) the Court determined when a parent corporation may be held liable for environmental cleanup costs at a subsidiary's facility. The Court held that the parent could be held indirectly liable if conditions were sufficient to pierce the corporate veil. The parent could be held directly liable if its own conduct were sufficient for it to be considered an "operator." The Court held that in order for the parent to be considered an "operator" by its direct actions, it "must manage, direct, or conduct operations specifically related to pollution. ..." 542 U.S. at 59. (Emphasis added.) Thus, there must be a causal connection between a person's activities and the pollution in order for a person to be considered an "operator" under Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). The same analysis applies to an "operator" for purposes of the Clean Water Act.

In United States v. Brittain, 931 F.2d 1413 (10^{th} Cir. 1991) the court held that a person who had "primary operational responsibility" for a treatment plant was responsible for violations of the NPDES permit. Similarly, in United States v. Gulf Park Water Co.' 972 F. Supp. 1056, 1064 (S.D. Miss. 1997) the court found individual liability for two defendants who "had actual hands-on control of the facility's activities, were responsible for on-site management, corresponded with regulatory bodies, and were directly involved in the decisions concerning environmental matters." [See also Friends of Sakonnet v. Dutra, 738 F. Supp. 623, 630-31 (D.R.I. 1990) (holding persons liable under the CWA who had control over the pollutants and caused the discharge.)]

Thus, the courts equate a person's discharge of a pollutant with the person's active and direct control of the pollutant. By contrast, Kentucky's regulation has made a person responsible for a discharge of a pollutant under an NPDES permit by requiring him to be a co-permittee and jointly and severely liable for violations of the permit conditions even though he has no active and direct control of the pollutant. The Commonwealth has attempted to shoehorn its newly created liability into the CWA framework by arbitrarily equating an owner of the animals with an "operator" of the discharging facility. There is no federal statutory authority for Kentucky's approach whatsoever, and therefore the Commonwealth cannot rely on its delegated authority to implement the CWA to justify its attempt to expand its authority.

There is no statutory authority for EPA to require a state and/or anyone who does not have direct control of the operational activities at a facility that must be permitted through the NPDES program, and thus the potential to be a part of the causal chain for potential pollution, to be a co-permittee or to have joint and severe liability with someone who does have such control. EPA's actions have not only crossed a bright line and violate the separation of powers provisions of the Constitution, but also usurped the power of Congress.

FINAL THOUGHS – FORECASTS OF GREATER CHANGES TO COME IN AGRICULTURE

Production agriculture is already struggling to deal with ongoing changes in production and marketing. Yet, some analysts see more changes coming in the years ahead. The following excerpts are comments made at the 10th annual conference of the International Food and Agribusiness Management Association in Chicago, Illinois. They provide a provocative insight into the changes that may lie ahead. Three economists spoke to the need for the U.S. agriculture industry to consolidate and bring product value in line with consumer demand.

W. MICHAEL COX, Senior Vice-President and Chief Economist at the Federal Reserve Bank in Dallas, Texas believes the U.S. is shifting to a new paradigm that will be even more remarkable than the last 100 years – a spectacularness to which agriculture has contributed but not reaped. Information and microprocessor technology have driven productivity to a competitive frenzy, creating more products and choices, at prices that are under constant downward pressure. This has led to consolidation across all businesses and industries, with the exception of agriculture. As businesses seek to accumulate a critical mass and scale to be competitive E-commerce will add even greater pressure to accumulate and price products competitively lower. For those who fail to offer more, better and cheaper, the internet and global market place will create a new business that will.

Businesses, including agribusiness, must expect dramatic, rapid change. Production will be driven toward a competitive structure. This will disrupt our production and marketing equilibrium – the plain fact is - we will just have to deal with that. There is a myth that consolidation decreases competitiveness, but in today's global marketplace, competitiveness increases as companies accumulate scale, offer more products with greater value at lower prices. Attempting to break up companies or stop consolidation in the U.S. only pushes technology to somewhere else in the world and the U.S. becomes less of the global leader and more dependent on foreign foods and services.

SHERRY S. COOPER, Senior Vice-President and Chief Economist at BMO Nesbitt Burns in Toronto, Ontario believes agriculture must consolidate production more quickly and substantially than it has so far to benefit from the new economy. Her view is that agriculture is currently structured as an industry where farmers compete on price and volume – not on demand and value. The consequence is that agriculture is a declining sector of the economy. To reverse this trend, there will have to be a serious reduction in the number of producers so production is more rational and value-added. She concludes that agriculture has lost one of its main means of raising prices, inflation. Therefore, the cyclical nature of commodity prices will result in more down side than up side price risk potential. The gross domestic product (GDP) from agriculture is decreasing in developed countries all around the globe (less than 2% of the U.S. GDP). Farm income has not kept pace with the U.S. economy because government subsidies have encouraged farmers to continue to produce, and technology has permitted them to produce too much. Greater deflationary pressure from the growth of e-commerce and the reduction of transaction costs is aggravating agriculture's plight. Productivity is increasing so fast that fewer and fewer producers will be needed in the future to produce the world's food supply. To not consolidate will keep agriculture outside the new economy and poor.

SAMUEL ZELL, Chair of the Equity Group Investments LLC in Chicago believes that in the new economy, agriculture must compete with high-technology industries to attract capital and provide an appropriate return on investment (ROI). Capital not only won't consider agriculture, as it is now structured, in the future it will "flee" the industry.

Agriculture has always been an industry of too many producers. It is also an industry that captures its profits and ROI at cyclical peaks and hands returns back at cyclical lows. Investment in agriculture has been timed to capture ROI at the peaks of the cycle and pulled out on the downturns. Agriculture has never had to compete for capital. In the 21st century economy, capital demands a higher ROI at less risk than agricultural capital can

provide. This has been compounded by an agricultural reliance on artificial price supports and political fixes for all its problems.

For agriculture to compete for capital there needs to be rapid consolidation and rationalization to respond to excess supplies, low prices, a need for more value, political disruption, risks and cycles. There are too many producers making decisions. Larger operations with fewer decision makers can compete more effectively for capital. Consolidation, if done well, will turn this industry into one that can get capital and participate in the new economy.

CONCLUDING REMARKS

What does all this mean and where does it lead us? It is hard to say, but we will conclude this paper with a few thoughts. First, even if the CWA granted EPA the authority to permit all livestock operations and require co-permits of all agricultural processors, it would still be bad public policy. The structural and global implications of this type of public policy have not been properly analyzed by EPA or tested within the legislative arena. Secondly, our Constitution provides for three distinct branches of government - if one branch over-reaches their authority, it is the responsibility of the other two to provide check and balances - my point - under our system of government, the ends does not justify the means and "popular environmental causes" are no different. Unfortunately, the relation between the ends and the means remain widely misunderstood within EPA. Milton Friedman believes "it is tempting to believe the social evils arise from the activities of evil men (or business) and that if only good men (like good EPA bureaucrats) wielded power, all would be well."

A. de Tocqueville, - predicted a "new kind of servitude" when – "after having thus successively taken each member of the community in its powerful grasp, and fashioned him at will, the supreme power then extends its arm over the whole community. It covers the surface of society with a network of small complicated rules, minute and uniform, through which the most original minds and the most energetic character can not penetrate to rise above the crowd. Such a power does not destroy, but it prevents existence; it does not tyrannize, but it compresses, enervates extinguishes, and stupefies a people, till each nation is reduced to be nothing better than a flock of timid and industrial animals, of which government is the shepherd."

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FUNDAMENTALS OF EMISSIONS TRADING AS A TOOL TO REDUCE POLLUTION IN AGRICULTURE

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ABSTRACT

Cap and trade programs have been successfully used to reduce air emissions at the local, state, and federal level these programs are established based on several fundamental principles: a cap on total emissions that protects the environment by reducing emissions; accountability in emissions reporting and compliance demonstrations to support the integrity of both the environment and the market,- and simplicity of design and operation. This regulatory model, incorporating these fundamental principles, could be applied to address other environmental concerns.

This paper discusses the evolution of the cap and trade model and its application to the,4cid Rain SO, emissions trading program established under Title IV of the Clean Air Act Amendments of 1990. After presenting the structure of the cap and trade program as it has been applied to air emissions programs, the paper describes why this model may be appropriate for other media such as effluent trading, and also describes the challenges inherent in applying the model to address water quality concerns.

BACKGROUND

Throughout the last decade, emissions trading programs have played an increasingly important role in the development of new air quality programs in the United States. This type of market based mechanism has been used to lower the cost of compliance and in some cases, to improve the environmental performance and accountability of air quality programs. Emission trading programs are currently operating at the local, state, regional, and national levels for a variety of pollutants and air quality problems. It is therefore not surprising that the fundamentals associated with emissions trading programs are being considered for application to other environmental areas such as water quality.

FUNDAMENTALS OF CAP AND TRADE PROGRAMS

Evolution of Cap and Trade: Similar to some effluent discharge control requirements, traditional air pollution control requirements are stated as technology, emission rate, concentration, or percent removal requirements. These air emissions requirements were not traditionally stated in the form of an allowable mass of emissions. Early emissions trading added flexibility to the existing regulatory structure, but did not alter it. This resulted in high transaction costs for each trade and therefore few trades and minimal cost savings.

However, the 1990 Clean Air Act Amendments introduced a different concept in emissions trading, the cap and trade program. This was an entirely new pollution control program that set goals and control requirements in terms of allowable emissions rather than technology or rate requirements. The program required that all emissions be reduced and capped at a particular level. The program also required measurement and reporting of all emissions.

Cap and Trade Structure: Cap and trade programs are premised on the establishment of a budget or "cap" on emissions for a specific group of sources. The sources in air emissions trading programs are usually defined as a certain type and size. The size of the cap is typically set based on a level of emission reductions necessary to achieve the relevant air quality goal. For example, Title IV of the Clean Air Act Amendments of 1990 established the cap for the national Acid Rain sulfur dioxide (SO_2) trading program in the year 201 0 at roughly a fifty percent reduction in SO_2 emissions below 1980 levels. Once the sources and the cap are defined, the cap is then allocated or distributed in some way to the sources as tradeable emissions permits, i.e., allowances, where one allowance authorizes a certain amount of emissions (e.g., one ton).

The sources have two primary responsibilities under a cap and trade program. First, sources must measure and report all of their emissions according to the requirements of the program because consistent emissions measurement and complete reporting provides environmental accountability. And second, the sources must ensure that their emissions are no greater than the amount of allowances they hold for a specific period of time (e.g., the SO_2 program operates on an annual basis).

Under a cap and trade program, the sources have significant flexibility to achieve compliance with the emissions limitations. Sources may reduce emissions and/or purchase allowances in order to comply with the program requirements. The trading provisions allow sources with low control costs to over-control their emissions, thus freeing up allowances that may be sold to sources with higher control costs. In this way, the market minimizes the total cost of compliance while the total emissions are maintained within the cap.

The administrator of the program, usually the regulatory agency involved with ensuring that the environmental goal is met, must collect, verify and disseminate data on emissions measurement and trading activity. At the end of the compliance period, the administrator will compare the allowances with reported emissions. The participant is in compliance if the allowances held by the participant exceed their reported emissions and out of compliance if allowances are less than the reported emissions. If a participant is out of compliance, the administrator enforces penalties for non-compliance.

Benefits of Cap and Trade: EPA's experience with the Acid Rain sulfur dioxide trading program shows that emissions trading can result in proven benefits. The program has achieved the required reductions at much lower cost than originally forecasted (a recent Resources for the Future economic analysis estimated the annual costs of the program at almost $4 billion less than EPA's original prediction). Ambient SO_2 concentrations dropped about 20 percent nationally between 1994 and 1997. Additionally, EPA has estimated the annual health benefits of the program will be $40 billion in the year 201 0.

The reasons for many of the cost-savings attributed to the program are related to the market based aspect of the program. The market has encouraged competition across all emission reduction options, and it provides continuous incentives for innovation leading to increased options at lower cost. The market also provides information on the true cost of controlling emissions, which enables the participants in the market to make better informed compliance decisions.

Importantly, the design of the program enables the market to achieve these successes. Maintenance of the emissions cap, the absence of trading restrictions, and the existence of useful and reliable data to ensure compliance and foster program improvements and analysis ensure the integrity of the environmental goal and encourage a development of the market and therefore cost savings.

APPLYING THE CAP AND TRADE MODEL TO EFFLUENT TRADING

While not directly transferable, many of the fundamentals discussed above might be applicable to address water quality problems caused by both point source and agricultural. Effluent trading is a tool, similar to the air emissions trading model discussed above, that may be used to implement a Total Maximum Daily Load (TMDL) that has been established for a watershed. Under an effluent trading program, individual sources may adjust their allotment, or permitted discharge level, by purchasing equivalent reductions from other sources. This approach offers flexibility in meeting reduction requirements, and trading is entirely voluntary. The EPA has discussed this type of program in its "Draft Framework for Watershed-Based Trading", released in May of 1996. Several examples of effluent trading have been developed including programs in the Tar-Pamlico River Basin in North Carolina, Rahr Malting, Minnesota, Cherry Creek Colorado, and most recently the Lower Boise River Demonstration Project.

The goal of effluent trading projects is to ensure that the TMDL that has been established for a particular watershed is not exceeded. These programs can provide opportunities for point sources to achieve reductions at lowest cost through trading. They also create opportunities for non-point sources to contribute to low-cost reductions through their participation in trading. Additionally, the effluent trading mechanism involves the local communities in the implementation of the TMDL. And as is the case in air emissions trading programs, effluent discharge programs may create a market for new low-cost reduction technologies and new, improved monitoring methods.

CHALLENGES INVOLVED WITH APPLYING THE CAP AND TRADE MODEL TO EFFLUENT TRADING

The most obvious challenge when considering effluent trading is that, unlike the Clean Air act which explicitly authorized emissions trading for S02 under Title IV, the Clean Water Act does not explicitly authorize effluent trading. While it does not prohibit it, interpreting existing requirements to allow for trading may sometimes be difficult.

Additionally, most existing air emissions trading programs affect large stationary sources for whom the monitoring and control costs are cost-effective when compared to the value of the

trading units as well as the benefits of the reductions obtained from the program. Effluent trading will more likely effect small and medium sized sources, and many of the reductions made by smaller non-point sources will only happen if the value of the trading units is sufficient to offset the costs of achieving the reductions. Whether the program is cost-effective will highly depend upon the particular mix of participants and the costs of reducing effluent discharges in the area of concern.

Other challenges are similar in both the air and water context. For example, to allow for unrestricted trading, program administrators assume that reductions from different sources and geographic areas are equivalent in their level of accuracy of measurement and equivalent in environmental impact, or that the benefits associated with the overall level of reduction required by the program will more than offset the effect of any particular trade. Providing sufficient certainty in measurement and analytical justification for such assumptions can be challenging. In many situations, and particularly when the overall level of reduction achieved by the program is not significant, that assumption may not be correct and therefore trading may not be the appropriate mechanism.

CONCLUSION

In summary, the past successes of air emissions trading are based on a sturdy framework of robust emissions measurement and clear rules with clear consequences. This framework incorporates flexibility in how, where, and when emissions are reduced. Most importantly, three goals must be kept in mind when designing an emissions trading program: certainty, simplicity, and accountability. While not appropriate in all situations, the emissions trading model discussed here may be able to provide benefits in other areas, including providing a mechanism for achieving water quality goals more cost-effectively,

WATER REGULATIONS FOR POULTRY PRODUCERS ARE CHANGING

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With its 1998 *Clean Water Action Plan*, the Clinton Administration signaled an all-out effort to tackle nonpoint source pollution and runoff from agriculture. The Plan outlined more than 100 different program initiatives and triggered numerous rulemakings to be completed before the end of President Clinton's term of office. Several of these took aim squarely at agriculture, and animal agriculture in particular. My presentation will discuss two of these key regulatory changes.

POULTRY ELGs AND NPDES PERMITS

One of the principal goals for the *Clean Water Action Plan* was to significantly reduce polluted runoff from animal feeding operations. The Clinton Administration proposed broad policy changes for animal agriculture in its March 1999 *Unified National AFO Strategy*. This strategy spoke of a day in the near future when all animal feeding operations (AFOs) and concentrated animal feeding operations (CAFOs) would operate in compliance with a comprehensive nutrient management plan (CNMP). CNMPs would identify proper steps for collection, storage, handling and land application of animal manure and poultry litter. It also spoke of a day when tens of thousands of CAFOs, including large poultry operations, would be regulated by federal National Pollutant Discharge Elimination System (NPDES) permits. It appears that day is coming soon.

The U.S. Environmental Protection Agency (EPA) will propose in December, 2000 new regulations that will significantly rewrite both the current NPDES regulations for permitting of CAFOs (40 C.F.R.§122.23) and the current effluent limitation guidelines (ELGs) for "feedlots" – including poultry operations (40 C.F.R.§412). The NPDES permit program determines which facilities are subject to permitting. Once a facility is determined to be subject to permitting, a permit must be issued that defines specific discharge (i.e., effluent) limits. The ELG defines the BMPs and other technology-based effluent limitations that are required of pork, beef, chicken and dairy AFOs above a threshold number of animals or managed in a way that could render the operation a CAFO status.

Overall, these requirements are likely to (a) increase producer environmental accountability, costs and manpower to keep up with EPA requirements, operations monitoring and reporting; (b) possibly result in reductions in flock size to meet phosphate restrictions on land application of litter and manure; (c) cause producers to find additional land for excess litter/manure if EPA restricts third-party use; (d) cause transport of manure/litter farther from houses in order to spread it properly; and (e) greatly increase the public's input into poultry operations.

The changes EPA is considering for this December's rules proposal include:

Regulating Dry Poultry Operations

Currently most dry poultry operations are excluded from permitting, inspections and enforcement under the Clean Water Act (CWA) because of EPA's rules defining CAFOs. EPA proposes to change this, which would bring legal costs for negotiating the permits, business compliance costs and requirements (e.g., additional planning, facility upgrades, record keeping, employee training, monitoring, reporting, etc.). The change would include as CAFOs all poultry operations with the potential to discharge pollutants to waters of the U.S. through any operation, including land application of litter and manure. In addition, operations above a threshold number of animals will also become CAFOs. This policy change will eliminate the "continuous overflow watering" exemption dry poultry operations now use to avoid regulation.

Co-Permitting

EPA proposes to require integrators and other corporate entities that exercise "substantial operational control" over animal production to be co-permitted with actual producers. Substantial operational control is defined as: (1) when the corporate entity directs the activity or persons working at the CAFO either through a contract or direct supervision of, or on-site participation in, activities of the facility; (2) when the corporate entity owns the animals; or (3) when the corporate entity specifies how the animals are grown, fed, or medicated.

New Criteria for Determining which Small AFOs are CAFOs

All operations meeting the definition of a CAFO would be required to apply for an NPDES permit. This would eliminate the current exemption claimed by many that they are not a CAFO (and do not need a permit) because they do not discharge except in a catastrophic storm. Smaller AFOs could also be designated CAFOs under some conditions, including: (a) the facility has been cited for a water quality violation within last 5 years; (b) the chicken house, feedlot or storage area is within 100 feet of waters of U.S.; (c) there is insufficient waste storage capacity to meet catastrophic storms; (d) the operator is not implementing a nutrient management plan (CNMP); or (g) the operator is transporting litter or manure offsite to a recipient that is not using a CNMP.

Permitted Manure Management

The NPDES permit would apply not only to the houses/feedlots and manure storage areas, but also to land application areas under the control of CAFO operations. EPA will propose that certified nutrient management plans (CNMPs) become an enforceable part of an NPDES permit, with compliance monitoring and record keeping to back it up. EPA also hints in the document that some restrictions will be placed on offsite litter/manure use by third parties ("*...recipients of CAFO-generated manure would not themselves be considered CAFOs, however, they would remain responsibly for not causing the addition of pollutants to waters of the U.S.*"). If too restrictive, these could upset the market for third party use of litter/manure by producers of row crops, hay and pasture.

Land Application

The proposal will clarify that when animal manure and wastewater are "excessively applied" the agricultural storm water exemption does not apply. EPA will do this by establishing a rate of application based on crop requirements as the agricultural limit for spreading, above which applications would be "disposal" and the facility would be ineligible for the agricultural storm water exemption. Managing phosphorus levels in the soil would become the standard for manure/litter application in several areas of the country. U.S. Department of Agriculture guidance for managing soil phosphorus levels would apply.

Other ELG Requirements

(a) Zero discharge even in presence of catastrophic storm;
(b) additional monitoring, recordkeeping and reporting requirements and BMPs to insure that zero discharge is met;
(c) phosphorus-based standards where appropriate;
(d) establish specific setback requirements for land application of manure in vulnerable areas;
(e) requiring an assessment to determine if the groundwater beneath a feedlot or manure storage area has a direct hydrologic connection to surface water, and protection to stop this if it occurs;
(f) ambient surface water monitoring adjacent to feedlots and/or land application areas;
(g) methane capture for anaerobic lagoons.

TOTAL MAXIMUM DAILY LOADS

Following months of tumultuous debate, EPA Administrator Carol Browner this summer signed into law new federal regulations designed to force the clean up of all "impaired" waters that do not meet state water quality standards -- including those waters impaired by agricultural runoff and airborne pollutants. With these changes, Browner ignored an explicit prohibition from the U.S. Congress, and further fanned the firestorm of opposition that has surrounded this issue since the rules were proposed a year ago. She cleverly avoided a Congressional ban by making the new rules effective a year from now – October 1, 2001. Many in Congress are committed to blocking the implementation, but the presidential election and change of administration complicates their efforts. Most likely, the rules will be implemented in 2001 as written; many states are already applying the rules.

Current Law

The Clean Water Act (CWA) now requires states or EPA to calculate what further discharge restrictions are needed to clean up rivers and lakes that do not meet state water quality standards despite the presence of enforceable point-source permit programs and voluntary nonpoint-source control efforts. This calculation, the Total Maximum Daily Load (TMDL) process, determines these further restrictions so that states can adjust federal NPDES permits to further limit discharges from point source industries in impaired watersheds. States and the federal government also target additional nonpoint source program funds to voluntary programs in such priority watersheds.

In calculating what further restrictions are needed under a TMDL, states must weigh the effects of pollutants coming from natural background and nonpoint source (NPS) runoff from farmland, home lawns, and city streets. Current law, however, does not authorize EPA to require states to regulate farms and other nonpoint sources – just consider their presence in calculating the TMDL. Furthermore, a federal court recently ruled in a California case that EPA also lacks the statutory authority to require states to implement the TMDLs once calculated. But this didn't deter EPA. Beginning in October 2001 states will be required to develop and fully implement TMDLs for all impaired watersheds, even those impaired solely from NPS activities (e.g., runoff of nutrients from land application of manure, soil erosion from field tillage, or air deposition of pesticides and pollutants).

New Rules for Poultry Producers

By the time the rules become law, many states will have voluntarily incorporated the new requirements into their water quality standards, industrial discharge permits, and TMDL program components. This will mean that in impaired watersheds, poultry producers facing the need to obtain an NPDES permit and livestock operators already in compliance with existing NPDES discharge permits will likely find their requirements much more stringent, or permits for expansion or new construction denied. But because the rules also require states to implement nonpoint source TMDLs to restore water quality standards, it could also mean that many farm programs that are voluntary today could become mandatory for landowners located in impaired watersheds.

Since TMDLs must be approved by U.S. EPA, the new requirement that a state demonstrate implementation plans that provide "reasonable assurances" that water quality standards will be attained poses a challenge for agriculture. Compliance with Comprehensive Nutrient Management Plans (CNMPs) will be universally required, although benefits of best management practices (BMPs) on water quality improvement are difficult to quantify, future climatic effects difficult to anticipate, and available BMP funding impossible to predict. Although many states will continue to use voluntary, incentive-based programs to manage nonpoint source runoff in impaired watersheds despite the new TMDL requirements, others will invoke enforceable mechanisms as an easy way to meet EPA's approval requirements.

STATE REGULATORY ISSUES AND IMPLICATIONS: EASTERN USA

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The water quality concerns related to animal wastes are an important environmental, economic, and political issue in the eastern United States. In recent years, there has been a considerable increase in the scope and intensity of state and federal regulations targeted toward animal feeding operations (AFO's). These regulations have important implications for the future of animal agriculture in this area.

The goal of this paper is to discuss the issues, or driving forces, that are behind the development of state regulations, and to explore some of the implications that these regulations have for animal agriculture in the eastern United States. The current and future role of certain federal programs and the impact of the public on these issues are presented in the context of pressures on the state agencies. A few examples of state regulations are provided, and references are included for additional information.

WHAT IS DRIVING STATE REGULATIONS?

State regulations are usually driven by pressure either from the federal government or from the public. Pressure from the federal government comes, largely, from the Environmental Protection Agency (EPA). Pressure from the public usually occurs because of an "incident" which motivates people to take personal interest in a particular issue. Often these two factors are combined, as in the case of environmental incidents that catch the attention of the Federal government. Which of these sources of "pressure" is more important varies by issue and location.

In a very general sense, the federal government has two different arenas of interest related to animal agriculture: point sources and nonpoint sources. Smaller animal operations are generally considered nonpoint sources of pollution, which means that a specific point of discharge cannot be identified. Larger operations, or operations that fit certain other specific criteria, are considered point sources and are regulated in much the same way as factories or sewage treatment facilities. The distinction between these source-types has had an important effect on the way State and Federal authorities interact. The following discussion explores some of the ways that the federal government and the public influence the development of State regulations.

The Role of the EPA

Although there are many statutes that direct EPA to issue environmental regulations (Portney, 1998) the EPA's involvement in water quality issues is largely derived from the 1972 Federal Clean Water Act (CWA), as amended (33 U.S.C.). Of particular interest is the Total Maximum Daily Load (TMDL) program. A TMDL is the maximum daily amount, or *load,* of a pollutant that can enter a body of water while still meeting water quality standards. The CWA requires that a TMDL include 1) a *Wasteload* Allocation (nutrients, or other pollutants, that can come from point sources such as wastewater treatment plant discharges); 2) a *Load* Allocation (such as nutrients from nonpoint sources like lawns, golf courses or agricultural fields); and, 3) a Margin of Safety. If the states do not complete a TMDL process, the EPA is required to do this directly.

Historically the EPA has been reluctant to directly develop TMDL's (Houck, 1997). Therefore, many states have not developed TMDL's within the timeframe specified by the CWA. As a result, the EPA has been sued in a number of states for failure to implement provisions of the CWA (Copeland, 1997). Nationwide, such lawsuits have been filed in approximately 34 states, and seventeen states are presently operating under consent decrees resulting from these actions. (Blacks Law Dictionary defines a consent decree as a court order to which all parties agree.) The most common form of a decree is an agreement on the part of EPA to achieve certain benchmarks (e.g. TMDL's) within a specified time (e.g. American Littoral Society et al. V. United States Environmental Protection Agency, et al: Civil Action No. 96-5920). Although the state may not sign the decree, the appropriate state agency often becomes involved through a separate arrangement with EPA (e.g. a memorandum of understanding, or MOU).

Consent decrees have been an important factor in EPA Region 3. This Region includes the states of Delaware, Maryland, Pennsylvania, Virginia, West Virginia, and the District of Columbia. Although only 17 states nationwide (14%) have consent decrees, four of these states are in Region 3 and the remaining two, Maryland and the District of Columbia, are in litigation (EPA, 1999a). In states such as Delaware, the consent decree has been a major driving force in the development of the TMDL program and the nutrient management program discussed later.

Increased pressure on EPA to fulfill their obligations under the CWA results in increased pressure on the states to develop and enforce regulatory programs that affect the agricultural sector. Pressure from the EPA comes in two ways. The first is the possibility that EPA will take over the TMDL process in the state. As noted earlier, this rarely occurs because EPA has neither the budget nor the personnel to accomplish this on a broad scale. Still, it occasionally *does* occur, and the possibility stimulates a "if we don't do it the EPA will come in here and do it" attitude in the states. A recent court ruling has some important implications for this relationship between state agencies and the EPA.

Pronsolino vs Marcus: The agricultural community has long disputed the authority of the EPA in nonpoint issues. A lawsuit filed in California (*Pronsolino, et al. Vs Marcus,* *et al.*) challenged a TMDL written for the Garcia River on the basis that, since there were no point sources of pollution, the EPA had no authority to initiate a TMDL. In March 2000, California District Court Judge William Alsup ruled in favor of the EPA. He cited both the CWA and prior case law to demonstrate that TMDL's are to be developed regardless of the source of pollution. This portion of the ruling was a setback for organizations (e.g. American Farm Bureau, American Forestry and Paper Association, etc.) that had hoped to show that EPA had exceeded their authority by addressing nonpoint issues.

The ruling also addressed the issue of how the TMDL's are to be applied. The CWA clearly grants the EPA authority to issue permits for individual point sources under the National Pollution Discharge Elimination System (NPDES), and states are required to incorporate TMDL's in their regulations for point sources. However, Judge Alsup noted that States have "...a large degree of discretion...in how and to what extent to implement the TMDLs for nonpoint sources" and could "...refuse to implement a TMDL." This finding was highlighted in an American Farm Bureau press release which stated that "...TMDLs for non-point sources are voluntary, and EPA cannot force states to implement them" (AFB, 2000). The question becomes, does the fact that the EPA has no *direct* authority over nonpoint sources mean that they cannot compel states to implement the TMDL's?

This raises the issue of the second, more indirect way that EPA can apply pressure to the states: funding for state programs. The *Pronsolino* ruling notes that, although states may decide to ignore TMDL's, the EPA could then decide to "...deny grant money..." to these states. This is an important point. The EPA provides funding to the states through a variety of different initiatives, and this funding is an integral part of many state programs. For example, EPA support for the various states in Region 3 exceeded $380 million in FY 1999 (Garvin, personal communication). In the current fiscal year, the state of Delaware will receive approximately $27 million. It is not clear how willing states will be to risk this support.

Point sources: Agricultural operations are effected by Federal regulation of point sources primarily by being designated as concentrated animal feeding operations (CAFO's). The United States Department of Agriculture (USDA) Draft Unified National Strategy for Animal Feeding Operations defines a CAFO as "...an animal feeding operation where more than 1,000 "animal units" (as defined by the regulation) are confined at the facility" (USDA/EPA, 1998). There also are provisions for including smaller operations on a case-by-case basis.

A CAFO is required to have a NPDES permit to operate. These permits are issued by the state agencies that have authority delegated by EPA. As discussed above, CAFO's are considered point sources, and the EPA has more influence over the regulation of these operations than in the case of nonpoint sources. Therefore, one possible way for the EPA to increase their impact within the States is to define more operations as CAFO's.

One example of this is the adjustment to the 1000 animal unit designation for poultry. If calculated by USDA guidelines, relatively few poultry operations would have 1000 animal units (for broilers this would be approximately 300,000 birds). However, the guidelines were changed so that poultry operations with more than 100,000 broilers are considered CAFO's. This means that many medium-sized poultry operations are subject to the more stringent requirements associated with NPDES permits, including comprehensive nutrient management plans (CNMP's) and reporting schedules. It also means that fewer animal operations fall under the direct control of the various state regulations.

On July 18, 2000 the EPA released a document titled "Proposed Regulatory Changes to the 1) National Pollutant Discharge Elimination System Concentrated Animal Feeding Operation (CAFO) Regulations and 2) Effluent Limitation Guidelines for Feedlots." If adopted, the proposed changes will dramatically alter the relationship between the States and EPA. For example, under the existing guidelines approximately 10% of the poultry operations in the State of Delaware are considered CAFO's. However, if this guideline were changed to 300 animal units, 70% of poultry operations would be classified as CAFO's (Delmarva Poultry Industry estimate).

This change in CAFO designation would effectively replace the Delaware regulations regarding animal operations with federal guidelines. Other potential changes that have serious implications for animal operations are requirements for co-permitting (this applies mostly to poultry) and the elimination of the long-standing exemption for 25-year, 24-hour storm runoff. It is interesting to note that this same document states that the proposed changes do "... not have substantial direct effect on the States, on the relationship between the national government and the States, or on the distribution of power and responsibilities among the various levels of government."

Other Federal Programs

Although the CWA has been the ultimate source of most of the recent changes in state regulatory policies in the eastern U.S., in the future other programs are likely to have a large impact. Two of the most important of these programs are the Clean Air Act and the Coastal Zone Management Act.

Clear Air Act (CAA) of 1970: In the past the CAA has focused mostly on emissions from manufacturing industries and from automobiles. EPA Emissions Trends Report (1999b) notes that air quality has improved measurably in the past 30 years. Therefore, public attention has shifted to issues such as ozone and carbon dioxide. Another important area of interest is atmospheric deposition and its contribution to water pollution.

The reauthorization of the CAA in 1990 included a program to study and address the effects of air pollution on water quality in the Chesapeake Bay (similar programs were established for the Great Lakes and a few other areas). Of particular concern is deposition of nitrogen oxides (NOx). In September of 1998 the EPA finalized what is known as the "NOx SIP Call" Rule which requires 22 eastern states and the District of Columbia to prepare State Implementation Plans (SIPs) to reduce NOx emissions. Although the focus of this Rule is on industrial sources, it is important to note that some authors have suggested that, nationwide, approximately 27% of all ammonia emissions come from poultry houses (USDA Air Quality Task Force, 2000). In the current regulatory environment, it is only a matter of time before the CAA becomes a bigger factor in the regulation of these operations.

Coastal Zone Management Act (CZMA) of 1972: This Act is administered jointly by the EPA and the National Oceanic and Atmospheric Administration (NOAA). It encourages states to "...preserve, protect, develop, and, where possible, restore or enhance valuable natural coastal resources..." such as wetlands, floodplains, and wildlife habitat. Although participation is voluntary, section 6217 of the CZMA reauthorization of 1990 required states to issue management measures for various categories of nonpoint pollution. For example, the coastal nonpoint program in the state of Maryland currently addresses issues related to sediment, grazing and septic systems.

The EPA estimates that a third of all Americans visit coastal areas each year (Fox, 2000). As tourism pressures increase, it is reasonable to expect that this Act will be utilized to restrict animal feeding operations in these areas.

In summary, the federal government influences states both by direct control of regulations and permits and by providing funding for a variety of state programs. The issue of direct influence is most evident with point sources, such as CAFO's and their associated NPDES permits, although this influence has also been important in the development of current state regulations. The issue of indirect influence through funding is probably more important with nonpoint sources since the EPA has little direct control over States activities. The federal government will continue to be an important factor influencing the regulation of animal agriculture in this region.

The Role of the Public

The public often plays an important role in the development of environmental regulations. In fact, the CWA discussed above was largely the result of overwhelming public concerns regarding water quality in the wake of incidents such as the burning of the Cuyahoga River in Ohio in 1969 (Ervin, 1998). Such dramatic incidents often have the effect of focusing public attention on an issue that may formerly have been of little general interest. The following is an example of such an incident in the eastern U.S.

***Pfiesteria piscicida* in the Chesapeake Bay:** In recent years, the mid-Atlantic region experienced a series of fish-kills, the cumulative impact of which was similar to the public interest in the Cuyahoga incident. The fish-kills occurred in tributaries of the Chesapeake Bay and in North Carolina. The cause of these incidents was identified as the dinoflagellate, *Pfisteria piscicida* (Burkholder *et al.*, 1999). This organism was particularly noteworthy because it was capable of not only killing fish, but also causing a variety of human health problems.

These incidents would likely have been of only local interest except for three factors: the economic dependence of the region on the Chesapeake Bay, the proximity of the Bay to the nations capital, and the implication of animal agriculture as a contributing factor to the Pfiesteria outbreaks. Researchers speculated that increased nutrient levels in the tributaries could prompt "blooms" of the organism, and the popular press was quick to identify animal agriculture as the source of these nutrients. The result was what has been referred to as "Pfiesteria hysteria" (Washington Times, 12/25/1997).

There is some disagreement in scientific circles over the role of Pfiesteria in these incidents. In addition, no clear connection between the organism and animal agriculture was ever established. Even so, media coverage of this issue was so pervasive that Pfiesteria became a household word, and is still cited as a rationale for more extensive environmental regulations (Fox, 2000). Today the immediate reaction of the press, and the public, to reported fish-kills is to suspect the "flesh eating organism."

It is difficult to overestimate the impact that the public perception of agriculture's role in the Pfiesteria outbreaks has had on regulation of animal operations in this region. For example, the Maryland Water Quality Improvement Act of 1998 was based largely on recommendations from the Governors Citizens' Pfisteria Action Commission (Simpson, 1998). Legislation in Delaware was also strongly influenced by concerns over this issue.

Urbanization: Another important issue related to the public is pressure from urban development. Urbanization reduces the amount of available farmland and, often, valuable wildlife habitat (Ervin, 1998). It also increases the amount of interaction, and conflicts, between urban environments and agricultural operations. The American Farmland Trust (Thompson *et al.*, 1994) ranked the mid-Atlantic coastal plain near the top of the areas in the U.S. threatened by development.

There are numerous examples of localized issues within the various eastern states. These range from incidences of swine lagoon failures in North Carolina to abnormal growth of sea lettuce in the Delaware Inland Bays. The net effect of these incidents, and increasing urbanization, is to focus public attention on environmental issues associated with agriculture. These issues will certainly continue to play an important role in driving state regulation of agriculture in the future.

EXAMPLES OF STATE REGULATIONS

State regulations in the eastern U.S. are generally focused on water quality issues not directly related to human health. Instead, their goal is to protect aquatic habitat by limiting the movement of nutrients to ground and surface waters. In recent years, there has been a considerable increase in the scope and intensity of these regulations, although they vary greatly from state to state (Copeland and Zinn, 1998).

The following is a brief summary of the existing regulations for three states in the mid-Atlantic region. The goal of this summary is to illustrate some of the different approaches to regulating poultry operations. References are provided for more specific information.

Delaware

The Delaware Nutrient Management Act (Title 3, Chapter 22 D.C.) was passed in June 1999. This Act established a Nutrient Management Commission within the Delaware Department of Agriculture (DDA). The Act effects animal operations with more than eight animal units or individuals that apply nutrients to more than 10 acres of land. This means that the Act effects agricultural operations, golf courses, tree nurseries, and the lawn care industry.

The Nutrient Management Program will certify effected individuals at four levels: nutrient generator, private nutrient applicator, commercial nutrient applicator, and nutrient planner. All effected operations must have nutrient management plans, which must be written by a certified nutrient planner. Nutrient management plans will begin to be implemented in 2003, and all plans must be implemented by 2007.

The program allows for uncovered outdoor storage of poultry litter. These stockpiles must be 1) at least 100 feet from any body of water or drainage ditch; 2) at least 100 feet from any public road; 3) at least 200 feet from any residence that is not located on the person's property; and 4) at least 6 feet high and in a conical shape.

For additional information, see the Delaware Nutrient Management homepage at (*http://www.state.de.us/deptagri/nutrient.html*).

Maryland

The Maryland Water Quality Improvement Act was passed in 1998, and regulations are contained in Title 15, Subtitle 20 of the Maryland Code. The Maryland Department of Agriculture administers the program. This Act effects all agricultural operations with annual incomes greater than $2500 or more than eight animal units. Individuals who apply nutrients to more than 10 acres of land must be certified by the State.

All effected operations must have a nitrogen-based nutrient management plan developed by 2001. Operations applying biosolids or animal manures must have a nitrogen-based and phosphorus-based plan by 2004. Soils that test "medium" based on use of the Phosphorus Site Index can receive phosphorus applications at a crop-removal rate. Soils that test "high" can receive the phosphorus rate recommended by the University of Maryland. Soils that test "very high" can not receive applications of phosphorus from any source.

Poultry litter may be temporarily stockpiled, but must be protected from rainfall and runoff. This requirement is less restrictive than Virginia but more restrictive than Delaware.

Maryland has some additional requirements that effect poultry companies, including the use of phytase by the end of 2000. Initially companies also were required to contribute up to $10 per ton for the litter transport program, with the balance being paid by the State.

For additional information, see A Citizens Guide to the Water Quality Improvement Act of 1998 (*http://www.agnr.umd.edu/waterquality/CitzWQ.html*) or the Cooperative Extension site at *(http://www.agnr.umd.edu/users/agron/nutrient/)*.

Virginia

Virginia passed the Poultry Waste Management Program (Section 62.1-44.17:1.1 of the State Water Control Law) in 1999 (Virginia DEQ, 2000). This legislation applies to operations with more than 200 animal units (20,000 chickens). Both the Virginia Department of Environmental Quality (DEQ) and the Department of Conservation and Recreation (DCR) administer this program.

Nutrient management plans are required, and must be written by a certified planner. Stockpiled poultry litter must be 1) covered, 2) located to prevent storm water runoff, and 3) a minimum of 3 feet separation distance from a seasonally high water table or use an impermeable barrier.

Draft regulations specify that nutrient management plans developed after October 1, 2001 must have phosphorus application rates no greater than crop removal or crop nutrient needs. For further information see Virginia's Nutrient Management Program at (http://www.state.va.us/~dcr/sw/nutmgt.htm)

SUMMARY

State regulation of animal agriculture is strongly influenced both by the federal government and by the public. Important issues associated with federal government programs include direct permitting of agricultural operations and compelling states to adopt stricter environmental standards through financial pressure. This form of top-down management has been costly, and many authors have argued for the devolution of environmental regulation to the states (Anderson and Hill, 1996; Kettl, 1998; Schoenbrod, 2000). Eastern states will face increasing challenges to match the demands of federal initiatives with the needs of a locally important industry.

Issues associated with the public include urbanization, tourism, and outrage over specific environmental incidents. Conflicts can be expected to arise as states struggle with these issues, all of which are likely to continue in the future. For agriculture to exist in high population areas, the industry should be proactive in preventing environmental incidents and also take steps to ensure that their concerns are represented in the rule-making process.

Regulations are likely to get more restrictive in the future. It will be important for the states to coordinate their approaches, at least on a regional scale, so that producers don't have such a wide variety of expectations between the different states, and between federal and state guidelines. The future of animal agriculture in the eastern U.S. will depend in large part on the ability of this industry to adjust to a changing regulatory environment.

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STATE REGULATORY ISSUES AND IMPLICATIONS

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There are two fundamental issues at stake regarding state regulatory issues and implications in Ohio – the current permitting process for concentrated animal feeding operations (CAFO) and regulation of agriculture under the Clean Water Act (CWA).

Currently in Ohio, livestock and poultry farms that exceed 1,000 animal units must obtain a permit to install (PTI) from the Ohio Environmental Protection Agency (OEPA) before construction begins. In its present form, the PTI is a construction permit. The theory behind it is that constructing the facility according to stringent plans and specifications will prevent the facility from discharging any pollutants. Therefore, the environment is protected. A livestock or poultry farm is defined as a CAFO if it contains a minimum of 1,000 animal units, which is defined as follows:

1. 1,000 slaughter or feeder cattle, or
2. 700 mature dairy cattle, milked or dry, or
3. 2,500 swine weighing over 55 pounds, or
4. 500 horses, or
5. 10,000 sheep or lambs, or
6. 55,000 turkeys, or
7. 100,000 laying hens or broilers (if the facility has continuous overflow watering), or
8. 30,000 laying hens or broilers (if the facility has a liquid manure handling system), or
9. 5,000 ducks, or
10. 1,000 animal units – combination of species.

For a variety of reasons that we will discuss, the current OEPA permitting process continues to be problematic for Ohio's livestock and poultry farmers. Existing livestock operations are electing not to expand and potential new facilities are choosing not to locate in Ohio because of the permitting process. Furthermore, the issues associated with one large poultry farm have given rise to many groups calling for additional regulations for large livestock and poultry farms. Legislation that provides reasonable, additional regulations for large livestock and poultry farms has been introduced.

When Congress enacted the Clean Water Act (Federal Water Pollution Control Act), it entrusted the United States Environmental Protection Agency (US EPA) with the authority to administer and enforce the Act at the federal level. Under the federal water pollution control program, it became illegal to discharge pollutants into most surface waters unless the discharger first obtained a permit for the discharge. This permit, known as the National Pollutant Discharge Elimination System (NPDES) permit, is the primary enforcement tool used to control whether, and if so how much, of a pollutant may be discharged into a particular stream.

As non-point source pollution, agricultural run-off was <u>not</u> a primary focus of Congress when it passed the Act in 1972 and amended it in later years. Historically, Congress concentrated most of its efforts on controlling pollution from factories and wastewater treatment plans. Not only were these sources perceived as the largest problems, but also their wastes were usually conducted through pipes directly into the stream ("point source" wastewater regulated at the point of discharge at the end of the pipeline). Technology could be developed to collect and treat these liquids more readily than pollutants washed from fields, roads and other land by precipitation. As a result, the Act concentrated on piped wastes, largely ignoring run-off.

In recent years, public interest in the control of precipitation-related agricultural run-off, particularly from livestock and poultry farming operations and facilities, has increased. Much of the public attention has been directed toward agricultural run-off, especially manure and other wastes associated with animal production. Public pressure has led the US EPA to escalate its regulation of animal manure and wastes. On March 9, 1999, in cooperation with the United States Department of Agriculture (USDA)/Natural Resources Conservation Service (NRCS), US EPA released a document entitled "Unified National Strategy for Animal Feeding Operations" (commonly referred to as the "unified strategy"). This document provided a roadmap for the federal government's plans to increase regulations of manure under the NPDES program. On August 9, 1999, US EPA issued a draft guidance document providing additional details about its strategy, entitled "Guidance Manual and Example NPDES Permit for Concentrated Animal Feeding Operations" (commonly referred to as the "draft guidance manual").

PERMITTING

For a variety of reasons, Ohio's current permitting process for CAFOs is problematic and inefficient. However, before we discuss and explore the rationale for this analysis, it is essential that we understand what the OEPA is looking to approve when it reviews a permit application:

- Physical structures on the farm that will hold the manure until it can be field applied.

- Making sure that such physical structures are constructed according to approved agricultural engineering standards. For poultry farms, where manure is typically dry and kept under roof, assuring that the buildings are sound. In all instances, storage structures must not allow any leakage or seepage of pollutants into the waters of the state.

- Manure management plan, which stipulates the methods of manure handling, transportation and application. The applicant must inform OEPA how much manure will be applied and upon whose fields it will be applied. The plan must be designed to assure proper care and final disposition of the manure, so that it is applied properly and does not pose a threat of contamination to the waters of the state.

- Other requirements may be added to the PTI that do not necessarily relate to water quality, such as disposal of dead animals and operational procedures.

So where has the current permitting system gone astray? OEPA has not codified its authority to issue permits specifically for livestock and poultry farms. As a result, the agency has not promulgated standards or procedures by which livestock and poultry permits are issued and enforced. Instead, the PTI process is done on a "case-by-case" basis, where the farmer/producer often does not know what is expected, since no standards are published. This has led to confusion and frustration, both on the part of the farmer, the agency, neighbors and communities.

Other issues have also arisen, and include the following:

- Even though the Ohio Revised Code (ORC) requires the OEPA to either issue or deny a permit within 180 days, several permits have been delayed at the agency for more than one year.

- The length of time to approve livestock permits has increased from 43 days in 1996 to 212 days in 1999.

- The agency adopted by policy, not by rule, a public hearing process where farmers/producers are subjected to needless scrutiny and harassment. (Some producers will not apply for a permit because of this.)

- Because there are no rules promulgated in the area of livestock permitting, each permit is treated as an individual permit and OEPA can add special conditions. A few years ago, it was typical to have only three special conditions added to a permit. Now, on average, there are 21 special conditions on permits.

- The permitting process is reacting to politics rather than taking into account the practical effect of the restrictions on the farm. An example of this is the hearing process that was adopted by the OEPA via policy, not rulemaking, in July 1998, whereby public notification of the filing of the permit is given to all governmental agencies and interested parties. A public hearing follows this notification.

- OEPA has extended its jurisdiction into areas where it has no authority, or where its authority for regulating the construction of at least some agricultural facilities (e.g., fields used for manure application is doubtful. Furthermore, the agency also inserts numerous special conditions into agricultural PTIs that regulate the operation of the facilities after construction. For example, PTIs for livestock facilities include conditions governing the procedures for waste storage and for land application of manure from the facility. Even if the agency's PTI authority applies to agricultural facilities, this authority does not extend to the operation of the facilities.

Other Actions

As previously mentioned, the issues associated with one large poultry farm has driven various groups to call for additional regulations on large livestock and poultry farms. The Ohio Attorney's General office became involved with this issue last year by seeking enforcement actions against Buckeye Egg Farm, Ohio's largest egg producing operation. On December 1, 1999, the Attorney General filed a 27-count lawsuit citing violations of Ohio's solid waste, waster pollution control, safe drinking water, and air pollution control and nuisance statutes. Since then the Attorney General has also filed two preliminary injunctions regarding discharges and fly control.

Legislation

Legislation that provides reasonable rules and regulations for large livestock and poultry farms has been introduced in the current session of the Ohio General Assembly. Senate Bill 141 (State Senator Larry Mumper, R-Marion, Ohio), has passed the Ohio Senate and been sent to the Ohio House of Representatives for consideration during its fall session. In addition to proposing reasonable rules and regulations, the legislation includes provisions to move permitting for CAFOs from the OEPA to the Ohio Department of Agriculture (ODA). Permitting would be a priority for the ODA, and its past regulatory enforcement has been exemplary. Furthermore, enforcement of rules and regulations would be on a pro-active basis at the ODA, not reactive, as has been the practice of the OEPA.

Senate Bill 141 should include the following provisions:

- Transfers from the Director of Environmental Protection to the Director of Agriculture the Authority to issue permits to construct or modify CAFOs that do not require NPDES permits.

- Requires a person applying to the Director of Agriculture for an initial permit to construct a CAFO to submit specified information, provides that information to be included in an application for a permit to modify a CAFO must be established in rules, and establishes causes and procedures for denial of permits.

- Requires the Director to issue a draft permit prior to issuing a permit to modify an existing or construct a new CAFO, and requires the Director to provide notice of an, under certain circumstances, public meetings or public hearings on draft permits.

- Transfers from the Director of Environmental Protection to the Director of Agriculture the authority to issue NPDES permits for agricultural operations that discharge agricultural pollutants from point sources into waters of the state and for the discharge of storm water resulting from agricultural operations, requires the Director of Agriculture to submit to the United States Environmental Protection Agency (USEPA) a program for the issuance of those permits, and provides that the authority of the Director of Agriculture to issue NPDES permits is dependent upon approval from the USEPA.

- Establishes requirements and procedures for the issuance of NPDES permits, and requires the Director of Agriculture to establish terms and conditions of NPDES permits in accordance with rules adopted under the bill.

- Provides for enforcement of the NPDES provisions through orders, adjudication hearings, and injunctive relief, and civil and criminal penalties.

- Authorizes the issuance, denial, suspension, or revocation of any permit by the Director of Agriculture under the bill to be appealed to the Environmental Review Appeals Commission.

- Requires a person applying for a permit who has not operated a CAFO in Ohio for at least two of the past five years and a person to whom a permitted CAFO is being transferred submit specified background information, and authorizes the Director to deny a permit if he finds that the person has a history of noncompliance with the Federal Water Pollution Control Act.

- Authorizes the Director of Agriculture to issue, modify, and revoke orders and assess civil penalties to ensure that owners and operators of CAFOs are in compliance with the terms of their permits, and establishes criminal penalties for failure to obtain a permit from the Director for the modification of an existing or the construction of a new CAFO.

- Authorizes the Attorney General, at the Director of Agriculture's request, to bring an action for an injunction or a civil penalty for a violation related to a permit for the modification of an existing or the construction of a new CAFO.

- Establishes requirements and procedures for the issuance and renewal of review compliance certificates for existing CAFOs.

- Requires persons responsible for manure management at a major CAFO and persons who transport, buy, or sell a certain quantity of manure annually to obtain a livestock manager certification issued by the Director of Agriculture.

- Requires an owner or operator of a CAFO to prepare and submit to the Director an insect and rodent control plan and requires the Director to enforce the plan.

- Authorizes the Director to conduct an adjudication hearing and requires the Director to assess a civil penalty against a person who violates the bill's requirements governing certifications or plans

- Authorizes the Director of Agriculture, if he determines that an emergency exists requiring immediate action to protect the public health or safety or the environment, to issue an order, without prior notice or hearing, stating the existence of the emergency and requiring that action be taken that is necessary to meet the emergency.

- Provides that any person that is responsible for an unauthorized spill, release, or discharge of agricultural pollutants that requires emergency action to protect public health or safety or the environment is liable to the Director for the costs incurred in investigating, mitigating, minimizing, removing, or abating the spill, release, or discharge.

- Requires any person proposing to establish a new major CAFO, to expand by 10% an existing major CAFO, or to expand a CAFO by 10% and to a design capacity of more than 10,000 animal units to meet with the board of county commissioners of the county and the board of trustees of the township where the operation is or will be located to discuss the operation's potential impact on local infrastructure prior to applying for an installation permit from the Director of Agriculture, establishes procedures for the determination of recommendations of needed improvements and their cost, requires the person to construct, modify, and maintain the improvements as provided in the recommendations, and authorizes the boards to initiate mediation to seek compliance with the recommendations.

- Authorizes the Director of Agriculture or his authorized representative to enter on property in order to conduct activities that are necessary for the administration and enforcement of the bill, and authorizes the Director or his authorized representative to examine and copy any records pertaining to discharges that are subject to the bill or any records required to be maintained by the terms and conditions of a NPDES permit issued under the bill.

- Authorizes the Director to enter into contracts or agreements to carry out the bill's purposes, and authorizes the Director of Agriculture to administer grants and loans using moneys from the federal government and other sources for carrying out its functions.

- Creates the Livestock Management Fund for the deposit of money collected from application feeds paid from civil penalties assessed and from civil actions to recover costs from agricultural pollutant spills under the bill, and requires money in the fund to be used solely to administer the bill.

- Establishes compliant procedures for nuisances related to a CAFO, and requires the Director of Agriculture to assess a civil penalty if noncompliance is determined and not acted on by the owner or operator of a CAFO.

- Establishes an affirmative defense in a private civil action related to nuisances arising from agricultural activities at a CAFO if the owner or operator is in compliance with best management practices and the activities do not violate federal, state, and local laws governing nuisances.

- Requires the parties to a dispute concerning an alleged nuisance related to agricultural activities conducted at a CAFO to submit the dispute to non-binding arbitration prior to filing a private civil action.

- Requires the Director of Agriculture to adopt rules that establish procedures for the protection of trade secrets from public disclosure.

- Creates the Concentrated Animal Feeding Operation Advisory Committee consisting of the Directors of Agriculture, Environmental Protection, and Natural Resources, the Dean of the College of Food, Agricultural, and Environmental Sciences of The Ohio State University, and nine appointed members, requires the committee to advise the Director of Agriculture in carrying out the bill and to conduct other duties, and makes an appropriation for the Committee's operation.

- Makes an appropriation for purposes of the Department of Agriculture's livestock regulation program and the Livestock Management Fund established by the bill.

SUMMARY

Clearly, it is time that Ohio, and other states, review legislation and encompassing rules and regulations for large livestock and poultry farms. Most states will probably find that legislation, rules and/or regulations need to be re-written and updated to keep pace with the accelerated rate of changes occurring within the livestock and poultry sector. Such legislation, rules or regulations should be reasonable, based on sound science, and economically feasible.

Additionally, states will need to consider the implications of US EPA's initiative for addressing agricultural run-off that includes large-scale and intrusive activities designed to control agriculture under the NPDES program. Some of these activities fall within the agency's authority under the Clean Water Act, but others do not. Agriculture, particularly livestock and poultry production, will need to decide the best strategy for meeting this challenge.

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CALIFORNIA'S POULTRY NUTRIENTS

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In California, the subject of manure has everything to do with nutrients and nothing to do with waste. Initially, the Nutrient Management Symposiums in our state received a few snickers from producers and scientists alike; but once we talked further about the subject, it became perfectly clear that poultry manure is most certainly a nutrient. A waste to me and to many in our state is something you throw away, has no value and is relatively useless. That's not the case in California, where the demand for poultry manure exceeds the supply. With 250 major and minor agricultural crops in California, poultry manure is a valuable fertilizer that enhances the soil, increases production and promotes both crop and soil health.

California is the number one agricultural state in the nation by far with sales in excess of $26 billion dollars. The sale of poultry, eggs and poultry products exceed $3 billion in the state, and while we are not the biggest poultry state, the contribution of both the poultry and egg business is huge.

While the poultry industry markets its poultry manure as fertilizer and compost, some producers also remanufacture the manure as feed. For the most part, as the barns are cleaned, the manure is hauled away, spread immediately and/or processed as compost, fertilizer or feed. While some manure remains stockpiled for a few days, in the winter months it is covered and secure from run-off into streams and rivers. Since California's poultry business is now concentrated in the bountiful Central Valley, where the agricultural land extends for miles, transportation is convenient, and the nutrients can be applied quickly without problems.

Certainly California's poultry industry faces the same issues as many other states like proper storage, application and handling. However, we don't presently have a problem finding a home for the nutrients; some months find prices better than others. However, I will not discuss the price of poultry nutrients today. And California has something else that continues to assist our industry........The California Dairy!

Today, California's dairies milk about 1,000 cows on average; some only milk 500, others milk thousands. As you know, California is now the dairy capitol of the world, far ahead of Wisconsin and still growing. Just last month a 14,000-cow dairy, planned for the south Central Valley, was discussed during a board of supervisors meeting. With all these cows and all their waste, regulators in California have hardly had time to look at our industry, let alone regulate it. That is good news, because two years ago our poultry industry started incorporating our Nutrient Management Plans into our well-known and effective Quality Assurance Plans.

While the dairy industry faces very close scrutiny by officials, the state's poultry industry continues to encourage volunteer procedures for incorporating Nutrient (or Waste) Management plans on our farms. So far, our efforts are working and our plans are being formulated on every ranch. I'd like to make the point right now that the future would appear rather exciting and doable if it wasn't for the problems some poultry producers have been having around the Potomac River. Whenever the Washington Post features a poultry waste problem, the nation hears about it; whenever Congress thinks it may be poisoned, we're all in trouble.

Because of the national publicity and the growth of dairy farms, California's poultry industry is facing many of the similar legislative remedies that other state presently have as laws. In the past two years, we have successfully killed any state legislation that would mandate "manure management plans" in the state. We continue to argue that volunteer efforts work best, but these arguments only work when we can show our plans are in place and working.

Legislation at the local level appears more eminent in California than at the state level. But the future of the state legislation may be affected by what happens at the Environmental Protection Agency. I'm saving the EPA discussion for later. Some counties are presently considering ordinances to control the manure from livestock. So far, the poultry industry has been able to move ahead without these threats, and although some large poultry and dairy counties are looking at these ordinances, so far it's the dairy industry that is being targeted.

I believe relationships make a big difference when talking to government leaders about the management of manure. Continued nurturing of both local and state officials makes the development of a plan like we're undertaking in California easier. Another word for nurturing is communicating; we communicate often with our local and state officials, and this communication helps us to show how we can be effective without more laws, more regulations and more burdensome oversight programs.

The fact that we haven't had major problems with manure handling in California also helps keep the regulators (and legislators) away. While our relationships continue to benefit by proper handling of manure, the entire "on-farm environmental agenda" is here to stay, and in California we will be discussing poultry's contributions to the environment for many years to come. Just last month, both the California Water Quality Control Board and the California Air Quality Control Board held meetings with the state's agricultural industry to talk about their concerns relating to the environment.

The permitting process in California falls under the California Regional Water Quality Control Board. Since it is already illegal in California for animal waste to runoff into waterways, California will use the existing "Industrial Activities Storm Water Permit" to meet the national requirements as outlined in the Clean Water Action Plan.

The state's Water Quality Control Board is currently holding focus group sessions on how they can increase their fee structure relating to the NPDES permit process. While this process is still in the infant stages, it is readily apparent that the regulators are trying to understand our industries better so that they can make their plans on how we should be regulated. This could be significantly affected by the decisions by the Environmental Protection Agency regarding its desire to revise regulations on the NPDES permit program. Today, our state regulators appear to be content with the fact that poultry manure is dry and NPDES permits would not be required on most facilities.

The state's poultry industry is just beginning to hear from state regulators regarding various issues that could fall under the heading of "Nutrient Management." While I certainly don't relish the idea of spending countless hours of staff time and volunteer time dealing with state and federal issues that I believe are presently being handled by our producers and companies on a voluntary basis, those days are almost here. The California Poultry Federation must continue to work with its national, state and local regulators so that the future contains some sensible guidelines for the management and application of poultry nutrients throughout our state.

MARKETING POTENTIAL OF VALUE ADDED PRODUCTS

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SITUATION

Without a doubt, everyone connected with the poultry industry agrees that we have a problem with too much poultry manure. If we conservatively assume that the seven billion broilers produced each year in the US produce one ton of manure per thousand birds, and assume that each ton takes up an area equal to two cubic yards, then the 14 million cubic yards of manure produced will form a pile three feet high by three feet wide by 7900 miles long. This is almost two and one half times the distance across the US.

In actuality, the problem may be one that is less associated with too much manure than it is one of too much manure in one place. If we think about the fact that we have from the Canadian border to the Gulf of Mexico to spread this ribbon of manure, then marketing and the logistics of transportation become very important.

As the poultry industry has grown, and as it has concentrated, we have seen a great increase in the amount of waste product that is located within one specific area. Because of this concentration, and because of the economics of production dictating that growout will be located proximate to processing and feed milling, in many cases, areas which have too much manure will be within a few miles of areas in which farmers would love to have manure to use as fertilizer.

Even though poultry manure can be used as fertilizer, its concentration of nutrients is such that transport of the product long distances is limited. Several authorities (Weaver and Sauder, 1990, and Ressler, *et al.*, 1992) have placed the distance for economic transport of poultry manure at between 100 and 350 miles when used as a fertilizer, and at least 300 miles when used as a feed (Weaver and Sauder, 1990). Concentration of the nutrients by changing the form of the manure can change the cost/benefit ratio, allowing the product to be transported a much longer distance. If litter is changed into new products with nutrient concentrations specific for a particular application, then marketing to that particular application becomes more important.

PRODUCTS

A whole range of poultry waste products is currently being used. Raw litter or raw manure, straight from the poultry house is usually used as fertilizer within a few miles of production. This product has not been changed and its use, as fertilizer, provides organic material for the soil and nutrients for the growing plants. Evidence suggests that the organic component of animal manure can positively affect soil structure (tilth) and the availability of nutrients (Rosen, 1992). The amount or proportion of certain nutrients however, can potentially cause problems if concentrations in the soil reach high levels. Parsons, *et al.*, 1992, showed no difference in weeds in soil fertilized with litter versus commercial fertilizer, thus allaying farmers fears that weed seed is contained in litter, itself.

Feed

"Deep stacked" poultry litter goes through a period of heating, and fermentation which provides a poultry litter "silage" which can be fed to ruminant animals. Over thirty years of scientific literature exists, which deals with the treatment and use of poultry manure for animal feed. In 1989, 21 states had feed laws which permitted the marketing of broiler litter as feed (McCaskey, *et al.*, 1994). Estimates of the value of poultry litter as feed range from equivalent to the value of alfalfa hay, to one-half the value of soybean meal, to (under a controlled experiment situation) $123.00 per ton (McCaskey, *et al.*, 1994). Covering the "deep stacked" poultry litter to decrease availability of oxygen decreases temperature levels, maintaining available nitrogen (Crude Protein), but still eliminating pathogenic organisms (McCaskey, *et al.*, 1991). In the mid 1990's, I worked with a western Virginia feed company to provide them with litter, which was manufactured, with the addition of other ingredients, into a pelleted feed supplement, which the company sold in a four state area.

Compost

Composted litter relies on stacking (or windrowing) and aeration of the mass for the biological processing of the product into a soil like material. Composting heats the product, thereby decreasing microbiological action for the elimination of odor and pathogens, and fixes nutrients that might normally be given off as ammonia or gas. Composting litter reduces the mass substantially, decreasing the cost of storage and handling. Composted litter can be spread on fields like raw litter, sold as bulk compost through garden centers and landscapers for commercial uses, or bagged and sold through garden centers for homeowner application. Bagged product sold through garden centers is often priced at over four dollars per 40-pound bag ($200 per ton). One product, noted recently in a garden center in Raleigh, North Carolina, packaged in 4-pound bags for indoor potted plant application, sold for over three dollars per bag ($1500 per ton). In any case, the retail price of the composted product is probably not closely related to its cost of production, but to its "marketability".

Efforts are currently underway (by North Carolina State University Cooperative Extension) to work with a mulch products company to compost broiler litter and add this product to its national marketing mix. The potential exists for moving North Carolina poultry litter as far away as the West Coast. This same company also has a division, which blows mulch in large commercial applications. The company is very interested in blowing composted litter to aid in the establishment or rejuvenation of lawns and golf courses. Other composting operations exist in North Carolina to supply a growing demand for a high quality, uniform product. This last point is important, because there have been a tremendous number of low quality products which have made their way into the marketplace, giving poultry litter products a name which is suspect among homeowners.

Pellets

Pelleting poultry litter acts to concentrate and cause slower release of nutrients, to some extent, but more importantly to make easier the handling of the mass. The heat generated in the pelleting process also "sterilizes" the pellets, increasing the safety of handling, transport, and usage. One successful company moves composted pelleted turkey litter from the upper Midwest to Washington/Baltimore/Philadelphia for golf course use. Another company has over a 20 year history of moving pelleted litter from Virginia, to Michigan and Indiana for sod farm and orchard applications. One of the major broiler companies is currently in the process of building a pelleting plant which will allow the company to return grain cards, which bring feedstuffs from the Midwest, to the Midwest filled with poultry litter based fertilizer.

There is at least one pelleting operation in North Carolina—Organic Litter Gro., Inc., of Merry Hill. According to its current sales information, one product that it sells is poultry litter pellets for soil remediation after oil/toxic substance spills. At least one other company is currently looking at North Carolina as a site for a pelleting operation; access to ports for shipment overseas is of primary importance. One of the major poultry equipment manufacturing companies has begun marketing a portable pelleting mill for litter, which might allow a number of farmers to purchase and use it in making cattle feed or pellets for their own needs.

Enhanced Pellets

Pelleting poultry litter has several problems including relatively low plant nutrient analysis (Ransom and Strickland, 1992). Enhancing, or augmenting, pellets with non-organic compounds can make the products specific for a particular application. If farmers spread litter at rates to meet the nitrogen needs of the crop and this is met by a build up of phosphorous, copper, and zinc, then increasing nitrogen rates by augmentation, could decrease the amount of litter needed per acre, maintaining nitrogen levels but decreasing application of potentially harmful elements. Enhancing pellets provides the potential for turning litter into a value added product. The more the litter can be turned into a product meant for a specific need, the greater is the potential for being able to market the product at a profitable price. One application is for poultry litter based pellets for cattle feed with the litter augmented with corn (or other carbohydrate) and vitamin mineral mix to make a complete supplement for livestock.

Mixes

Mixes of poultry litter compost with other substances can successfully be used for specific applications in the vegetable, greenhouse and nursery industries (Rosen, 1992, Builderback *et al.*, 1992). These provide potential for value added product and relatively high profits. They also provide the potential for the movement of litter into new channels of use. Mixes of litter compost, sand, and clay are often marketed as "top soil" to the landscaping industry.

Meat, Bone, Blood, Feathers, Fat, Mortality and Eggshells

All of these are waste products of the poultry industry. Treatment of these products, in some manner, makes them useable, usually as a supplement in the feed, pet food, and fertilizer industries. As technology changes, making technology less expensive, we can expect to see more processing of this type in close proximity to poultry complexes, allowing the recycling of all of these products back into animal or pet feed. Included in this will probably be normal poultry mortality. The average dead bird has cost the company over a dollar. It only makes sense for the companies to look at recovering and recycling the products.

CONCERNS

Quality Control

One of the problems that has arisen in trying to market waste products has been the lack of quality and uniformity of product. Because of the variability in nutrient levels in the litter, itself, there is a certain amount of variation in the nutrients contained even in further processed waste products. Composted products are highly variable due to the variation in litter nutrients, moisture level, and composting procedures observed. Often, further processed litter products are marketed only with a guaranteed minimum nutrient analysis which is set so low that the company is actually making no guarantee of the product other than that it is an organic soil amendment. Increasing quality control over the product can lead to an increase in the value of the product and (ultimately) the price the user is willing to pay. The customer will probably only use a low quality product once.

Marketing

One of the tenets in marketing is that it is usually easier to make a product than it is to sell it. This has been a trap into which many of the operations that have come and gone in trying to find a value added poultry waste product haven fallen. Finding a home for the final product is very important. One North Carolina composting operation receives hatchery waste from all over the Southeast. The operation receives in excess of 100 tons of waste per week. This hatchery waste is mixed about 3:1 with organic material—litter, manure, municipal yard waste, and municipal mixed paper. This 3:1 mix of 100 tons of hatchery waste per week means that there is actually up to 400 tons per week of initial product. On a yearly basis, 400 tons per week becomes over 20 thousand tons of material to being composting. At the end of the cycle, this results in a substantial amount of product to sell to a fairly limited market (chiefly commercial landscapers in the Raleigh/Durham area). This operator was up to his ears (a scientific term) in compost until he hired a full time professional to market the end product. Note that even though the product might be excellent, it still needs to be sold.

Competition and Pricing

One major problem with value added products from poultry waste is competition. Poultry Waste products can command no higher price than the market will bear. The price will be controlled by the supply and demand for poultry waste products, and also by the supply and availability of competing products. Commercial inorganic fertilizers are a major competitor. Either a poultry waste product must be a better fertilizer, or easier to handle, or lower in cost, or many farmers will not consider its usage.

Composted municipal wastes are a major competitor and if not sold as a fertilizer, must be land filled by the municipality at a cost of 30-70 dollars per ton, or sold at a low price to landowners. I have been told, though have not verified, that New York City will deliver composted municipal waste anywhere in the contiguous states for less than 16 dollars per ton (Jim Cummings, NCDA, personal correspondence, 1998). Milorganite, available in bags in garden centers nationally, is composted sewage sludge from Milwaukee, that can be sold at a very low price because it must be disposed of by the municipality, and disposal in a landfill will cost a substantial amount of money. Competition from similar products holds the profit level of many poultry litter products to a minimum.

Regulations

Regulations on the use and disposal of animal manure have to be observed no matter if the product is raw litter or if it is a value added product. In North Carolina, animal manure becomes subject to North Carolina fertilizer laws once it has been altered in some manufacturing procedure—pellets, for instance. This means that the product has to be sold with a guaranteed analysis for major nutrient content. The product also has to be treated as an animal waste, which includes the same nutrient management record keeping and setbacks that must be observed with raw manure. For many farmers, this last requirement may negate some interest in using a value added poultry manure as a fertilizer

In The Future

With the amount of poultry litter that is produced, other alternatives may need to be developed which can remove poultry manure from the waste stream, once and for all.

Electricity Generation and Cogeneration

Electricity generation, or cogeneration of electricity and steam, has been tried in the past. A cogeneration project was tried in Pennsylvania, over 15 years ago (Forest Muir, personal correspondence), with procedural but not economic success. In the early 1990's, I worked with a coal-fired power plant in West Virginia to look at burning poultry litter as a solution to West Virginia's poultry manure problems. The energy equivalent of poultry litter is about half that of soft coal.

Fibrowatt, LTD, of England owns and operates three power plants which burn essentially all of the poultry manure produced in England and Scotland. They are currently trying to interest U.S. entitles in a similar type system. Fibrowatt is honest in that they have been heavily subsidized by the British government, and would need to be subsidized by the U.S. government or by the poultry industry to be successful, here.

The abundance of inexpensive electricity in the U.S. is a problem. The average energy price in the U.S. is slightly over eight cents per KW. Generating power and dumping it on the national power grid will yield only a portion of this KW price, making profitability from this type of undertaking unlikely.

Gasification

Several companies have developed gasification systems which can use poultry litter, and are in the early stages of marketing these systems, for methane generation from biomass. These companies have used broiler litter with a great deal of success. With this technology, poultry litter could be removed from the waste stream, then turned into gas, which could be burned to generate heat, steam, or electricity to power an industry. Replacing purchased power at eight cents per KW with power of your own generation can make this technology look much more potentially profitable than large scale power generation which jumps power into the national power grid.

If we look at central North Carolina as an example, the high energy use by the poultry industry, the wood products industry, and the brick industry, coupled with the availability of poultry litter, all make systems such as these of much interest.

Direct Heat

Several of us, in the past, have looked at burning poultry litter to provide heat for brooding young birds. The fact that the litter packed caused poor oxygen introduction, and resulted in smoldering rather than fast, hot burning of the product was a problem. In the past couple of years, I have heard of at least two separate projects which dealt with small scale fluidized-bed technology, specific for the burning of poultry manure to heat poultry houses. The portable pelleting mill mentioned earlier in this article should also make it possible to generate heat for brooding in pellet stoves.

SUMMARY

At least in part because of a need to manage nutrients from the animal industries, we are in the beginning of a movement toward utilizing our animal waste products, as products other than simply raw manure for fertilizer on field crops. As products are developed, the industry will have to take care that the products they make are saleable and profitable. Products must be designed with marketing in mind.

The industry also needs to be cognizant of the possible problems that can arise as they move into new areas. One example might be problems that could be associated with power generation. If the particulate matter going up the smokestack is more potentially harmful to the environment than over application of manure nutrients to the soil, then the use of a new idea has solved no problems, but has simply caused others.

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LIVESTOCK AND POULTRY ENVIRONMENTAL STEWARTSHIP: A NATIONAL EDUCATIONAL PROGRAM FOR PRODUCERS

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ABSTRACT

A national curriculum project addressing poultry and livestock environmental issues has been funded by the United States Department of Agriculture (USDA) and Environmental Protection Agency (EPA). This project will deliver a national curriculum and supporting educational tools to livestock industry information providers throughout the U.S. for the purpose of supporting livestock producer certification and education programs designed to encourage environmentally sustainable animal feeding systems. A national team of land grant university, USDA, and EPA experts with publication development and marketing assistance from the Midwest Plan Service (MWPS) will develop a user-friendly, core curriculum addressing environmental and regulatory compliance issues. This curriculum will be reviewed and pilot tested regionally prior to its completion. Animal industry information providers will access the core curriculum through regionally sponsored inservice programs, an EPA Ag Center web site, and MWPS publication services. The project was initiated in 1999. A completed curriculum that has been regionally reviewed and piloted is expected to be available in the fall of 2001.

INTRODUCTION

On May 5, 1998, Secretary of Agriculture Dan Glickman stated that animal waste is "the biggest conservation issue in agriculture today, bar none" at the National Summit on Animal Waste and the Environment sponsored by Senator Tom Harkin. Livestock and poultry production can negatively affect surface water quality due to pathogens, phosphorus, ammonia and organic matter; ground water quality due to nitrate; soil quality due to soluble salts, copper, arsenic, and zinc; and air quality due to odors, dust, pests, and aerial pathogens (Council for Agricultural Science and Technology, 1996). Livestock and poultry in the United States produces 111,728,000 tons of manure annually (dry matter) of which 61,538,000 tons is collectible. This represents 3.5 and 3.1 million tons of plant-available nitrogen and phosphorus, respectively.

In light of these environmental issues, greater regulation has resulted at all levels of government. A 1998 survey of Concentrated Animal Feeding Operation (CAFO) regulations in 35 states found that 31 states are experiencing controversy, 30 states have increased incidence of conflict and media attention, and 19 states have proposed legislation within the past year (Edelman and Warner, 1998). A recently released USDA and EPA Unified National Strategy for Animal Feeding Operations presents a plan for expanded federal regulatory efforts to address this issue (USDA/EPA,1999).

A growing number of states require mandatory educational or certification of livestock and poultry producers on manure management and compliance issues. In 1998, 10 states required mandatory training programs for managers of animal feeding operations and/or manure applicators (Edelman and Warner, 1998). Additional states have implemented mandatory certification programs since that time. Land grant universities through their Cooperative Extension programs commonly provide leadership for state certification programs (North Carolina Cooperative Extension Service, 1997; Funk, 1997).

Voluntary educational programs will also be critical to addressing environmental issues within the livestock industry. The Unified National Strategy for (AFO's) states that "Voluntary and regulatory programs serve complementary roles in...ensuring protection of water quality and public health." The strategy further suggests that "Through an aggressive environmental education and outreach effort, USDA and EPA believe that awareness of possible problems can be heightened and producers will be able to identify practices that may be contributing to water quality problems" (USDA/EPA,1999).

PROJECT OUTCOMES

A call for proposals was made for the USDA/EPA National Agriculture Compliance Assistance Program. which was intended to encourage educational programs that would be designed to foster the livestock industry's compliance with environmental regulations. To respond to this project opportunity, a national team of land grant university and Natural Resources Conservation Service (NRCS) experts was assembled to develop a proposal title "Livestock Environmental Issues Curriculum Project". This proposal was accepted and funded in late 1998.

The project's mission statement is: "This project will deliver a national curriculum and supporting educational tools to animal feeding industry information providers throughout the U.S. for the purpose of supporting livestock producer certification and education programs designed to encourage environmentally sustainable animal feeding systems."

The anticipated outcomes from this national curriculum project are:

1. **A nationally recognized, producer-oriented, core curriculum addressing high profile livestock and poultry environmental issues will be developed.** A core curriculum will be developed to facilitate individual state efforts to implement quality educational programs addressing management and compliance topics.
2. **The curriculum will be reviewed and pilot tested regionally.** A team of land grant extension specialists, NRCS staff, and EPA staff will participate in the review process. Cooperative Extension specialists will also participate in the six regionally based pilot tests of the curriculum with 30 producers each.
3. **Curriculum resources will be made available to livestock and poultry producers and information providers through multiple, readily accessible delivery methodologies.** The curriculum will a be made available in electronic format via the web through the EPA Ag Center web site and in hard copy format through MWPS. MWPS, a cooperative publication service for 12 midwest land grant universities will provide national marketing and dissemination of a printed national curriculum. Five regional inservice programs will be implemented for the purpose of introducing information providers to the curriculum.

PROJECT TEAM

To complete these intended outcomes, the project's cooperators have been assembled into three functional teams based upon the three outcomes of this project. Those teams include an author team, a review and pilot team, and a resource access team. Funding agency representatives from USDA Cooperative State Research, Education, and Extension Service (CSREES) staff and EPA Agricultural Compliance Assistance Center (Ag Center) staff are members of this project. A listing of the current project cooperators and their associated involvement follows:

Project Leaders:

Rick Koelsch, University of Nebraska
Frank Humenik, North Carolina State Univ.

Project Manager:

Diane Huntrods, MWPS, Iowa State University

Author Team:

Brent Auvermann, Texas A&M
Charles Fulhage, University of Missouri
Rick Grant, University of Nebraska
Joe Harner, Kansas State University
John Hoehne, University of Missouri
Frank Humenik, North Carolina State Univ.
Larry Jacobsen, University of Minnesota
Rick Koelsch, University of Nebraska
Jeff Lorimor, Iowa State University
Todd Milton, University of Nebraska
Pat Murphy, Kansas State University
Paul Patterson, Penn State University
Karl Shaffer, North Carolina State University
Andrew Sharpley, USDA/ARS
Ron Sheffield, North Carolina State University
Donald Stettler, USDA/NRCS
Theo van Kempen, North Carolina Sate Univ.

Review/Pilot Team:

Ted Funk, University of Illinois
Carol Galloway, EPA Ag Center
Gary Jackson, University of Wisconsin
Barry Kintzer, USDA/NRCS
Rick Koelsch, University of Nebraska
Deanne Meyer, Univ. of California-Davis
Mohamed Ibrahim, North Carolina A&T
Mark Risse, University of Georgia
Peter Wright, Cornell University

Curriculum Access:

Don Jones, Purdue University
Jack Moore, MWPS, Iowa State Univ.
Ginah Mortensen, EPA Ag Center

A critical challenge for the project has been to include discipline and regional diversity in the project team. Individuals representing engineering, agronomy, and animal science have been included in the project team. Regional diversity has been achieved, in part, through regionally located review and pilot team members. (Figure 1).

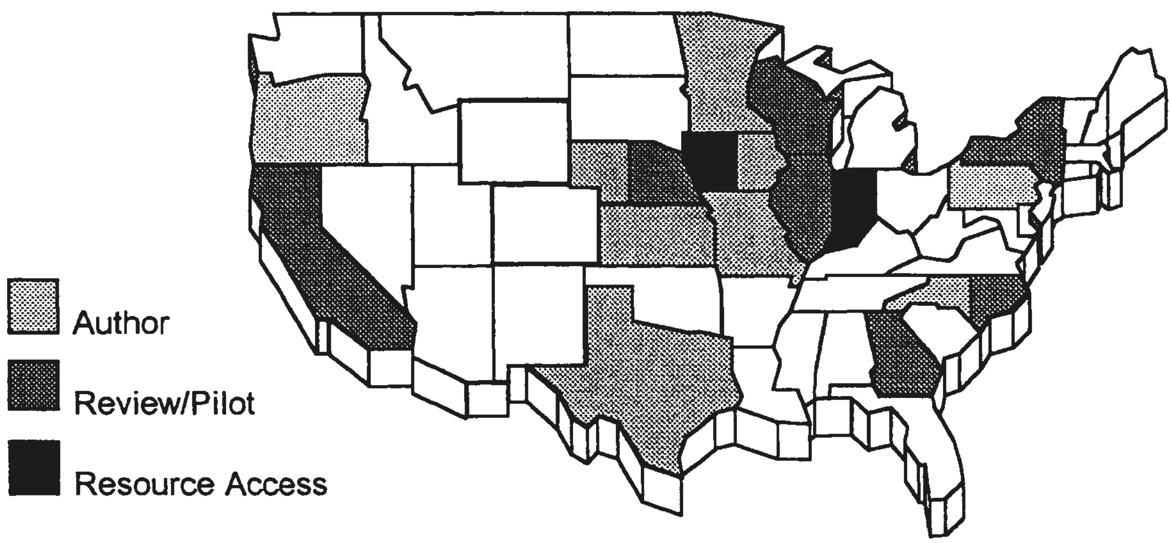


Figure 1. Project Cooperators were Selected to Provide Technical Expertise in Critical Issue Areas and Regional Representation.

CURRICULUM

The proposed national core curriculum will provide user-friendly resources tailored to the needs of livestock and poultry producers. It will promote consistency and quality in the presentation of management practices and compliance issues. Six modules have been identified around which the curriculum is being assembled:

- Introduction,
- Animal dietary strategies.
- Manure storage facilities design, management and compliance,
- Land application and manure nutrient management in a cropping program,

- Outdoor air quality, and
- Related issues.

For additional information on the overall design of this curriculum as well as topics of individual lessons contained within each of the modules, refer to Figure 2.

Faculty from land grant universities currently implementing innovative state educational programs related to the identified topics have been recruited to provide leadership for development of the national curriculum. NRSC also provides access to critical resource people and publications necessary for the development of the national core curriculum.

The curriculum will include 1) a reference publication for each of 28 individual lesions; 2) assessment tools to assist in a producer's self-evaluation of individual facilities and management practices as it relates to regulation compliance (Table 1) and environmental stewardship (Table 2); and 3) teaching aides for information providers including pre-planned presentations with electronic visual aids (Figure 3).

REVIEW AND PILOT TESTING

The single greatest challenge with our national curriculum will be its ability to span the variations in manure management facilities, livestock and poultry species, climatic, and regulatory and compliance related requirements. The "Review and Implementation Team" will provide the regional and species specific review and pilot testing necessary for the curriculum. Faculty from five regionally located land grant universities and one 1890's institution have been identified to participate in this team. In addition, NRCS and EPA will provide technical resource people to review all curriculum. Gary Jackson, National Farm*A* Syst program leader, is providing leadership for the team and will be responsible for impact evaluation of our pilot efforts.

Responsibility for informing the producer about compliance issues specific to individual states will be a prime responsibility of local information providers involved in presentation of local classes. The national curriculum will include tools within each lesson that will assist the information provider in the identification of common compliance issues, their relevance to a local situation, and whether or not the producer has achieved compliance (Table 1). Local information providers will need to supplement this discussion with a review of state specific rules and regulations.

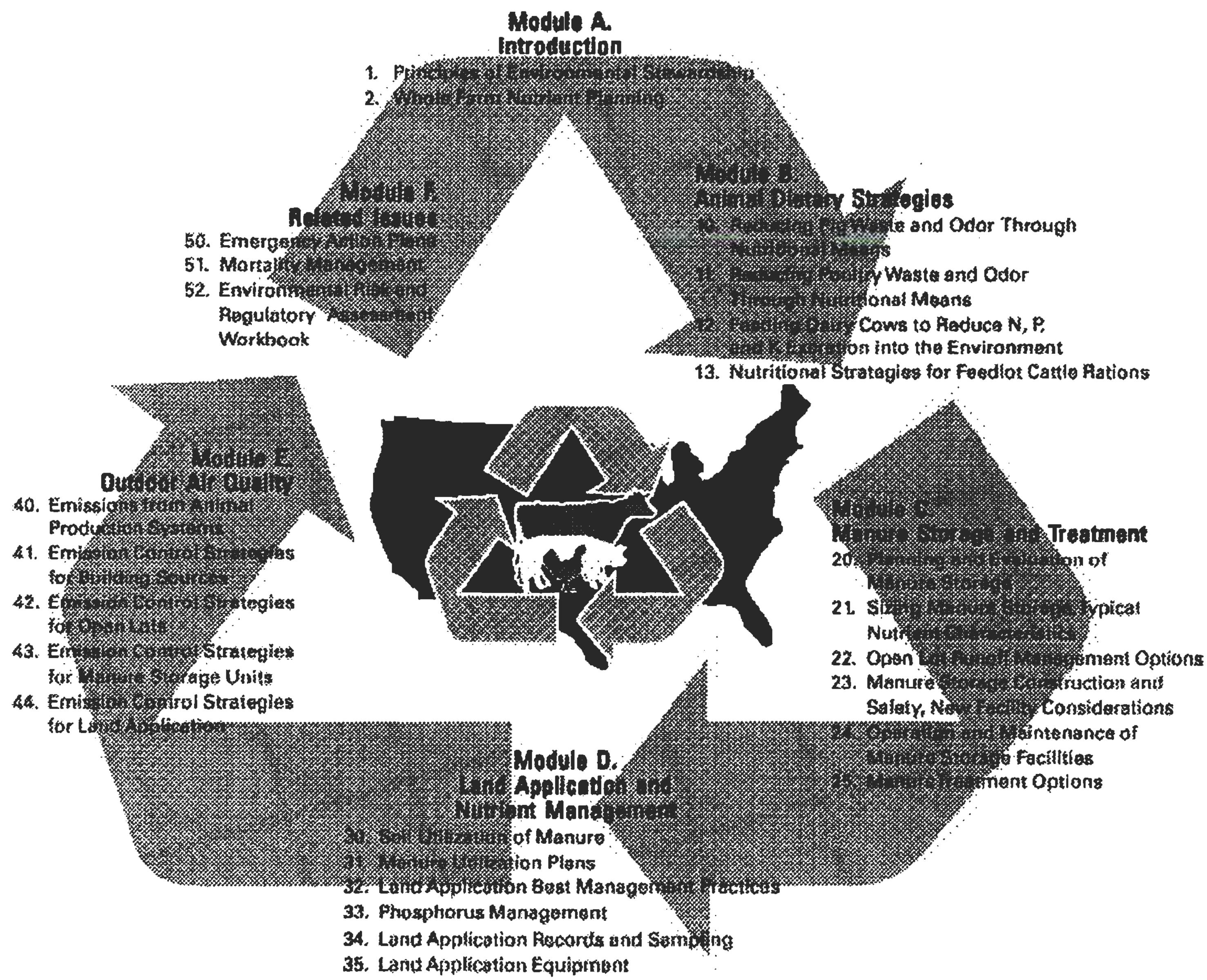


Figure 2. The curriculum's design includes 6 distinct modules typically focused on a broad issues supported by multiple lessons.

Table 1. Sample tool for assisting information provider in discussion of regulations.

REGULATION COMPLIANCE ASSESSMENT FOR AIR QUALITY

The goal of this assessment package is to help a livestock or poultry producer identify regulations that apply their operation. For each issue listed (left hand column) of the worksheets, identify if this issue is regulated by federal, state, or local authorities (middle column), and determine if your operation is in compliance with these rules (right hand column).

Regulatory Issue	Is this issue addressed by regulations? If "Yes," summarize those regulations.	Is my operation in compliance?
What agency(s) is (are) involved in administrating regulations related to odor or air quality?	___ US EPA ___ State ___ Local List Name, Address, Phone # of nearest field office.	
Is my facility subject to standards set by Federal Clean Air Act amendments for air pollutants such as particulate matter or hydrogen sulfide?	___ Yes ___ No	___ Yes ___ No ___ Not applicable ___ Don't Know
Is odor regulated locally (possibly by set back regulations or numeric air quality measures)?	___ Yes ___ No	___ Yes ___ No ___ Not applicable ___ Don't Know
Is a State Construction or Operating Permit dependent upon air quality measures or conditions?	___ Yes ___ No	___ Yes ___ No ___ Not applicable ___ Don't Know
Are individual gases regulated by your state or local agencies?	___ Yes ___ No ___ Hydrogen Sulfide ___ Ammonia ___ Other: ______	___ Yes ___ No ___ Not applicable ___ Don't Know
Are measures of odor or individual gas concentrations used by state or local regulations?	___ Yes ___ No	___ Yes ___ No ___ Not applicable ___ Don't Know
Are setback distances established for your rural community?	___ Yes ___ No	___ Yes ___ No ___ Not applicable ___ Don't Know
Do regulations vary based upon size of livestock/ poultry operation?	___ Yes ___ No	___ Yes ___ No ___ Not applicable ___ Don't Know
Do regulations vary based upon livestock/poultry species?	___ Yes ___ No	___ Yes ___ No ___ Not applicable ___ Don't Know
Do regulations vary based upon manure handling system?	___ Yes ___ No	___ Yes ___ No ___ Not applicable ___ Don't Know

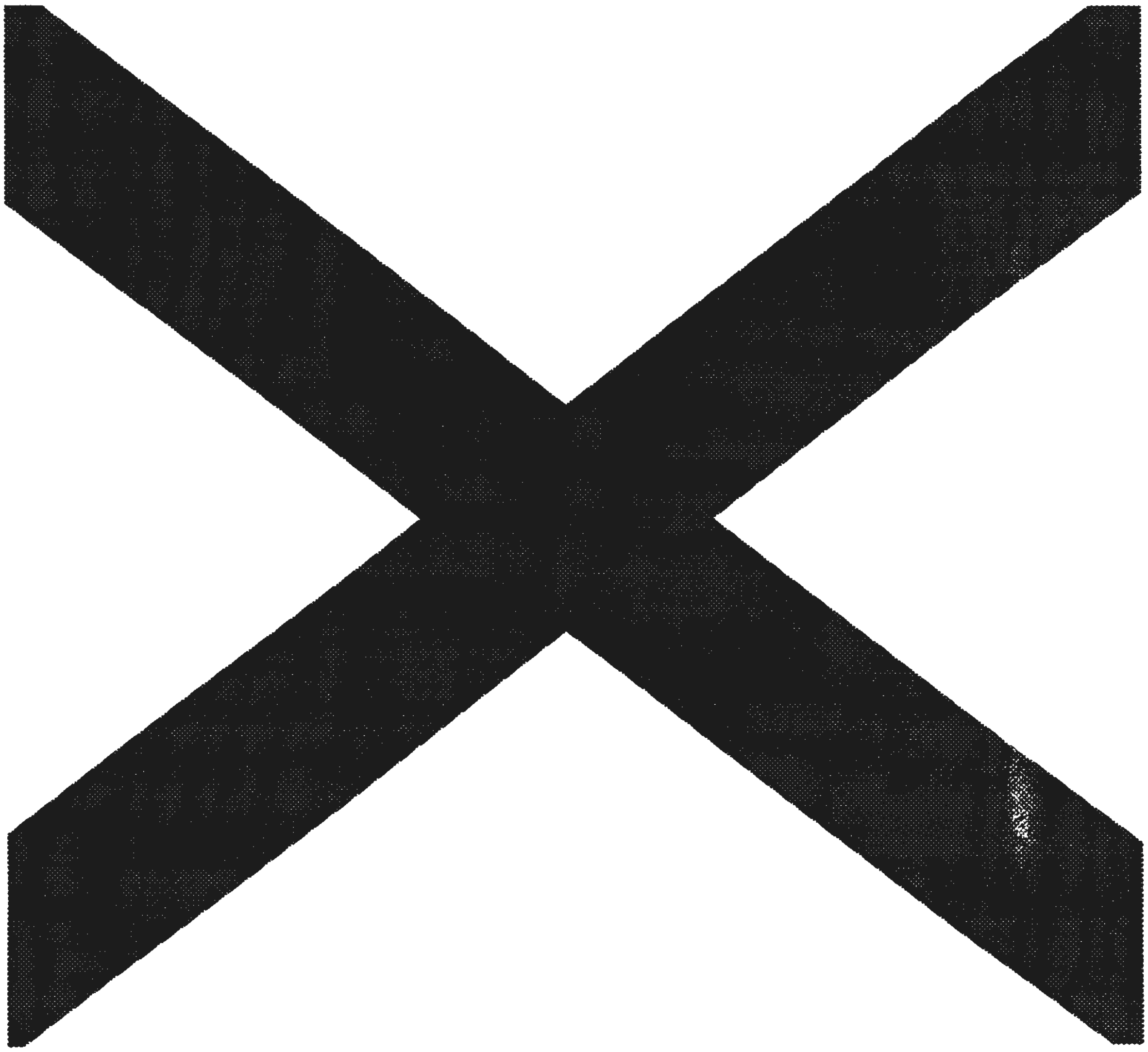
Table 2. Self assessment tools are provided to assist individual producers in an evaluation of their own environmental stewardship.

Environmental Stewardship Assessment for Air Quality Issues
Animal Housing

The goal of this assessment is to help a livestock or poultry producer confidentially evaluate environmental issues that relate to outdoor air quality. For each issue listed in the left-hand column of the worksheet, read across to the right and circle the statement that best describes conditions on your farm. Leave blank any categories that don't apply.

Potential odor risk:	High risk	**Moderate risk**	**Low risk**
Indoor Confinement Animal Housing			
Manure is handled as a	Slurry or liquid	Solid with limited dry organic matter additions.	Solid with substantial dry organic matter additions.
Rate (by checking appropriate response) the cleanliness of your animal housing relative to that of other similar production facilities for:	Not as clean as other facilities	At least as clean as typical facilities	As clean or cleaner than all other facilities
- Cleanliness of animals	☐	☐	☐
- *Manure and feed accumulation on floors and walkways.*	☐	☐	☐
- Manure buildup below the floor.	☐	☐	☐
- Feed spillage (Outdoors)	☐	☐	☐
- Manure or contaminated water around outside of facility	☐	☐	☐
- Weed growth, debris and accumulation around facility.	☐	☐	☐
Rate the drainage around your animal housing relative to that of other similar production facilities.	Not as dry as other facilities.	At least as dry as typical facilities.	As dry or drier than all other facilities.
Is manure controlled and collected?	Some manure regularly pools or accumulates in areas around the animal housing.	Some manure occasionally pools accumulates in areas around the animal housing.	All manure is contained within housing and not allowed to collect around animal housing.

Figure 3. Sample from Powerpoint presentation to support presentation of Lesson 1. All lessons will be accompanied by a similar presentation.



RESOURCE ACCESS

The "Technical Resources Access Team" and "Review and Implementation Team" will play critical roles in providing livestock producer and information providers access to the curriculum. The Resource Access Team will:

1. Construct an internet site that provides access to curriculum educational resources and teaching aides. This electronic web site will be integrated into EPA's Ag Center web site.

2. Prepare a printed version of the curriculum for distribution through MWPS and the EPA's Ag Center.

3. Develop and implement national marketing and distribution plan for the curriculum. This plan will include technical support for the curriculum through MWPS after the completion of the project.

PROJECT TIMELINE

The project is a three year program that started April 1, 1999. The primary focus of year 1 will be development and regional review of the curriculum. The emphasis of year 2 will be on piloting of the curriculum at six regional sites and the evaluation of the delivery and impact of the curriculum. The final year will focus on education of information providers through a series of five regional training programs. A completed curriculum should be available for interested parties not directly involved in this project by the fall of 2001.

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PERSPECTIVES ON ENVIRONMENTAL PROTECTION: WHEN WILL AGRICULTURE GET THE CREDIT IT DESERVES?

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The purpose of this conference is to discuss managing the wastes from poultry production and processing. But the discussion has a far larger relevance than many would expect. In truth, we are here to discuss not just agriculture, but the basis for government regulation, the future of our rural economies and global environmental protection. The implications of this discussion affect all Americans and most of the world.

It is clear that we are in the midst of a media/cultural war against confinement livestock operations. Across the nation are individual State initiatives aimed at preventing, halting, or banning modern, high-efficiency, confinement livestock operations. Colorado has mandated covers for all hog waste lagoons that will likely force many operations to shut down. North Carolina's hog industry has just agreed to a phase-out of waste lagoons and spray fields after intense pressure from North Carolina's Attorney General, despite the lack of any viable alternatives or evidence of environmental degradation. The Virginia poultry industry has apparently agreed to poorly founded phosphorus standards for poultry litter land application. There are also federal initiatives, including USDA's CAFO regulations and the latest EPA clean water initiative of Total Maximum Daily Loads, recently resurrected from the original language of the Clean Water Act.

While some see these initiatives as positive trends in reining in out-of-control industries that do great environmental harm, we see these as unjustified attacks on an industry with a very positive record of environmental stewardship and success. In fact, we believe these initiatives will ultimately cause great harm to environmental stewardship efforts.

The most important question that must be asked is whether we will truly get any added environmental protection with all of these initiatives and regulations? The answer must be derived from a global, long-term perspective and in that sense the answer is no. Will the industry finally get peace from the activists and regulators once it agrees to the current initiatives? The answer is again no.

The regulators are reacting to public opinion. Public opinion is absolutely necessary for new regulatory initiatives. Activists and the media, in turn, are shaping public opinion. The activists have been wonderfully successful in recent years, linking high-profile environmental events to the livestock industry—poisoning public opinion and setting the stage for dramatic increases in regulatory oversight.

Pfiesteria is a prime example. As I'm sure this audience knows or should, there is very little if any evidence that nutrients from poultry waste are a significant factor in outbreaks of toxic Pfiesteria. However, this has hardly stopped environmental activists from insisting the link exists and setting the stage for a radical increase in the regulatory burden on the poultry industry of the Eastern Shore. Their goal is not solving environmental problems, but controlling land use and society.

Another prime example is the fate of North Carolina's hog industry. North Carolina's hog industry was also accused of causing pfiesteria after suffering from poor neighbor relations due to rapid increases in the size of hog operations and several high-profile waste lagoon failures. As a result, North Carolina has banned any new hog production facilities for the past four years. The industry has also just agreed to a total phase out of land application of hog wastes. What the alternative will be, nobody knows. But where is the evidence, any evidence, that land applying nutrients is bad for the environment or water quality? There simply is none, except in the fictitious computer models so in vogue these days in regulatory circles.

If we truly care about environmental stewardship, then we must approach it with reason and science. This means that we must do the hard work of monitoring and data collection. If we want cleaner waters, we must know first how dirty or clean the waters are now. We haven't done that. While we've spent nearly $1 trillion on water quality improvements over the past 30 years, mostly to install sewage and wastewater treatment technologies, we've spent next to nothing on water quality monitoring. The disclaimer on EPA's own National Water Quality Inventory (NWQI) says it all: "The data cannot be used to estimate national water-quality trends over time, and they cannot be used to compare the status of waters among States." In other words, the NWQI is worthless.

The bottom line is that modern, confinement livestock and poultry operations offer a multitude of advantages in both the resource costs for meat and egg production and in environmental stewardship. Moreover, that assertion is grounded in scientific data. Data collected by the North Carolina Department of Environment and Natural Resources (DENR) shows this is true even in the most intensive hog production area in the nation—North Carolina's Black River watershed that drains Sampson and Duplin counties. This area increased its hog population five-fold during the late 1980s and early 1990s, but the Black River's water quality remains excellent. In fact, despite the 500% increase in the hog population in the watershed, nutrient concentrations in the Black river declined slightly during the 1990s. It is also worth noting that the North Carolina DENR rates the Black River an "outstanding resource water" with "excellent" fish habitat.

A broad, long-term environmental perspective requires a full accounting of the impacts of regulation and the benefits of confinement livestock and poultry systems. For example, producing all of U.S. poultry on free range instead of confinement would require an additional land area more than twice the size of Delaware. (Calculated using a production inventory of 600 million birds at 200 square feet of range per bird = 4,300 square miles of pasture). Moreover, while the nutrient runoff and soil erosion from the free-range poultry pasture would be largely uncontrollable, poultry waste from confinement systems is easily collected and applied at agronomic rates where needed. This calculation doesn't even factor in the higher mortality and lower feed efficiencies of pasture systems over climate-controlled confinement systems.

France raises an estimated 27 million free-range birds per year, but loses about 140,000 of them (0.5%) each year to foxes alone. Assuming a 2:1 feed conversion ration, France is essentially losing over a half a million pounds of feed each year to foxes.

And the demand for poultry products worldwide is set to make dramatic advances—making it even more important that we use our agricultural resources efficiently.

The food challenge of the 21st century, in fact, is not the challenge of population growth, but the challenge of affluence. Virtually all the people of the 21st century will be affluent by today's standards and able to afford education, nice clothes and TV sets. Such people are unwilling to accept minimal diets.

The same modern couples who are willing to practice family planning, with two children instead of 15, demand that their two children get rich diets high in meat protein for growth, and milk calcium for strong bones. Affluent people insist on fresh fruits and vegetables all year round. Such diets take far more resources than boiled rice or corn-flour tortillas.

There is no vegetarian trend in the world; instead we are seeing the strongest surge of demand for resource-costly foods in all history. Currently, only about 4 percent of the First World's population are vegetarian, and most of these vegetarians are consuming lots of resource-costly eggs and dairy products.

There will even be a pet food challenge. The U.S. has 113 million pet cats and dogs for 270 million people. All over the world, ownership of companion animals and pet food sales rise with incomes. Already, China's one-child policy is stimulating pet ownership. It is reasonable to project that China in 2050 will have more than 500 million cats and dogs.

The debate in development economics is whether the challenge of affluence requires a 250 percent increase in the world's food output, or a 300 percent increase. The universal human hunger for high-quality protein, combined with the pet factor, convinces us that the world must be able to triple its farm output in the next 40 years.

LAND—THE SCARCEST NATURAL RESOURCE

But this intense increase in food demand will force even greater competition between farming and wildlife for land.

- Agriculture already uses about 37 percent of the earth's land surface, and any land not already in a city or a farm is wildlife habitat.

- If the world has 30 million wildlife species (a reasonable biologist's "guesstimate") then 25-27 million of them are probably in the tropical rain forests, with most of the remainder in such critical habitats as wetlands, coral reefs and mountain microclimates. These are places we have not farmed, and should not farm.

Through confinement meat production, pesticide use, fertilizers, and modern food processing, modern high-yield farming has already saved millions of square miles of wildlife habitat. Our peer-reviewed estimate is that the modern food system is currently saving something on the order of 15-20 million square miles of wildlands from being plowed for low-yield food production. That makes it the greatest conservation triumph in modern history.

Thus the key to conserving the natural world in the 21st century will be what the Hudson Institute calls "high-yield conservation." Meeting the food, fiber and forestry challenges, while leaving room for nature, will depend on our ability to continue increasing the yields and resource-use efficiency from plants, animals and trees on our best land, and transporting the products to where the demand is. Our success will also depend heavily on how urgently we explore such high-tech methods as biotechnology in food and forestry.

HAMSTRINGING HIGH-YIELD CONSERVATION

The trends in dietary changes and increased animal protein consumption we have seen over the last two decades will continue into the next. Worldwide poultry consumption has been growing at about 0.5 percent per year. This growth rate should actually increase during the next five to ten years as more Asian populations reach the critical development stages where meat consumption increases most rapidly. The increase in poultry consumption should progress for the next 30 years at least.

The question is not whether or not there will be growth in the demand for poultry products. The question is where the poultry products will be produced and how?

Yet the world's most advanced societies are attempting to legislate low-yield agriculture. All over the First World, government funding for agricultural research is being cut back, or shifted to low-yield "sustainable" farming. Governments in affluent countries subsidize low-yield organic farming, while regulators respond to public opinion by driving up regulatory burdens to unjustified levels.

Fueled by nostalgia for an agricultural past most have only read about, and longing for a more direct connection to earth, the public (at least as portrayed by the media) has convinced itself that it doesn't want production agriculture. Of course, the public has always sided with small, family farms over large agribusiness when asked in polls, but the difference is that today the anti-agribusiness sentiment runs much deeper. It's not just who is farming and how big they are, but what they produce and how they produce it.

There is no better example of this than biotechnology—where fear of the new and unknown have created a backlash in Europe.

Yet biotechnology is only the most visible example of a much broader, global backlash against agricultural technology. There is a fundamental reason for this backlash: lack of understanding. One of the most important and neglected areas in agriculture today is communicating with the public. Only two percent of the public farms, with many of those farming only for the tax break. A tiny minority produces the vast majority of the food produced in this country. The public doesn't care anymore about protecting the farmer's way of life—in fact they want to reshape it. Environmental organizations have convinced the public that farming is controlled by corporate moneymen who will rape the environment for profit. The enemy has become production agriculture in much of the public's mind.

We must now realize that modern agriculture is being targeted, not because it is bad for the environment, but because modern farming 1) represents the greatest success of technological abundance; and 2) because farming controls much of the world's land and water. The environmental movement seems to want managed scarcity for a few people. It seems to want more bison and prairie dogs—and fewer corn plants—on American land even if that sacrifices wildlands and biodiversity elsewhere.

A GLOBAL TREND TOWARD MORE ACTIVISTS AND BAD JOURNALISM

It is the nature of activists to push for something different.

In Peru, activists demanded an end to the chlorination of drinking water because the U.S. Environmental Protection Agency found chlorine, at high levels, could cause cancer in laboratory rats. Peruvian officials took the chlorine out of the water, and the cities promptly suffered a cholera epidemic that killed 7,000 people.

I don't blame the activists. I blame the people who trusted the activists, and the people who should have represented the other side of the question. I also blame the press, which should have sought out the broader reality. One can see the same lack of depth and balance in the coverage of agricultural and environmental issues today.

Like it or not, the world is on a trend to have more activists, in more countries. Democracy and affluence encourage activists and the free, open debate of public questions. The internet and instant global communication will also spur the creation of more activists. If modern agriculture is to succeed, it must learn to succeed in an activist-rich environment.

Unfortunately, today's mainstream media are not living up to their professional obligations for objectivity and research. Somewhere during the Vietnam era, journalists got the idea that refereeing the game of life was not as satisfying as playing on the winning team. Among the causes they have adopted as their own in recent decades is the environment.

Not too long ago, our Center put out a press release noting that the water quality in North Carolina's Black River has improved over the last 15 years, even though the hog population in its watershed had quintupled to one of the highest densities in the U.S. Of the 300+ media outlets we sent the press release to, one lone skeptical reporter called to inquire further. She asked whether the hog industry had sponsored the study. No, we told her, the data was from the State environmental agency. "But that's not what my readers want to hear," she lamented, and then hung up.

That's how far behind the public affairs curve modern agriculture currently finds itself. This is not a problem that can be dealt with by writing press releases, or by hosting community tours of poultry farms.

Someone must tell the urban public about the environmental benefits of high-yield modern farming. I submit that it will have to be agriculture. As the pfiesteria and North Carolina water quality debates clearly illustrate, it is no longer enough to have science on your side.

We must offer the public the global perspective so that they can finally see the full value of modern agriculture. Let us adopt the full meaning of the environmental slogan "Think Globally, Act Locally." Agriculture and agricultural researchers must talk about saving wildlands and wild species with better feed conversion ratios. We must talk about how if we are to conserve wildlife resources, then we must use agricultural resources to the utmost efficiency. We must point out that where high-yield farming is practiced, the amount of forest is expanding. We must point out that the losses in wildlife habitat overwhelmingly occur where the farmers get low yields.

We must analyze every eco-activist proposal in terms of its land requirements:

- Free-range chickens for the U.S. would take wildlands equal to all of the farmland in Pennsylvania.
- Organic farming for the world would mean clearing at least 5 million square miles of wildlife for clover and other green manure crops.
- Reducing fertilizer usage in the Corn Belt would mean clearing many additional acres of poorer-quality land in some distant country to make up for the lost yield.
- Blocking free trade in farm products and farm inputs will probably mean clearing tropical forest for food self-sufficiency in Asia.

How can we present the environmental case for high-yield agriculture if the journalists will not write it and politicians fail to support it?

Modern agriculture must take its case directly to the people, through *advertising*.

My model is the American Plastics Council, which spends about $20 million per year to keep plastics virtually out of the environmental discussions in America. The Weyerhaeuser Company is another good example of positive imaging; Weyerhaeuser has been telling me for years that it's the tree-growing company. Not the tree-cutting company, not the tree-using company, but the tree-growing company.

Many of the firms with billions of dollars invested in modern agriculture are already talking to urban America. DuPont and Dow have whole rosters of consumer products and millions of dollars worth of consumer advertising. Cooperatives like Land-o-Lakes and Countrymark have consumer ad budgets too. Wildlands conservation would be a winning message with both their customers and their farmer members.

So far, agriculture has failed to accept the challenge, and the momentum for high-yield conservation is waning. This country is not increasing public investments in high-yield research. Its regulators are continuing to strangle farm productivity and our farm communities.

In the long run, of course, farmers and farm researchers will be vindicated even without a public affairs campaign. But that vindication could come too late for the wildlands and the wild species—and too late for most of today's high-tech farmers and agribusinesses.

The poultry industry cannot afford to duck any longer. Public opinion is far too important in today's business world to leave it to hope others will do the job. If the industry fails to communicate its message to the public, they risk losing the support of government leaders needed to open foreign markets and continue operating profitable operations in the 21st century.

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Alex has written on agricultural, food safety, regulatory and global population issues for major newspapers, including *The Wall Street Journal, The Washington Times*, *St. Louis Post-Dispatch*, *Fort Worth Star-Telegram* and the *Des Moines Register*. He has also been published in *USA Today* magazine, *Regulation* magazine, *Feed Management*, and scientific publications such as *Environmental Health Perspectives* and the *Journal of the American Dietetic Association*. His article on international food regulations will appear in the *Wiley Encyclopedia of Food Science & Technology, second edition*.

In addition to his publications, Alex has spoken to a wide range of groups, including the Australian Weed Science Society, American Veterinary Medical Association, American Phytopathological Society, as well as numerous industry and university audiences.

AIR QUALITY MANAGEMENT AND REQUIREMENTS IN EUROPE

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Intensive livestock farming in the Netherlands, and several other regions in Western Europe, causes environmental problems due to emissions to soil, water and air. In this paper we present the state of the art on relevant aspects which are related to the emissions to the air caused by poultry production. However, due to (chemical) reactions in the air, transport and deposition, emission to the air affect soil and water ecosystems. The topic of 'Air quality management' in livestock production is not integral addressed in research programs, nor in regulations. Therefore, this paper follows three lines, namely the more scientific one (basics of air quality and processes), the regulatory one (rules, laws and obligations) and the practical one how farmers try to meet the requirements in commercial production and the contradictions they encounter. It finishes with trends and coming regulations

POULTRY PRODUCTION IN EUROPE

Poultry production in Western Europe mainly consists of layers, broilers and turkeys, but large differences are present between countries within Europe. Environmental and nuisance problems of all sorts typically occur in regions with a high production in a restricted area. Examples are regions in The Netherlands (Veluwe, Achterhoek, Brabant), in Germany (Vechta area), France (Brittanie) and Italy (River Po area) (Groot Koerkamp *et al.*, 1998).

PARAMETERS OF AIR QUALITY

The most important parameters of the quality of the air are for Western Europe, followed by there primary effect, are (with differences per country, of course):

• Odor concentration	nuisance
• Ammonia concentration	acidification, eutrophication
• Concentration of green house gases (CO_2, CH_4 and N_2O)	global warming
• Noise	nuisance
• Dust concentration (inhalable and respirable)	human health, nuisance
• Concentration of pathogens in dust	human and animal health
• Sulphur gas (H_2S)	safety of man and animal

WHICH AIR IS ADDRESSED IN REGULATIONS

The various parameters of the air quality as given before are not always addressed directly by regulations. Figure 1 shows that, when considering a poultry house, we can distinguish the air quality at four completely different positions, followed by their regulatory field of interest:

1. Air inhaled by the human (or the animal)	working (living) conditions
2. Air in the animal house	rough general indication
3. Air in the exhaust	safety, emission
4. Air in the environment (dispersed and diluted, depending on the distance from the house)	local environmental effects and perception

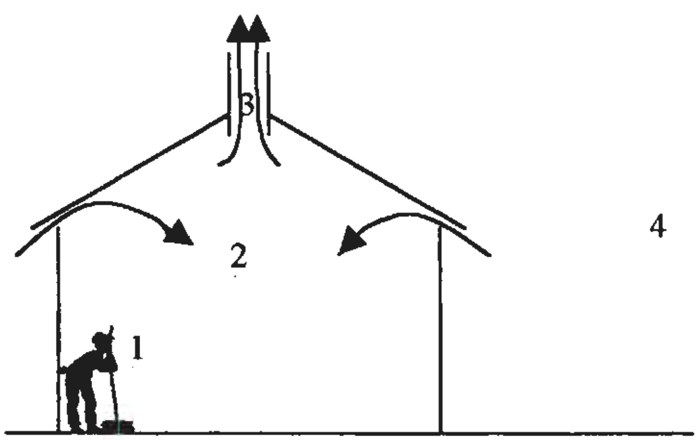

Figure 1. Cross section of an animal house with four locations where air quality is of interest. 1: air inhaled by man, 2: air in the house, 3: air in the exhaust and 4: air in the environment. Arrows indicate air flow direction.

It is important to recognize that measurement are generally take at point 2, while the actual dust concentrations as being exposed to at point 1 differ due to e.g. variation of the concentration in time, exposure time, working intensity and the use of dust protection masks.

PRACTICE IN THE NETHERLANDS

When commercial poultry farmers want to reconstruct an existing house or build a new one in The Netherlands, they have to obtain the following permits from the local authorities:

- Environmental permit, which regulates:
  - Ammonia emission: effects on vulnerable nature in the neighborhood
  - Odor emission: current legislation will be changed, based on intensive research
  - Manure treatment & disposal
  - Town and country planning, zoning plan, building regulations, building plot
  - Quota on ammonia emissions, phosphate production by the animals (will be changed to 'rights' for number of poultry,
- Building permit, which regulates:
  - Technical aspects: e.g. insulation, electricity, waste water disposal, strength calculations
  - Safety aspects on e.g. fire
  - Building structure: materials, colors, roof angle, roof height, etc.
  - Architectural aspects (external appearance of buildings) and fulfill the current obligations for the following laws and regulations:
- EU
- National
- Obligations from special brands, e.g. SKAL (organic / biological), free range eggs.

ARE THERE SOLUTIONS, OR, HOW DOES THE FARMER SURVIVE?

General

In practice, farmers are not confronted with regulations on all air quality parameters as mentioned before. For some of them there are no regulations yet (green house gases, sulphur), or the regulations do not fully apply or are difficult to control (dust), or regulation is foreseen (pathogens in dust). The three most important topics are further discussed (ammonia, odor and dust), as well as the developments in practice.

Ammonia Emission

The Dutch Green Label system for livestock housing systems stimulated the development of housing systems with low ammonia emission. Table 1 gives an overview of housing systems for layers and broilers with known annual emission rates (Wijziging UAV, 2000; IMAG and PP, 2000). The systems with an ammonia emission lower than 15 gram NH_3 per layer or broiler per year have a Green Label certificate. From this list can be seen that both for layers and broilers two systems have such a certificate. The housing system for layers are being applied in practice, but the systems for broilers not. Housing systems for broilers without litter are actually not forbidden in The Netherlands, but strongly discouraged by the Ministry of Agriculture because of welfare reasons. The low emitting housing systems for broilers with litter fulfil welfare recommendations, but do not meet other requirements, such as costs-effectiveness, hygiene and energy consumption.

In Green Label housing systems generally the same ventilation rate is applied, so that ammonia concentrations in the exhaust air of both layer and broiler houses decreases from 25-50 ppm for free range system with litter to less than 3 ppm for the housing systems with the lowest emissions. The lowest concentrations in broiler houses occur at the start of the production cycle, whereas new wood shavings gradually are being spoilt with manure.

Table 1. Overview of the Housing Systems for Layers (upper part) and Broilers with Their Ammonia Emission Rate and Typical Concentrations of the Air in the Exhaust

Housing system Description	NH_3 emission gram / animal per year	NH_3 concentration ppm
Free range with litter, manure storage in pit	315	25-50
Free range, drying of manure in the pit	125	15-35
Aviary with litter, belts under tiers	90	10-30
Cages, storage of slurry in pit in the house	83	10-30
Cages, removal of manure on belt 2/week	35	5-15
Cages, drying of manure on belt	35	5-15
Cages, improved drying of manure on belt	10-15	< 3
Litter on floor, traditional (old house & management)	50	0-40
Litter on floor, traditional (well insulated & modern)	80	0-50
Warming and cooling of litter through system in the floor	45	0-25
Cages with wire floor, belts underneath and manure drying	5	0-10
Drying of litter on a raised floor, air through litter	5-14	0-10

Odor

Recent research by IMAG on poultry and pig farming in the Netherlands revealed interesting effects of the Green Label housing system on the odor emission. For many Green Label pig housing system the odor emission was reduced by half as compared to traditional housing system. But for the poultry housing system (layers and broilers) the reduction of the ammonia emission did not have a clear effect on the odor emission. This again showed that ammonia and odor come from different sources and are influenced by different processes and factors.

End of pipe techniques, such as bioscrubbers, biofilters and chemical scrubbers for the exhaust air from houses, are in some cases applied in the Netherlands to reduce emissions. The advantage of air filtration is the reduction of concentrations of dust, ammonia (70-90%), and to a varying extent also the odor concentration (20-90%). But the costs (investment and operational), as well as the demand for environmental friendly disposal of waste water with nitrate (can not be simply discharged) make them less interesting.

Dust

Table 2 gives an impression of dust concentration in traditional commercial housing systems for poultry in Northern Europe. Ellen *et al.* (2000) summarized the latest information on dust levels and control possibilities in animal production facilities. Dust concentrations in poultry houses varied from 0.02 to 81.33 mg/m³ for inhalable dust and from 0.01 to 6.5 mg/m³ for respirable dust. Houses with caged laying hens showed the lowest dust concentrations, i.e. less than 2 mg/m^3, while, the dust concentrations in the other housing systems, e.g. perchery and aviary systems, were often four to five times higher. Other factors affecting the dust concentrations are animal category, animal activity, bedding materials and season. The most important sources of dust seem to be the animals (feathers) and their excrements. Further studies on the effects of housing systems on dust sources and their compounds are desired for development of a healthier working environment in poultry production facilities. Adjustment of the relative humidity (RH) of the air in a broiler house to 75% will have an effect on inhalable dust, but not on respirable dust. A slight immediate effect on the respirable dust was observed after fogging with pure water or water with rapeseed oil. In an aviary system, a 50 to 65% reduction of the inhalable dust concentration was found after spraying water with 10% of oil and pure water, respectively. To obtain a higher dust reducing efficiency, improvement of techniques for application of droplets onto dust sources will be desired.

Table 2. Inhalable Dust Concentrations (mg/m^3) in Common Housing Systems for Layers and Broilers in Western Europe, Followed by the Respirable Dust Concentration (PM5, mg/m^3; Takai *et al.*)

	United Kingdom	Netherlands	Denmark	Germany
Layers – battery cages	1.5 / 0.2	0.8 / 0.1	1.6 / 0.2	1.0 / 0.1
Layers – perchery	2.2 / 0.4	8.8 / 1.3	4.9 / 0.9	- / -
Broilers - traditional	9.9 / 1.1	10.4 / 1.1	3.8 / 0.4	4.5 / 0.6

Regulations give MAC values for inorganic dust, but not specifically for organic dust as it appears in livestock production facilities. In general, it is difficult to establish a safe maximum threshold value for inhalable and respirable dust concentrations in animal houses for working people. Direct and acute effects of dust are limited, while severe effects on the long run are known for pig and poultry farmers. Yet, there are no regulations on endotoxins, but these are to be expected in the future.

Practice

In case of reconstruction of animal houses, the traditional mechanical ventilation system with ventilators and ducts in the roof along the ridge of the house, is substituted by a so-called 'length ventilation system', in which case all ventilators are positioned in the end wall of the house. Inlets are maintained along the side-walls of the house. This has several advantages for the farmer:

- With animal houses of over 50 m long the emission point is generally substantial further away from private houses

- Repositioning of the emission point, which is generally useful for the permit on emission of ammonia and odor
- Ventilators with a diameter >0.7 meter use less energy, are cheaper to buy and less noisy
- Single point emission sources offers the possibility (for future) treatment of the air, e.g. settlement of dust or treatment with water.
- Lower noise production and farther away

It is clear that it is not always easy to fulfil the requirements, whereas in several cases farmers are confronted with obligate contradictions, such as:

- Ventilators is the roof give better possibilities to control the climate, but are often left away to reposition the exact emission point
- Emission can be strongly reduced in housing systems with cages / 100% wire floors, but for both broilers and in future also layers legislation prescribes the presence of litter for the well being of the animals.
- Drying of manure and litter decreases ammonia emission (as applied in most low emitting housing systems; Groot Koerkamp, 1998), but in general increases the dust generation and thus dust concentration in the house.
- Reduction of ammonia emissions by drying of manure is widely applied, but goes together with additional electricity use for ventilators and gas use for air heating of air. Besides an increase of costs, this increases the carbon dioxide production (a green house gas, and its production has to be reduced) and affects the environmental permit.

TRENDS AND COMING REGULATIONS

In 1999 the poultry production sector in the Netherlands voluntarily agreed with the Ministry of Agriculture a so called 'stand still' in growth of the number of layers and broilers. This was agreement was mainly the result of discussion in politics and the society on the intensive husbandry farming, especially after the pig pest in 1997 / 1998 and the feed contamination with dioxin in 1999. Despite the fact that the highest number of poultry ever registered in The Netherlands occurred in 1999, a gradual decrease is expected for the coming years.

The surplus of manure in the Netherlands resulting from the import of feed stuff and the relative small amount of arable land with restricted maximum allowed doses, stimulates the treatment of poultry manure highly. On one hand to stimulate the discharge from the farms (export), on the other hand to reduce costs of untreated manure. The following development can be seen:

- Optimal drying of layer manure on the belts in the house up to 60% DM
- Further drying of layer manure up to 85% DM in drying tunnels with perforated belts
- Composting of layer manure resulting in a DM content of up to 80%
- Pelleting of manure with approx. 80% DM, followed by heating and further drying

- Burning or gasifying of layer and broiler manure in energy production plants, which is labeled as 'green or renewable energy' (no plants operate yet, the first is to start in 2001). Main goal is to export manure or use the manure in other markets than the agricultural one.

The Green Label system, which focussed on ammonia emission only, will be transformed to a new system called 'SDL' and aims to stimulate sustainable agriculture. Sustainability is covered by minimum demands on the topics 'environment', 'welfare' and 'animal health'. This implies e.g. that higher emissions of ammonia are tolerated in case of welfare friendly housing systems. Besides technical and constructive measures, also management measures are incorporated in the new system (Zeijts *et al.*, 1999).

National and EU regulation for broilers is foreseen in the coming years concerning the maximum number of birds with a certain age that may be kept per surface area (in fact kg/m^2). In 1999 the EU approved a Directive (CEC, 1999) which bans conventional cages from 2012 and allow no new investments in cages from 2003. Hens have to be kept in free range systems with litter (barn or aviary) with or without an outdoor area, or modified cages with a perch, lying nest and a litter box. Market regulations and consumers behavior will determine what the effect of this directive will be on the extent and the method of the poultry production in Europe.

FINAL REMARKS

It is clear that farmers both in The Netherlands as well as in Europe are facing many regulations they have to comply with. And it is certainly not easy to keep the overview of all these rules and regulations. On top of that livestock farming has to regain its 'license to produce' from society. Because of this complex situation research and development of new housing systems for primary production has to be organized in another way: multidisciplinary, chain oriented, in cooperation with society and consumers.

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HOW THE MOVE FROM PM_{10} TO PM_{25} IS SIGNIFICANT TO ANIMAL PRODUCTION

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The atmospheric concentration of compounds is regulated through the Clean Air Act (Public Law 80-159, 1955). This Act and its subsequent amendment specifically established National Ambient Air Quality Standards (NAAQS) for six compounds: carbon monoxide, ozone, particulate matter (PM), sulfur dioxide, nitrogen oxides, and hydrocarbons. The PM standard initially was based to control total suspended PM (particles up to 40 μm in diameter. In 1978, the standard was revised to regulate inhalable particles, or particles that can deposit in the respiratory tract and therefore have greater potential for causing adverse health effects (PM_{10} -- particulate matter with an aerodynamic diameter less than or equal to a nominal ten micrometers). Recent federal review of the NAAQS resulted in a new standard for PM. The new proposed standard is for $PM_{2.5}$. The rationale behind having a PM standard relates to the impact of PM on health. The NAAQS were developed in order to protect the health of the population, particularly those thought to be sensitive.

WHAT ARE PM_{10} ?

Particulate matter consists of a variety dusts and droplets. These particles consist of a complex mixture of human and natural sources. The size and origin of these particles varies. Thus, the chemical composition, physical and biological properties of PM will vary depending on the local environment. The most commonly used descriptor of particle size is aerodynamic diameter. Based on this parameter, ambient particles tend to fall into three size classes (modes): ultra fine or nuclei mode (particles less than0.1 μm in diameter); fine or accumulation mode (particles between 0.1 and 2.5 μm in diameter). Fine and ultra fine particles are dominated by emissions from combustion processes while coarse particles (particles between 2.5 and 10 μm in aerodynamic diameter) are mostly generated by mechanical processes from a variety of non combustion sources. Generally, the ultra fine and fine fractions are composed of carbonaceous material, metals, sulfate, nitrate and ammonium ions. The coarse fraction is composed mostly of mechanically generated particles and consists of insoluble minerals and biologic aerosols, with smaller contributions from primary and secondary aerosols and sea salts (US EPA, 1996).

How do these categories related to poultry production? Activities that generate atmospheric dust can contribute to coarse PM.. These include bird activity, dander, and feed, manure, and mortality handling. The fine particles can include some of the dust particles. Formation of chemical compounds will result in fine particles as well. Ammonia volatilized from manured or composting areas and gaseous nitric acid (a pollutant formed in air when NO_x. (nitrogen oxides) react with water in air to form particulate nitrate (Russell and Cass, 1986).

HOW ARE ENFORCEMENTS DONE?

The US EPA is obligated to enforce the Clean Air Act. They operate through 10 regional offices. Each region is responsible for oversight for its States. States have the ultimate authority to enforce compliance with Federal and State air quality requirements. Numerous sampling sites exist throughout the United States. The data from these sites are used to determine if the local area is in compliance with NAAQS. When a site or numerous sites fail to meet NAAQS it is obligated to develop an implementation plan for compliance. State implementation plans (SIP) must be approved by the Regional EPA. When a State fails to adequately develop a SIP in a timely fashion, or does not implement a SIP, private citizens and groups can file suit. Most SIPs will include methods to reduce emissions of parameters in non-attainment. If NAAQS are not met, groups can also file suit against US EPA. The results may be for the Regional EPA to develop a Federal Implementation Plan (FIP) to be imposed on the State.

Point source operations, predominantly industrial stacks or chimneys, are obligated to meet emission criteria for the various compounds potentially emitted. Permits are issued for the emission quantity. Operations are in violation when emissions exceed permitted levels. Citations and fines can be leveed. Non-point sources are from mobile or stationary sources. Mobile sources include vehicles (they move as they discharge pollutants) and compounds in the airstream. Stationary sources are non-mobile. Categories include coatings and solvents, petroleum operations, combustion sources, agricultural operations, homes, businesses, etc. Non-point sources are not currently permitted through Federal regulations.

WHAT HAPPENS WHEN AN AREA IS OUT OF COMPLIANCE?

When sampling data indicate non-compliance the lead agency will identify the composition of PM. What percent of the PM is from dust, particulate nitrate, particulate sulfate, or other components? Once origin is identified then attention is focused on inventories. An example will be used to illustrate the methodology followed by the lead agency.

The South Coast Air Quality Control District (SCAQMD) is out of compliance for ozone, PM and CO. Their sampling data indicate that during the periods of non-compliance particulate nitrate is a large contributor to PM. The SCAQMD has regularly done ammonia emission inventory for their basin. The most recent one (Botsford *et al.*, 1999) identified that livestock were great contributors to ammonia emissions. Table 1 is an incomplete presentation of their data. Detailed information is provided for the livestock categories and categorical data are provided for the remaining categories. The domestic category includes cats, dogs, cigarette smoking, household ammonia use, human perspiration, untreated human waste (homeless and other), and cloth and disposable diapers. From these calculations, 58 of 180 tons of ammonia produced per day are estimated from the livestock. The previous inventory had livestock responsible for about 50% of ammonia emissions. Auto emissions have increased, and horse emissions have been decreased since the previous inventory.

Methodology for determining emissions. Three key elements are needed. The first step is the ability to obtain statistical animal husbandry populations. Typically, county agriculture and livestock reports are used. These data describe slaughtered or sold animals. Production data are used to estimate head count for resident animals (milking cows, laying hens). The next item is to identify emission factors. The last component is the ability to adjust the emissions to reflect the actual amount of waste being produced from animals during any one inventory year. Residency and adjustment factors are necessary. As an example, if 1,000,000 broilers are slaughtered, they are not present for 365 days. A residency factor of 51 days should be employed.

Emissions factors are determined by one of three methods. The first is a review of the literature. A standard call will include a number of categories. So, the response to the request for proposals will address numerous categories of emitters (livestock being just a small part of the project). Previous reports on the subject and reports issued by US EPA have high visibility. Data from animal production journals have low visibility. The second method is to model emissions given assumptions of local conditions (to include more than just the previously mentioned literature review). This is more time consuming and more expensive. It still requires reasonable inputs. The last method is to measure emissions under local conditions. This would best reflect diurnal and seasonal patterns. It is the most expensive and typically requires the greatest amount of time.

PARTICIPATING IN AN INVENTORY PROCESS

Get involved. It is critical to become involved in the inventory process to minimize the amount of problems. If an inventory under-estimates the contribution of an industry and restrictions are imposed to reduce emissions, the industry may have an impossible task ahead of them. If the inventory over-estimates the contribution the potential press associated with such values may require extra attention. All parties benefit when an inventory is reasonable.

- Production individuals understand residence factors for different types of production. They best understand yields and animal population ratios.
- Production individuals have a greater understanding of the environment and are best suited to identify if data make sense. (Look back at Table 1. Does it make sense that the ammonia emissions value used is about 75% greater from a beef cow than a dairy cow?).

- Production individuals are more inclined to check the data to be sure they are reasonable.

THE FUTURE IS HERE

The new standards that will also have requirements on $PM_{2.5}$ will impact animal operators in some airsheds. If $PM_{2.5}$ standards are exceeded, then implementation plans will need to be developed to reduce production of PM. When particulate nitrate is part of the collection of particles, the implementation plan will focus on the limiting compound. If ammonia limits the formation of the particle, it is a given that implementation plans will include management practices that address reduction of ammonia emissions.

The first conclusive study that addresses the association of particulate matter components (the various sized particles) and health impacts is now available (Lippmann *et al.*, 2000).

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Table 1. Ammonia emission factors and activity data for 2000 inventory (1997 data).

Source Category	Activity	Emission factor	Emissions, t/d
Horses and ponies	134,201 hd	26.9 lb/hd/yr	4.32
Beef cows	16,089 hd	87.57 lb/hd/yr	1.93
Milk cows	298,968 hd	51 lb/hd/yr	19.00
Heifers and calves	171,599 hd	28.75 lb/hd/yr	6.59
Steers, bulls & calves	61,787	30.39 lb/hd/yr	3.05
Hogs and pigs	18,059 hd	20.3	.5
Layers and pullets	16,190,706 hd	.996 lb/hd/yr	22.09
Broilers	970,099 hd	.368 lb/hd/yr	.489
Sheep and lambs	52,070 hd	7.43 lb/hd/yr	.53
Goats	4,279 hd	1.28 lb/hd/yr	.01
Rabbits	25,254 hd	.37 lb/hd/yr	.01
Total livestock			**58.52**
Soil activities			39.00
Fertilizer activities			7.68
Domestic			22.58
On-road mobile			33.20
Industrial sources			9.05
Composting			9.69
Landfills			.0156
Sewage treatment (POTW)			.08
Mobile (other)			.08
Native animals (deer and bear)			.21
Prescribed burning			NA
Total			**180.11**

EFFECTIVENESS OF OZONATION AS A MANURE TREATMENT

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Environmental pollution by livestock waste is a major nationwide problem of the animal agriculture industry (Mallin, 2000). An increasing number of civil litigations, more restrictive township ordinances, demands for the protection of public health and new Federal and State regulations concerning surface runoff and groundwater contamination necessitate that the livestock industry address the problem. Issues related to animal and public health, such as pathogens, antibiotic resistance, endocrine disruptors, and drug residues are emerging concerns. Treatment of livestock manure prior to release into the environment is inevitable and new technologies must be developed and implemented to prevent the degradation of air, soil, and water resources.

Ozonation is not a new technology. Ozone has been used for decades for odor and pathogen removal in municipal wastewater treatment plants (Debevec, 1990). An earlier study by Priem (1977) examined the ozone treatment of air in swine facilities. However, only recently has ozonation been applied to the problems of stored livestock manure slurry (Watkins *et al.*, 1977; Wu et al., 1998; Wu *et al.*, 1998, 1999). Because of its strong oxidizing properties, ozone has the potential to break numerous chemical bonds of toxic compounds, steroidal compounds, drug residues, and odorous metabolites. Ozone also has bactericidal and virucidal properties (Vaughn *et al.*, 1987; Takamoto *et al.*, 1992) which, from the standpoint of public health, could reduce the potential for the contamination of groundwater and surface run-off by pathogenic bacteria and viruses, including those that are antibiotic resistant, that are often present in livestock waste.

Other beneficial effects for the ozone treatment of livestock manure are currently being identified. The purpose of this paper is to discuss the effectiveness of ozonation as a manure treatment with specific reference to poultry manure.

ODOROUS COMPOUNDS

Ozonation of stored swine manure slurry at dose levels ranging from 0.25 g/L-1.00 g/L effectively reduced the concentrations of the volatile phenolic and indolic metabolites (Figures 1-4), commensurate with a significant reduction in the malodor (Wu *et al.*, 1999). The concentration of other analytes, such as ammonia nitrogen, phosphate, sulfate, chemical oxygen demand (COD), biological oxygen demand (BOD), and volatile fatty acids were not affected by ozonation treatment.

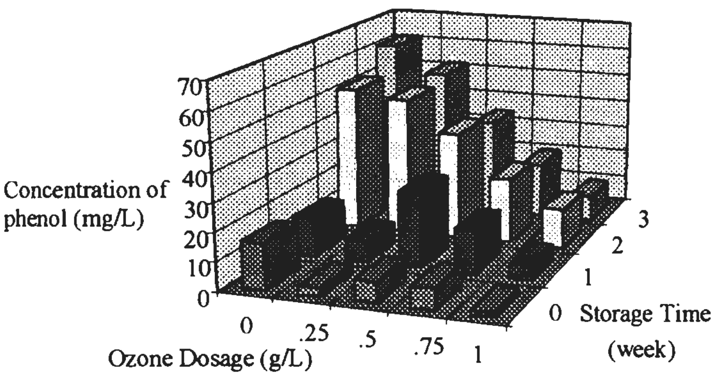

Figure 1. Changes in phenol concentrations during ozonation and storage (post-ozonation) of swine manure slurry.

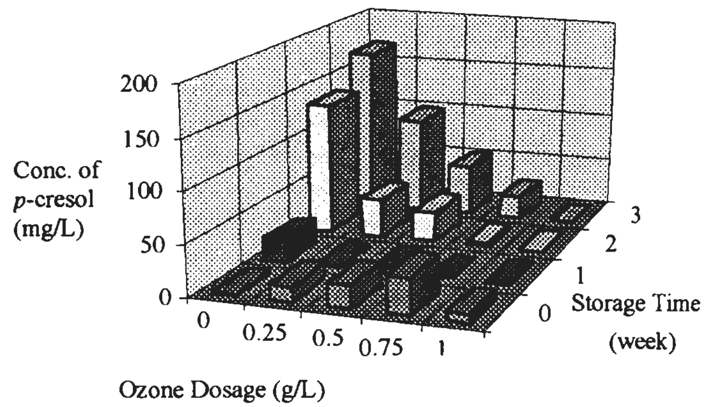

Figure 2. Changes in *p*-cresol concentrations during ozonation and storage (post-ozonation) of swine manure slurry.

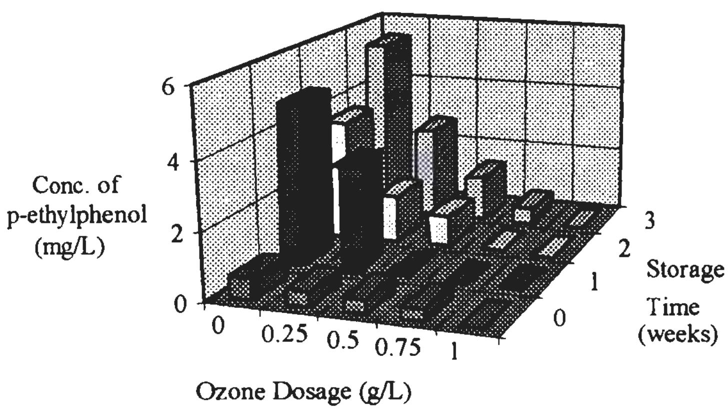

Figure 3. Changes in *p*-ethylphenol concentrations during ozonation and storage (post-ozonation) of swine manure slurry.

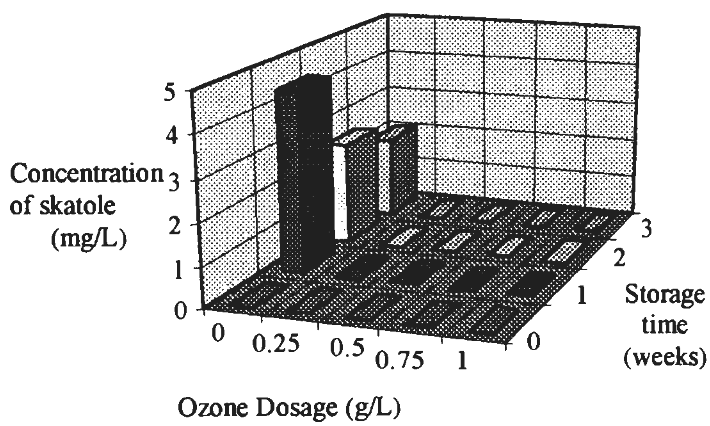

Figure 4. Changes in skatole concentrations during ozonation and storage (post-ozonation) of swine manure slurry.

The volatile phenolic and indolic metabolites in air dried caged layer manure was not determined but the volatile fatty acid concentrations were not affected with ozonation over 15, 30, and 60 minutes (Table 1). There was also no appreciable change in the ammonium ion concentration in the ozonated caged layer manure in comparison to the control untreated manure (e.g. 19.33 mg/g vs. 22.2 mg/g, respectively) (Kim-Yang *et al.*, 1999).

Table 1. Volatile fatty acid concentration in air dried caged layer manure with ozonation of 15, 30, and 60 minutes.

VFA[a]	Control	15 minutes	30 minutes	60 minutes
Acetate	1.08	0.8	1.22	0.88
Propionate	0.16	0.13	0.18	0.15
Butyrate	0.10	0.10	0.10	0.09
Iso-Butyrate	0.11	0.09	0.11	0.10
Valerate	0.096	0.078	0.08	0.08
Iso-Valerate	0	0	0	0

[a] Unit: X10^{-8} moles VFA/g sample (Kim-Yang *et al.*, 1999).

MICROBIOLOGY

Ozonation treatment decreases the total numbers of aerobes and anaerobes (50% and 25%, respectively) in stored swine manure slurry, but at the ozone concentrations (0.25 g/L-1.00 g/L) sufficient to eliminate the malodor, complete disinfection is not achieved. There was, however, minimal recurrence of the malodor with storage of the ozone treated slurry for up to 12 weeks (Wu *et al.*, 1998) suggesting that the odor causing bacteria were killed by the ozone treatment. Total coliforms, total *Escherichia coli*, and total coliphages also decreased with ozone treatment. *E. coli* numbers decreased from 10^4/ml to zero with ozonation.

Ozonation of air dried caged layer manure for 15, 30, and 60 minutes decreased the total number of aerobes by 50%, 75%, and 78%, respectively, over the control untreated caged layer manure. Total coliforms were decreased by 25% with 60 minutes of ozonation but no decrease was observed for the 15 and 30 minute ozone treatment. A two log decrease in the numbers of *E. coli* was also observed after 60 minutes of ozonation but not with 15 or 30 minutes of ozonation (Kim-Yang *et al.*, unpublished data).

Further studies are needed to determine the effectiveness of ozone and dose levels needed to eliminate pathogens such as *Salmonella typhimurium* and *Salmonella enteriditis* in poultry manure.

OZONE TREATMENT OF AIR AND WATER

Bob Bottcher and others at North Carolina State University (Bottcher *et al.*, 2000; Oehrl *et al.*, 2000) have conducted research on the ozonation of the air in swine finishing houses. They observed about a 60% reduction in total dust emissions from the ozonated house when compared to a similar adjacent house. Analyses of the dust for odorants by gas chromatography (GC) also showed a reduced level of several odorous metabolites in the dust from the ozone treating house versus the dust from the control house (Oehrl *et al.*, 2000).

There are reports of on-going research in which ozone treatment of the air in poultry facilities is being investigated. However, the data from such studies are still not available for evaluation. Since the dust in poultry facilities is a major carrier of odorants (Hartung and Rokicki, 1984), a reduction in dust particles, as has been observed in swine facilities with ozonation of the air, may be beneficial to controlling malodors emanating from poultry facilities.

Some interesting research is being conducted by Jerry Turnbull (Global Livestock Group, Alabama) in which he has been treating the drinking water of layers and broilers with ozone. Besides observing an increase in feed and water consumption when compared to a control group, he observed a slight improvement in gain to feed ratio and about a 25% decrease in ammonia levels in the house with the birds receiving the ozonated drinking water (see Figures 5 and 6).

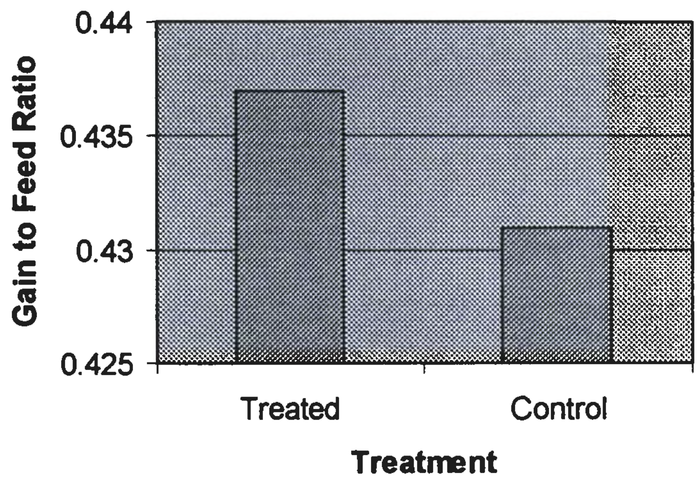

Figure 5. The effect of treating drinking water with ozone on gain to feed ratio.

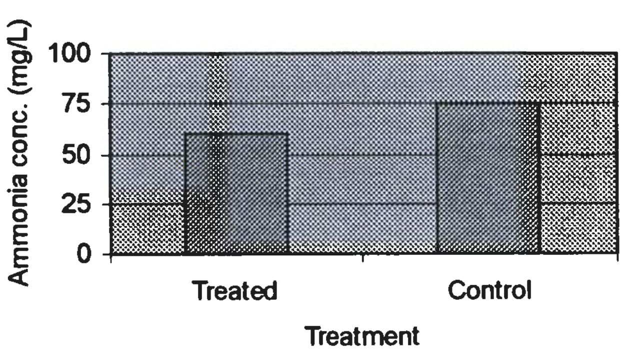

Figure 6. The effect of treating drinking water with ozone on ammonia concentrations.

Hens receiving ozonated drinking water also showed an increase in total egg production and improved hatch. While a mode of action can be debated, Turnbull (1999) suggests that the improvement in feed utilization and a mild "antibiotic" effect of the ozone treatment may be responsible for the beneficial effect being observed.

STEROIDAL COMPOUNDS AND DRUG RESIDUES

Testosterone and estrogen in poultry manure (Shore *et al.*, 1993) and drug residues may be a problem with ground water contamination and surface run-off into rivers and streams. Ozone treatment of poultry manure has the potential to eliminate steroidal compounds and drug residues. However, there are very few, if any, studies which have examined the effectiveness of ozone and dose levels required for such remediation.

OTHER BENEFICIAL EFFECTS

Ozonated swine manure slurry does not appear to be phototoxic for field crops (e.g. corn, wheat, soybean) and the data would suggest that ozonation may speed up the availability of nutrients to plants (Roman *et al.*, 1998). Studies we have conducted also show that ozonated swine manure slurry is toxic to flies (*Musca domestica*) (Kim-Yang *et al.*, 1999). When ozonated swine manure slurry is provided as the sole source of moisture for flies, it results in 100% mortality within two days (Fig. 7).

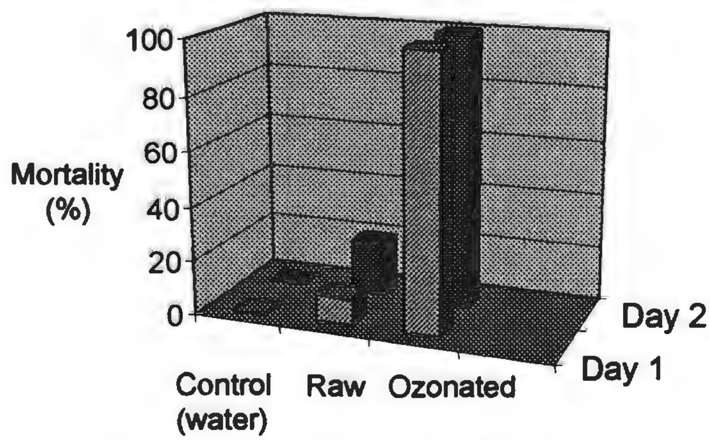

Figure 7. Toxicity of ozonated swine manure to *Musca domestica.*

A similar, but lesser, response is also observed with ozonated dairy and beef cattle manure slurry but not with ozonated poultry manure and the manure from other livestock species (Kim-Yang *et al.*, 1999).

SUMMARY

Ozonation has the potential to effectively remediate livestock manure for problems which are of concern to the environment and public health. Further studies need to be conducted to determine its practical usage and benefits for treating poultry manure.

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OCCUPATIONAL HEALTH HAZARDS AND RECOMMENDED EXPOSURE LIMITS FOR WORKERS IN POULTRY BUILDINGS

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ABSTRACT

Numerous manuscript articles have been published regarding the adverse respiratory health consequences of working in intensive livestock and poultry housing. Threshold limit exposure guidelines are not currently applied to this environment, but are essential in order to implement and monitor effective environmental controls.

Previous dose-response research work with swine workers has resulted in exposure limit recommendations of 2.4 mg/m^3 total dust, 0.23 mg/m^3 respirable dust, 800 EU/m^3 endotoxin, and 7 ppm ammonia. Reported here is an industry-wide study of poultry production regarding dose-response relationships of bioaerosol exposures and worker respiratory health. A total of 257 poultry workers were studied for respiratory symptoms, pulmonary function, and exposure to dust (total and respirable), endotoxin (respirable and total), and ammonia. Significant dose-response relationships were observed between exposures and pulmonary function decrements over a work shift. Threshold concentrations were identified as follows: 2.5 mg/m^3 total dust; 0.25 mg/m^3 respirable dust; 600 EU/m^3 endotoxin; and 12 ppm ammonia. Based on the similarity of these findings to those in swine production, generic exposure thresholds for worker health for the swine and poultry industries are proposed.

INTRODUCTION

Three studies have been published where environmental threshold concentrations for human health have been calculated (Reynolds *et al.*., 1996; Donham *et al.*, 1995, 1989). One study has been published recommending threshold limits for swine health (Donham, 1991). This paper presents new data recommending worker health exposure limits for poultry workers. This data will be considered, together with the swine worker data, and generic recommendations for exposure limits for livestock and poultry workers will be made.

Poultry workers (as do swine workers) have high prevalences of acute and chronic work-related symptoms including cough, phlegm, eye irritation, dyspnea, chest tightness, fatigue, nasal congestion, wheezing, sneezing, nasal discharge, headache, throat irritation, and fever (Zuskin *et al.*, 1995; Reynolds *et al.*, 1993; Morris *et al.*, 1991; Brown, and Hagmar *et al.* 1990; Muller *et al.*, 1986; Thelin *et al.*, 1984; Donham *et al.*, 1977; Boyer *et al.*, 1974).

Patterns of lung function change in poultry workers are suggestive of primary obstructive disorders with less consistent indication of restrictive functional changes. Baseline measures of forced vital capacity (FVC) and forced expiratory volume in one second (FEV_1) were found to be significantly lower than normal predicted values in chicken breeders, growers, and catchers (Zuskin *et al.*, 1995; Stahuljak-Beritic *et al.*, 1977). Cross-shift decreases in FEV_1, FVC, and forced expiratory flow between 25 and 75 percent of lung volume (FEF_{25-75}) have been seen among live-hang shacklers; turkey, broiler, and layer workers; and chicken catchers (Zuskin *et al.*, 1995; Donham *et al.*, and Hagmar *et al.*, 1990 Vols. 17 & 62; Thelin *et al.*, 1984; Stahuljak-Beritic *et al.*, 1977). These pulmonary function changes have been associated with high concentrations of dust, endotoxin, ammonia, and bacteria (Reynolds *et al.*, 1993).

Environmental studies in live poultry facilities have quantified ammonia, dust, bacteria, and endotoxin in ranges where health effects have occurred in other occupational settings (Nielsen *et al.*, 1995; Reynolds *et al.*, 1993; Morris *et al.*, and Pickrell, 1991; Jones *et al.*, 1984; Clark *et al.*, 1983; Lenhart *et al.*, and Olenchock *et al.*, 1982). Dust can act as a nonspecific irritant by overwhelming the clearance mechanisms of the respiratory tract. Endotoxins, derived from the lipopolysaccharide portion of gram-negative bacterial cell walls, are inflammatory substances capable of neutrophil recruitment, macrophage activation, complement activation, and histamine release (Castellan *et al.*, 1987). Ammonia, a by-product of bacterial action on body excreta, is adsorbed to dust particles, inhaled, and distributed through the respiratory tree, to exert effects as an alkaline respiratory irritant (Donham, 1986).

Dose Response of Poultry Exposures

Although no dose-response studies with poultry workers have been available previously, at least one laboratory model demonstrated a dose-gradient response between concentration of poultry dust extract and obstructive respiratory pathology. The contractile activity of nonsensitized guinea pig tracheal rings was found to be dose-dependent on the concentration of water-soluble poultry dust extract, suggesting nonspecific inflammatory reaction in airway smooth muscle (Zuskin *et al.*, 1995; Schachter *et al.*, 1994).

In addition, poultry-worker field studies have shown that greater cross-shift declines in FEV_1 were correlated with higher levels of dust and endotoxin (Thelin *et al.*, 1984). Likewise, turkey growers working in barns with relatively high concentrations of dust, endotoxin, ammonia, and total viable bacteria demonstrated the lowest pre-shift FEV_1 and FVC (Reynolds *et al.*, 1993). Broiler growers, exposed to relatively high concentrations of respirable dust and respirable endotoxin (compared to layer operators, turkey farmers, and loaders/shacklers), showed the greatest cross-shift declines in FEV_1 and FEF_{25-75} (Donham *et al.*, 1990).

Evidence for the time component of dose-response relationships has also been suggested in several studies. Frequency of reported respiratory symptoms in egg producers was correlated with hours per week worked in laying facilities (Leistikow *et al.*, 1989). Morris *et al.*., (1991) found that chicken catchers with five or more years of occupational exposure reported more chronic respiratory symptoms and had lower baseline pulmonary function measures compared to workers exposed less than five years. Reynolds *et al.*., (1993) found higher prevalences of respiratory symptoms and significantly lower FEV_1 and FVC in persons who had worked in the turkey industry greater than 10 years. Similarly, Zuskin *et al.*., (1995) found that growers and catchers occupationally exposed to poultry for more than 10 years had higher prevalences of acute and chronic respiratory symptoms, and significantly lower FVC, than those with fewer years of exposure.

Environmental controls, the basis for prevention of occupational-induced respiratory diseases, are based on recommended standards, which in turn are based on established dose-response relationships. If threshold levels for exposure variables can be determined, exposure guidelines can be recommended, environmental control programs can be targeted and monitored, and the respiratory health of poultry workers can be protected. The objectives of this study are to: 1) determine if dose-response relationships exist between environmental dust, endotoxin, and/or ammonia concentrations and cross-shift changes in FEV_1 and FEF_{25-75}; and 2) determine the specific concentrations of dust, ammonia, and endotoxin that are related to respiratory dysfunction.

METHODS

Study Population

Two hundred and fifty seven poultry workers (women 30%, men 70%) were recruited from the complete Iowa membership rosters of the relevant producer organizations, including 124 turkey growers/loaders and 92 egg producers. Additionally, 26 broiler growers, and 15 shacklers were recruited from the U.S. Poultry Industry Directory, and the U.S. Who's Who in the Egg and Poultry Industries. A nonexposed blue-collar comparison group (42% women, 58% men) was assembled from 100% samples of local postal carriers (111), and workers at a medium-sized Iowa City electronics plant (39).

Medical Evaluation

Modified standardized ATS questionnaires, with additional questions to assess occupational and exposure histories, were administered by a trained interviewer (Ferris, 1978). Pulmonary function tests were conducted by a trained research assistant using a Spirotech S500 spirometer (Ohio Instruments). ATS guidelines for spirometry were followed (Ferris, 1978). Pulmonary function tests were performed before and after a work period (exposure periods varied from two to four hours) to assess cross-shift changes.

Environmental Evaluation

Personal sampling was conducted for total and respirable dust, total and respirable endotoxin, and ammonia. Ammonia was quantified by attaching passive diffusion tubes to poultry workers during their work shift. Dust samples were collected gravimetrically on 5um pore, 37mm low ash PVC membrane filters housed in two-stage closed cassettes in line with personal air sampling pumps (Gelman, Inc.), utilizing flow rates of 1-2 liters per minute. Respirable samples were collected by incorporating MSA cyclone preselectors into sampling trains, with flow rates of 1.5-1.8 liters per minute. Probed respirators (3M 9920) were utilized for in-mask sampling of total dust in 34 workers who usually wore respiratory protection. The QCL1000 endpoint method of the Limulus amebocyte lysate assay was utilized for endotoxin analysis (NIOSH, 1994).

Statistical Analysis

Relationships of cross-shift lung function changes (FEV_1 and FEF_{25-75}) were examined relative to environmental concentrations of total and respirable dust, total and respirable endotoxin, and ammonia. Initially, univariate procedures were utilized to yield descriptive statistics for each variable of interest. Histograms were examined to evaluate normality of distributions. Because the data were not normally distributed, they were log transformed for evaluation. Non-parametric Spearman correlation coefficients were calculated to determine relationships among environmental exposures, and between environmental exposures and lung function changes.

The data on concentrations of total and respirable dust, total and respirable endotoxin, and ammonia were divided into quartiles, and the PFT data from subjects within these exposure quartiles were examined statistically. Bivariate analysis was performed using two-by-two tables, with a correction of 0.5 added to every cell that contained a zero. Cross-shift declines in FEV_1 and FEF_{25-75} at 3%, 5%, and 10% levels were assessed in relation to each quartile of each quantified exposure (total and respirable dust, total and respirable endotoxin, and ammonia). Dependent variables (FEV_1 and FEF_{25-75}) were selected based on previous analysis by Donham *et al.*., (1995), which reported working in poultry facilities was significantly associated with cross-shift decline in these pulmonary functions. Three, five, and ten percent or greater cross-shift declines were selected as points for study because these values were used in previous swine confinement studies for recommended thresholds (Reynolds *et al.*, 1996; Donham *et al.*, 1995). Cross-shift declines in FEV_1 and FEF_{25-75} were calculated as follows:

$$\frac{\text{Pre-shift } FEV_1 - \text{Post-shift } FEV_1}{\text{Pre-shift } FEV_1} \times 100\% = \% \text{ change } FEV_1$$

$$\frac{\text{Pre-shift } FEF_{25-75} - \text{Post-shift } FEF_{25-75}}{\text{Pre-shift } FEF_{25-75}} \times 100\% = \% \text{ change } FEF_{25-75}$$

Odds ratios and 95% confidence intervals were calculated for 3%, 5%, and 10% lung function declines (FEV_1 and FEF_{25-75}) for each quartile of exposure.

Multiple logistic regressions were performed using environmental parameters as main predictor (independent) variables and cross-shift lung function decreases as dependent variables. Each environmental parameter was analyzed individually (controlling for age, years worked in poultry industry, gender, smoking status, and education) in relation to cross-shift changes in FEV_1 and FEF_{25-75} of 3%, 5%, or 10% (or greater). Odds ratios and 95% confidence intervals were determined for each quartile of environmental exposure to facilitate interpretation of dose-response relations.
The significance of trends was evaluated for cross-shift declines in FEV_1 and FEF_{25-75}, as related to increasing quartiles of dust, endotoxin, and ammonia exposures, using Cochran-Armitage trend tests (StatXact-3 software, Cytel). The probability of a trend was determined for each environmental exposure (Ho: beta=0, indicating no trend) for 3%, 5%, and 10% cross-shift declines in FEV_1 and FEF_{25-75} in separate models. Ninety-five percent confidence intervals and exact p values were calculated for beta.
Backward elimination models were created to determine which environmental exposures contributed significantly when total and respirable dust, total and respirable endotoxin, and ammonia were considered simultaneously. Separate models were created with 3%, 5%, and 10% cross-shift declines in FEV_1 and FEF_{25-75} as dependent variables, controlling for age, years worked, sex, smoking status, and level of education.

RESULTS

Table 1 is a list of the major demographic characteristics of poultry workers and controls. The mean number of years worked in the poultry industry was 9.7 (sd = 9.1). Race of poultry workers and controls was primarily Caucasians (99.8%).

Table 1. Demographic Characteristics of Study Subjects

	Poultry Workers (n=257)	Controls (n=150)
% Male	77%*	58%
Age	38.8 (4.2)†	42.1 (9.5)
Education (years)	12.2 (2.1)	13.1 (2.0)
Smoking Status (%)		
Never	52.9%	42.7%
Former	19.1%	30.7%
Current	28.0%	26.7%

* Categorical values are expressed as percentages
† Continuous variables are expressed as mean and (standard deviation)

Preliminary data analysis by Donham *et al.*., (1990) had shown that measures of pre-shift pulmonary function (FEV_1, FVC, FEF_{25-75}, and FEV_1/FVC) did not differ significantly between poultry workers and the comparison group. However, poultry work status was significantly associated with a work shift decline in FEV_1 and FEF_{25-75}, after adjusting for current smoking status (Donham *et al.*, 1990). The mean percent cross-shift decline in FEV_1 was 0.02% in controls compared to 1.10% in poultry workers. Mean cross-shift changes in FEF_{25-75} were a 2.10% increase in controls compared to a 1.50% decline in exposed workers (a 3.6% difference). Figure 1 graphically presents the percentage of workers that had declines in FEV_1 or FEF_{25-75} over shift. Workers more frequently had FEF decrements (ranging from 24% to 45% for 10% and 3% declines respectively). Decrements in FEV_1 ranged from 4% of workers (10% decline) to 30% of workers (3% decline).

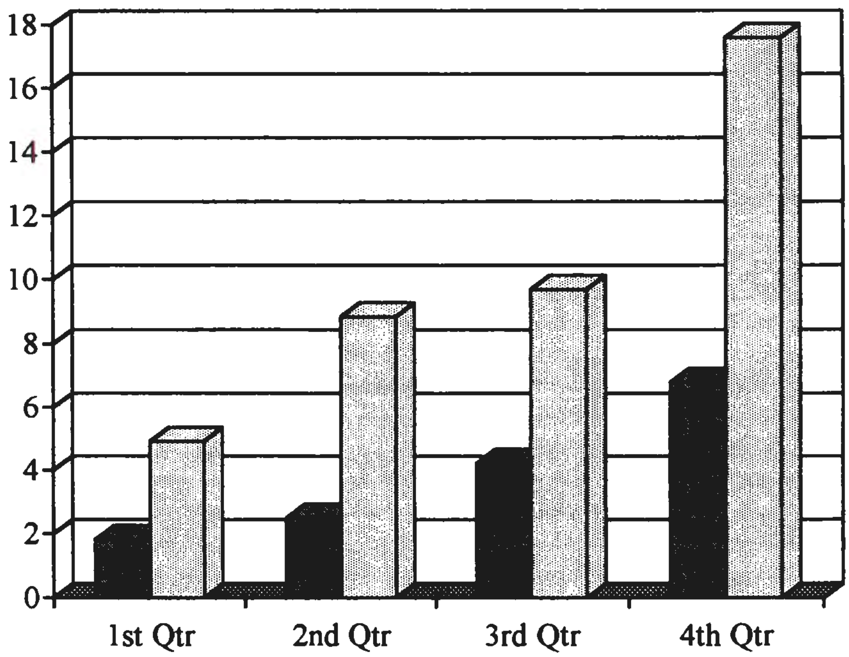

Figure 1. Percent of Poultry Workers Exhibiting 3%, 5%, and 10% or Greater Cross-Shift Declines in FEV_1 or FEF_{25-75}

Environmental Exposures

Table 2 summarizes personal environmental measures of total and respirable dust, total and respirable endotoxin, and ammonia. Ranges for the environmental variables were as follows: total dust (0.02-81.33 mg/m^3), respirable dust (0.01-7.73 mg/m^3), total endotoxin (0.24-39,167 EU/m^3), respirable endotoxin (0.35-694 EU/m^3), and ammonia (0-75 ppm). Approximately 10% of total dust (based on gravimetric means of airborne samples) was in the respirable range. The respirable portion of endotoxin was 3.7% of total endotoxin. The mean concentration of endotoxin per milligram of dust was 94 EU/mg for the respirable fractions and 245 EU/mg for total endotoxin/total dust.

Table 2. Environmental Exposures of Poultry Workers

Total Dust (mg/m^3)	n=238	6.5 ± 7.8*
Respirable Dust (mg/m^3)	n=210	0.63 ± 0.98
Total Endotoxin (EU/m^3)	n=236	1589.1 ± 3394.1
Respirable Endo (EU/m^3)	n=210	58.9 ± 97.3
Ammonia (ppm)	n=174	18.4 ± 17.5

Mean ± standard deviation

Table 3 summarizes Spearman correlations between environmental variables. Highly significant (e.g. $p \leq 0.0001$), moderately strong (e.g. r=0.4-0.8), Spearman correlation coefficients were observed between all combinations of total and respirable dust, total endotoxin, and respirable endotoxin. Ammonia was weakly ($r<0.3$) but significantly correlated to total dust and respirable endotoxin. Spearman correlation coefficients between environmental variables and cross-shift changes in lung function (Table 4) revealed that cross-shift decrements in FEV_1 were weakly but significantly correlated to all environmental variables except ammonia. Cross-shift decrements in $FEF_{25\text{-}75}$ were weakly and significantly correlated with total dust and total endotoxin only. However, the correlation of cross-shift decline in $FEF_{25\text{-}75}$ and respirable dust approached statistical significance for a weak relationship (r=0.12, p=0.08). Cross-shift decrements in FEV_1 and $FEF_{25\text{-}75}$ were moderately (r=0.66) and significantly correlated.

Table 3. Spearman Correlation Coefficients Between Environmental Exposure Variables

	Total Dust	Respirable Dust	Total Endotoxin	Respirable Endotoxin	Ammonia
Total Dust	1.000* (0.0000)†	0.539 (0.0001)	0.590 (0.0001)	0.466 (0.0001)	0.178 (0.0190)
Respirable Dust	0.539 (0.0001)	1.000 (0.0000)	0.461 (0.0001)	0.562 (0.0001)	0.007 0.9352)
Total Endotoxin	0.590 (0.0001)	0.461 (0.0001)	1.000 (0.0000)	0.646 (0.0001)	0.095 (0.2125)
Respirable Endotoxin	0.466 (0.0001)	0.562 (0.0001)	0.646 (0.0001)	1.000 (0.0000)	0.170 (0.0427)
Ammonia	0.178 (0.0190)	0.007 (0.9352)	0.095 (0.2125)	0.170 (0.0427)	1.000 (0.0000)

* upper number denotes r value

† lower number denotes p value

Table 4. Spearman Correlation Coefficients Between Environmental Exposure Variables and Cross-Shift Changes in Lung Function

	% Cross-Shift Decline	
	FEV_1	FEF_{25-75}
Total Dust	0.265* (0.0001)†	0.275 (0.0001)
Respirable Dust	0.155 0.0253)	0.122 (0.0785)
Total Endotoxin	0.193 (0.0030)	0.201 (0.0020)
Respirable Endotoxin	0.157 (0.0232)	0.085 (0.2198)
Ammonia	0.081 (0.2885)	0.058 (0.4443)
FEV_1	1.000 (0.0000)	0.658 (0.0001)
FEF_{25-75}	0.658 (0.0001)	1.000 (0.0000)

* upper number denotes r value
† lower number denotes p value

Dose-Response Evaluations

Results of the logistic regressions are summarized in Tables 5 and 6. Trends were generally strong and consistent of increasing odds ratios for lung function declines (FEV and FEF_{25-75}), relative to quartiles of increasing total and respirable dust, total and respirable endotoxin, and ammonia exposures. Cochran-Armitage trend tests showed statistically significant trends in odd ratios for 3% and 5% cross-shift declines in FEV_1 and 3%, 5%, and 10% cross-shift declines in FEF_{25-75} (Figure 1).

Threshold Values

Threshold values were estimated from the lower bound of the lowest quartile range exhibiting statistical significance for a 3% cross-shift decline in FEV_1 (see Table 5). Threshold concentrations predicted by logistic regression results for 3% or greater cross-shift declines in FEV_1 include 2.4 mg/m^3 for total dust (Figure 2), 0.162 mg/m^3 for respirable dust, 614 EU/m^3 for total endotoxin (Figure 3), 7.15 EU/m^3 for respirable

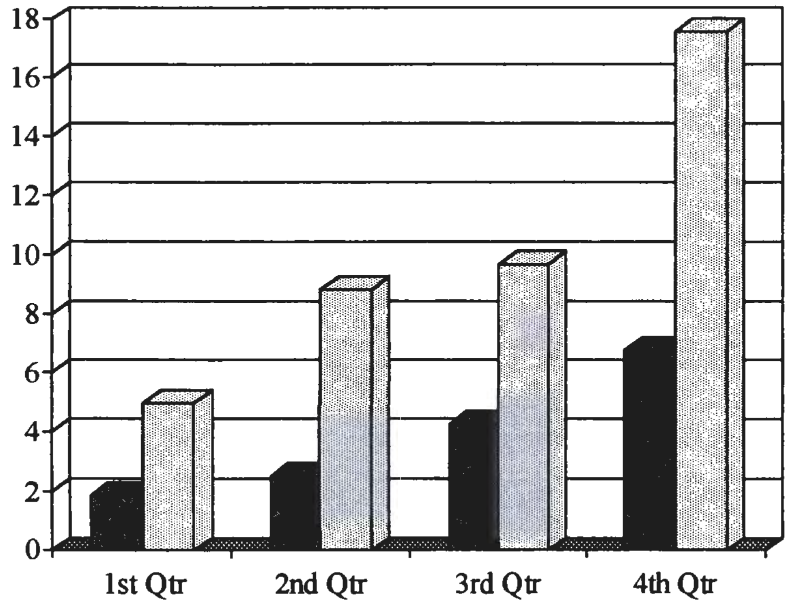

Figure 2. Total Dust Exposures (mg/m^3) Predictive of 3% and 5% or Greater Cross-Shift Declines in FEV_1

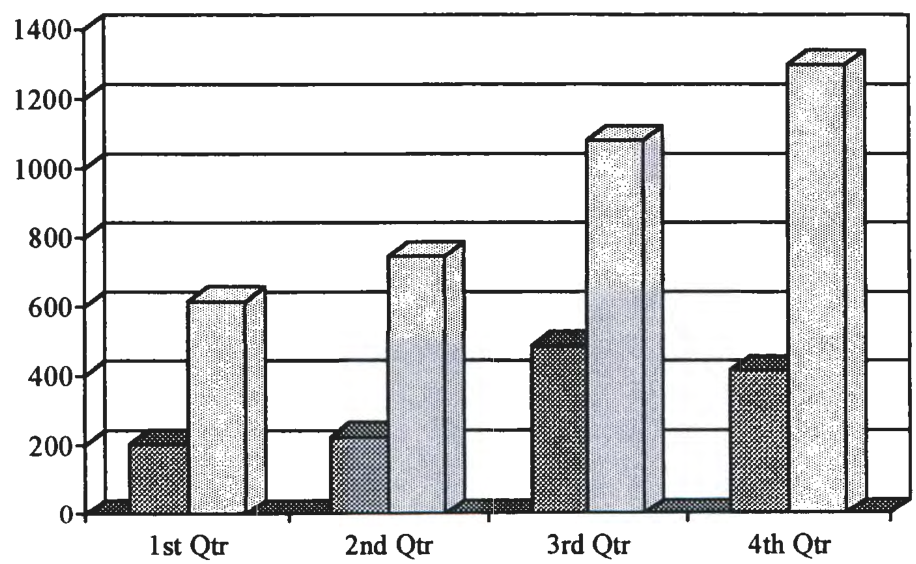

Figure 3. Total Endotoxin (IU/m^3) Predictive of 3% and 5% or Greater Cross-Shift Declines in FEV_1

Backward Elimination Models

Backward elimination models with 3%, 5%, and 10% (or greater) cross-shift declines in FEV_1 and FEF_{25-75} as dependent variables with continuous environmental independent variables as primary predictors revealed that ammonia was a significant predictor ($p=0.045$) for a 5% cross-shift decline in FEF_{25-75}. Furthermore, total dust was a significant predictor of a 5% or greater cross-shift decline in FEV_1 ($p=\leq 0.0015$).

DISCUSSION

The percentages of poultry-exposed workers exhibiting 3%, 5%, or 10% or greater cross-shift declines in FEV_1 were 29.8%, 17.3%, and 3.9% respectively. Similarly, percentages of poultry workers exhibiting 3%, 5%, or 10% or greater cross-shift declines in FEF_{25-75} were 46.3%, 39.2%, and 24.3% respectively.

Environmental Exposures

Environmental measures of total and respirable dust, total and respirable endotoxin, and ammonia were highly variable, but consistent with other poultry studies (Nielsen *et al.*, 1995; Reynolds *et al.*, 1993; Morris *et al.*, and Pickrell, 1991; Leistikow *et al.*, 1989; Mulhausen *et al.*, 1987; Jones *et al.*, 1984; Clark *et al.*, 1983; Olenchock *et al.*, 1982). Ranges of environmental measures were wide because sampling was done in variable seasons and diverse poultry environments (layer houses, broiler houses, turkey houses, load-out operations, and live-hang areas).

Total And Respirable Dusts

Total dust concentrations ranged from 0.02-81.33 mg/m^3. Because poultry house dusts are largely organic in content and have many bioactive substances, the OSHA standards (set only for nuisance dusts) for environmental agents are inappropriate in poultry confinement. However, it is interesting to note that the OSHA Permissible Exposure Limit (PEL) of 15 mg/m^3 for nuisance dusts was exceeded in work environments for 7.1% of poultry workers. Sixteen percent of poultry laborers worked in conditions exceeding the American Conference of Government Industrial Hygienists (ACGIH) nuisance dust standard of 10 mg/m^3. More importantly, the 4 mg/m^3 grain dust American Counsel Guideline for Industrial Hygiene (ACGIH) standard was exceeded for 54.2% of poultry workers, and the recommended swine confinement dust limit of 2.5 mg/m^3 was exceeded in 74.8% of personal measures (Reynolds *et al.*, 1996; Donham *et al.*, 1995; NMAM, 1994).

Endotoxin

Total endotoxin exposures ranged from 0.24-39,167 EU/m^3 and respirable endotoxin exposures ranged from 0.35-694 EU/m^3. Approximately 10% of measures of respirable endotoxin exceeded the proposed limit of 9 ng/m^3 (90 EU/m^3), based on cotton dust (Castellan *et al.*, 1987). The respirable portion of endotoxin was 3.7% of total endotoxin, lower than 5.7% reported by Olenchock *et al.*., (1982) and 11-30% reported by Pickrell (1991) for poultry confinement. Comparing the respirable portion of total endotoxin (3.7%) to the respirable portion of total dust (~10%), suggests that endotoxin is not concentrated in smaller, more respirable fractions. This is in contrast to earlier work of Donham *et al.*., (1986) in the analysis of swine house dust.

Ammonia

Ammonia exposures ranged from 0-75 ppm. The OSHA PEL of 50 ppm for ammonia was exceeded by only 5.7% of poultry workers. However, 21.3% of workers were exposed to conditions exceeding the ACGIH limit of 25 ppm and approximately 70% of personal samples exceeded the 7.5 ppm recommendation for swine confinement workers (Reynolds *et al.*, 1996; Donham *et al.*, 1995, 1989).

Dose-Response Evaluation

Assignment of causality between a risk factor and a disease or dysfunction is supported if dose-response relationships can be demonstrated. A dose-response relationship is suggested if the degree of exposure to a suspected risk factor parallels a gradient of risk (Donham *et al.*, 1994). Evidence of dose-response trends between poultry confinement exposures (total and respirable dust, total and respirable endotoxin, and ammonia) and impaired lung function (FEV_1 and FEF_{25-75}) was noted from increased odds ratios with increasing environmental exposures. The trends for all exposures were particularly prominent for 5% or greater declines in FEV_1.

Total and Respirable Dust

Statistical significance at the second quartile of total dust exposure for a 3% decline in FEV_1 is consistent with previous findings of Donham and Reynolds in swine confinement workers (Reynolds *et al.*, 1996; Donham *et al.*, 1995). While this study suggests a total dust threshold of 2.4 mg/m^3, the swine worker studies resulted in recommendations for maintaining dust levels below 2.5 mg/m^3 to promote healthful environmental working conditions. Likewise, statistical significance at the second quartile of respirable dust exposure (0.162-0.323 mg/m^3) for a 3% cross-shift decline in FEV_1 is comparable with recommendations for vertically elutriated cotton dust (0.2 mg/m^3 in preparation) and swine confinement respirable dust (0.23 mg/m^3) (Reynolds *et al.*, 1996; Donham *et al.*, 1995; Castellan *et al.*, 1987, 1984).

Threshold Values

Thresholds suggested by logistic regression results for 3% declines in FEV_1 include 2.4 mg/m^3 for total dust, 0.16 mg/m^3 for respirable dust, 614 EU/m^3 for total endotoxin, 0.35 EU/m^3 for respirable endotoxin, and 12 ppm for ammonia. Thresholds were selected for 3% cross-shift declines in FEV_1 based on previous swine confinement threshold studies (Reynolds *et al.*, 1996; Donham *et al.*, 1995). Environmental variables predictive of 5% FEV_1 declines showed larger odds ratios and more robust statistical significance compared to 3% declines, because relatively small numbers of the comparison group exhibited 5%, as compared to 3%, cross-shift declines.

Previous dose response studies of swine confinement workers have yielded exposure limit recommendations, including total dust at 2.4-2.5 mg/m^3, respirable dust at 0.23 mg/m^3, endotoxin at 0.1 ug/m^3 (1000 EU/m^3), and ammonia at 7-7.5 ppm (Reynolds *et al.*, 1996; Donham *et al.*, 1995, 1989). The threshold limits for ammonia and total dust in this study are very similar to those of swine studies, and therefore support previous recommendations of Donham and Reynolds (2.4 mg/m^3 total dust, and 7.5 ppm ammonia) for swine workers. Poultry confinement thresholds for respirable dust and endotoxin (0.162 mg/m^3, 61.4 EU/m^3) appear slightly lower than suggested by Donham (0.23 mg/m^3, 100 EU/m^3) for swine workers. In considering the limitations of this dose-response study (e.g. loss of information from categorization), there may be no actual differences between the poultry and swine thresholds, suggesting the possibility of a common threshold recommendation for poultry and swine confinement exposures. (It is important to note that swine study recommendations were based on exposure predictions for defined cross-shift changes in FEV_1 using linear regression models. In contrast, threshold values for this study were estimated from the lower bound of the lowest quartile range exhibiting statistical significance for a 3% cross-shift decline in FEV_1.) The current data combined with previous threshold data of other agricultural dusts (swine and cotton) suggest evidence for a generic threshold for workers exposed to agricultural dusts (Reynolds *et al.*, 1996; Donham *et al.*, 1995; Castellan *et al.*, 1987).

Trend Tests

Tests of trend for each environmental exposure variable verified the significance of dose-response relationships between total and respirable dust, total and respirable endotoxin, and ammonia and cross-shift declines in FEV_1 and $FEF_{25\text{-}75}$. Figures 2 and 3 are graphic examples of the trends of environmental exposure and cross-shift decline in pulmonary function. Figure 2 represents relationships between total dust and FEV_1, and Figure 3 shows the relationships in endotoxin and FEV1 response.

SUMMARY

This study supports and extends previous research of dose-response relationships between environmental organic dust exposures in livestock confinement and acute lung function declines. This is the first study of poultry confinement workers which exhibits dose-response trends between increasing environmental dust, ammonia, and endotoxin concentrations with corresponding cross-shift declines in worker lung function. Strong dose-response trends for cross-shift declines in FEV_1 and FEF_{25-75} were observed with both total and respirable endotoxin concentrations. Furthermore, high dust was consistently retained as a significant contributor in all FEV_1 and FEF_{25-75} models when expressed as a categorical variable. Furthermore, specific threshold concentrations were defined (total dust, 2.4 mg/m^3; respirable dust, 0.16 mg/m^3; total endotoxin, 614 EU/m^3; respirable endotoxin, 0.35 EU/m^3; and ammonia, 12 ppm). The thresholds suggested for minimal adverse FEV_1 effect are in general agreement with previous swine confinement studies. The fact that total dust, total endotoxin, and respirable endotoxin were all significantly correlated makes it especially difficult to tease out the "causal" effects of individual components. Organizing the exposures into quartiles appears to fit these data better, possibly because of interactions and non-linearity of the data.

Control Measures

Because the poultry industry is vertically integrated into the control of a few major companies, environmental control efforts are feasible despite dispersion of contract farmers. Short-term solutions to exposure reduction include improving ventilation, use of respiratory protective devices, humidity control, addition of ammonia stabilizers to litter, power washing buildings between production cycles, use of dust binders such as aerosolized vegetable oils, electrostatic precipitation of dust, use of extra oil/fat in feed, and use of the new strains of high oil corn as a feed component.

CONCLUSIONS

In summary, consistent relationships between environmental exposures inside livestock buildings, lung function changes, and or respiratory symptoms in workers have been observed in four separate studies (Donham *et al.*, 1999, 1995, 1989; Reynolds *et al.*, 1996). These studies are special in that exposure-response thresholds for workers have been identified. Based on these studies, we suggest exposure response thresholds for poultry and swine confinement environments. Although results for poultry and swine environments are very close, where there were difference, the lowest level is recommended. The threshold concentrations for human health inside livestock or poultry buildings are as follows:

Total Dust: 2.4 mg/m^3
Ammonia: 7 ppm (results from the poultry studies were 12 ppm)
Respirable Dust: 0.16 mg/m^3 (results from the swine studies were 0.23 mg/m^3)
Total Endotoxin: 614 EU/m^3 (results from the swine studies were 800 EU/m^3)
Respirable Endotoxin: 0.35 EU/m^3

In order to protect the estimated one million workers, owners and operators in the swine and poultry production industry, the authors think efforts to develop threshold limit standards should begin in the near future (Donham *et al.*, 1990, 1977).

Exposure limits for swine health have been previously recommended, and are very similar to limits for workers. The limits for swine health are as follows (Donham, 1991).

Total Dust: 3.7 mg/m^3
Respirable Dust: 0.23 mg/m^3
Endotoxin: 1,540 EU/m^3
Ammonia: 11 ppm

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Table 5. Environmental Exposures Predictive of 3% or Greater Cross-Shift Declines in FEV_1 Using Logistic Regression Methods*

Environmental Exposure by Quartile	OR†	95% CI	X^2	p
Total Dust (mg/m^3)				
0<Tdust≤2.409	1.833	(0.731, 4.599)	1.67	0.1964
2.409<Tdust≤4.551	2.502	(1.005, 6.227)	3.89	0.0487
4.551<Tdust≤8.221	4.220	(1.714, 10.392)	9.81	0.0017
8.221<Tdust	6.797	(2.794, 16.536)	17.85	0.0001
Respirable Dust (mg/m^3)				
0<Rdust≤0.162	2.377	(0.868, 6.508)	2.84	0.0921
0.162<Rdust≤0.323	4.789	(1.960, 11.704)	11.80	0.0006
0.323<Rdust≤0.660	3.322	(1.282, 8.610)	6.11	0.0134
0.660<Rdust	3.973	(1.648, 9.580)	9.44	0.0021
Total Endotoxin (EU/m^3)				
0<TEU≤154.975	2.029	(0.808, 5.095)	2.27	0.1319
154.975<TEU≤613.978	2.236	(0.872, 5.736)	2.81	0.0939
613.978<TEU≤1504.977	4.859	(2.093, 11.282)	13.53	0.0002
1504.977<TEU	4.158	(1.735, 9.964)	10.21	0.0014
Respirable Endotoxin (EU/m^3)				
0<REU≤7.153	3.867	(1.439, 10.395)	7.19	0.0073
7.153<REU≤29.749	2.805	(1.102, 7.143)	4.68	0.0306
29.749<REU≤64.998	3.822	(1.512, 9.666)	8.03	0.0046
64.998<REU	4.659	(1.935, 11.216)	11.78	0.0006
Ammonia (ppm)				
0<NH3≤5	1.876	(0.684, 5.144)	1.49	0.2217
5<NH3≤12	1.934	(0.724, 5.169)	1.73	0.1886
12<NH3≤25	4.247	(1.604, 11.246)	8.47	0.0036
25<NH3	2.450	(0.876, 6.851)	2.92	0.0877

* Logistic regression analysis results controlled for age, years worked in poultry industry, gender, smoking status, and education

† Individual exposure variables were divided into quartiles and an odds ratio and 95% Confidence Intervals were calculated for each quartile of exposure compared to controls.

Table 6. Environmental Exposures Predictive of 3% or Greater Cross-Shift Declines in FEF_{25-75} Using Logistic Regression Methods*

Environmental Exposure by Quartile	OR†	95% CI	X^2	p
Total Dust (mg/m^3)				
0<Tdust≤2.409	1.075	(0.492, 2.348)	0.03	0.8553
2.409<Tdust≤4.551	2.081	(0.955, 4.533)	3.40	0.0651
4.551<Tdust≤8.221	3.194	(1.439, 7.087)	8.15	0.0043
8.221<Tdust	4.597	(2.054, 10.289)	13.78	0.0002
Respirable Dust (mg/m^3)				
0<Rdust≤0.162	1.686	(0.696, 4.082)	1.34	0.2471
0.162<Rdust≤0.323	4.284	(1.877, 9.774)	11.95	0.0005
0.323<Rdust≤0.660	2.819	(1.205, 6.593)	5.71	0.0168
0.660<Rdust	2.828	(1.272, 6.288)	6.50	0.0108
Total Endotoxin (EU/m^3)				
0<TEU≤154.975	1.012	(0.454, 2.255)	0.00	0.9763
154.975<TEU≤613.978	2.504	(1.122, 5.591)	5.02	0.0251
613.978<TEU≤1504.977	3.331	(1.553, 7.148)	9.54	0.0020
1504.977<TEU	3.143	(1.438, 6.872)	8.23	0.0041
Respirable Endotoxin (EU/m^3)				
0<REU≤7.153	2.631	(1.092, 6.340)	4.64	0.0311
7.153<REU≤29.749	2.481	(1.094, 5.629)	4.73	0.0296
29.749<REU≤64.998	2.959	(1.284, 6.819)	6.49	0.0109
64.998<REU	3.429	(1.547, 7.602)	9.20	0.0024
Ammonia (ppm)				
0<NH3≤5	1.568	(0.661, 3.724)	1.04	0.3076
5<NH3≤12	2.663	(1.144, 6.199)	5.16	0.0231
12<NH3≤25	4.390	(1.795, 10.735)	10.52	0.0012
25<NH3	2.089	(0.850, 5.134)	2.58	0.1082

* Logistic regression analysis results controlled for age, years worked in poultry industry, gender, smoking status, and education

† Individual exposure variables were divided into quartiles and an odds ratio and 95% Confidence Intervals were calculated for each quartile of exposure compared to controls.

TYSON'S ENVIRONMENTAL AWARDS PROGRAM

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BACKGROUND

As our national population continues to grow, we continue to experience a reduction in available farmland with increased demand for farm products, especially chickens. In recent times we have experienced much negative publicity about the impact of our industry on the environment. The environmental impact, whether real, perceived or imagined as viewed through the public eye, has been less than what we desire for our corporate image. In an effort to promote sound environmental stewardship and recognize those who practice it, Tyson Foods has chosen to establish the Tyson Foods Poultry Environmental Award.

Tyson chickens, like most of the nations poultry, are primarily produced on small family owned farms. These producers have consistently risen to meet the challenges of modern day poultry production. It is through their continued efforts and superior stewardship of the resources available to them that we will continue to have the basic raw materials required to produce high quality poultry based food products. This program is designed to select and reward the best stewards of the environment from among our many producers.

WHO MAY BE CONSIDERED?

Any Tyson poultry producer regardless of type or size of the operation may be considered. The only exception is previous national award winners who must wait three (3) years before again becoming eligible to compete. This is to ensure strong competition and bold environmental improvements by all producers.

HOW DOES THE PROGRAM WORK?

The producer must apply or be nominated to be included in the selection process. There will be a winner selected by a local committee from each Tyson complex where live chickens are produced. Each local complex winner is automatically considered in the national level competition for the five- (5) top awards. A committee appointed by the Tyson Corporate Environmental Compliance Department will select the national level winners. This selection committee may include individuals from any or all of the following or other sources: USDA Extension Service, Natural Resource Conservation Service (NRCS), local Soil and Water Conservation District, Environmental Protection Agency (EPA), financial institutions, colleges and universities, and Tyson management. Local complexes are encouraged to use committees selected from the same or similar sources. The application is based on information from the following environmental areas:

1. General nature, history and production information.
2. Manure management and other best management practices (BMP's).
3. Off -farm agriculture related activities
4. Aesthetics and community involvement.
5. Other environmental or agricultural awards.
6. Innovations and wildlife management.

The complex facilities will be divided into three (3) regions (see below). The dividing factors are number of complexes per region, similarities in state requirements and location. The national selection committee will narrow the local winners to three per region based on the information submitted in the application. After selecting the three top candidates per region, the producers selected will then be visited by the national selection committee. Each region is guaranteed one national winner. After selecting the top applicant in each region the remaining six (6) applicants, that were visited, will then compete for the remaining two national winners.

REGION ONE	REGION TWO	REGION THREE
Arkansas	Texas	Georgia
Missouri	Mississippi	Florida
Oklahoma	Alabama	North Carolina
	Tennessee	Virginia
	Kentucky	Pennsylvania
	Indiana	Maryland

WHAT DO THE WINNERS RECEIVE?

Local complex winners receive a certificate and $500.00 cash. The service technician for each complex winner will also receive $500.00 cash. The five- (5) national winners will each receive a trophy, an all expense paid trip to the annual stockholders meeting and $2,500.00 cash. These five (5) winners will be accompanied by their service tech at the annual stockholders meeting. In addition, the awards committee will receive input from the local complexes represented by the five- (5) national winners and the winners themselves to select five (5) organizations that promote sound environmental policy and education. Tyson Foods will then contribute $500.00 to each of these organizations.

HOW TO APPLY OR BE NOMINATED?

Application/nomination forms are available from Tyson Foods, Inc., Environmental Compliance Department, PO Box 2020, Springdale, AR 72765. Anyone desiring to apply or nominate a producer should submit an application to the local complex no later than June 1, 2000. The local complex winners must be submitted to the Tyson Environmental Compliance Department no later than July 15, 2000. Additional information may be requested from the applicants if needed by the selection committee. Farm visits may be necessary by the selection committee and/or a sub-committee.

ENSURING ENVIRONMENTAL EXCELLENCE

We, at Tyson Foods, believe that our poultry producers can, do, and will continue to make environmental improvements while producing poultry with superior quality. Please share with us your management ideas that have resulted in responsible, environmentally sound care of your operation. Stewardship comes from hard work and sound knowledge applied in a common sense approach. You can make a difference by helping others.

View Video (10 min.)

Selection process for Tyson Foods, Inc. National Environmental Award winner.

Please direct questions or comments to the Tyson Environmental Compliance Department at 1-800-643-3410 in Springdale, Arkansas.

Tyson Foods Poultry Environmental Award
Application Form

Name:____

Address: ____

City/State/Zip: ____

Telephone: ________________________ Signature:__________________________

Complex: ____________________________________

Which best describes this poultry operation?
_____ Broiler _____ Breeder_____ Pullet

Total Capacity of birds per flock:______________

Total number of acres (owned and rented):_______________

<u>Instructions for submitting Application form</u>:

- On separate pages, please provide complete details and full documentation in each of the seven areas listed below. Please use black ink or typewritten format.
- Photographs may be submitted with a minimum of 6 and a maximum of 12.
- If supplements are used, i.e., magazine/newspaper articles, please summarize the highlights of these items within your application. Applications, photos, tapes, etc., cannot be returned to you.
- **Forms must be returned for the local complex <u>nominations</u> no later than June 1, 2000. For local complex <u>winners</u> no later than July 15, 2000. Please send all nomination information to the local complex. Local complex winner applications must be submitted to corporate Environmental Compliance CP032.**

Winners will be selected based on the following criteria:

1. Give a brief description of the general nature, history, and production information of the operation? **(10 points)**

2. Describe the manure management practices including any manure management program contributing to additional profitability on the farm. Highlight information regarding water quality protection measures, odor control and land application practices including soil/ crop management practices. Things to include are how long

farm/nutrient management plan has been in place and applied, Best Management Practices (BMP's), bird disposal, and any other things that are above and beyond the requirements of the state and Tyson Foods, Inc. that promoted environmental stewardship on the farm **(35 points)**

3. Provide details about any agriculture-related activities, off the farm, in which the producer and his family are involved. **(15 points)**

4. Farm aesthetics and neighbor relations are important to the poultry industry. List the steps taken to present a positive visual image for this operation and to improve communications and relations with neighbors and community. **(20 points)**

5. List and briefly describe any environmental or agricultural award previously won by the producer. **(5 points)**

6. Describe any new innovative ideas applied to this farm and nutrient management plan including wildlife management. **(15 points)**

7. In 500 words or less, please describe "What Environmental Stewardship means to you."

A NEW METHOD FOR FORMULATING RATIONS

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Excess nitrogen and phosphorus levels in animal waste are a major concern relative to air and water quality (Patterson and Blake, 1994; Turner and Usry 1992). Historically, the economics of animal production were calculated by maximizing meat animal growth or egg and milk production, while minimizing feed costs (Scott, 1992). In the future, the cost of insuring efficient nutrient management may be added to the feed price tag (Scott, 1992). Considerable effort has been exerted to improve the availability and determination of nutrients.

DETERMINATION OF NUTRIENT AMOUNT AND AVAILABILITY

Several methods have been suggested and implemented to reduce nutrient wastage including the use of enzymes (such as phytases) and digestible amino acid values to make nutrient levels in ingredients more available to meet the nutrient requirements of the animal (Dudley-Cash, 1998; Summers, 1997). In addition, protein levels are being lowered and amino acids are being supplemented in a chemical form to meet nutrient requirements and minimize nutrient waste (Cantor *et al.* 1999).

Because amino acid determination is expensive due to chemical analysis and the laboratory turnover time required for analysis the expense in time and money has prompted a search for alternatives to chemical analysis. Two quantitative methods of predicting amino acid levels have been developed using linear regression with an input of either crude protein (Degussa Corporation, 1990) or proximate analysis (PA) (Monsanto, 1986a,b,c). The equations have divergent and sometimes low R^2 values. The R^2 value reflects the amount of variability explained by the equation. Artificial neural networks have been shown to be an alternative to regression analysis for amino acid prediction (Cravener and Roush, 1999). Artificial neural networks were inspired by the structure and function of biological neurons in animals. The neural network may more effectively reflect the complex relationship between inputs (ingredient proximate analysis) and outputs (amino acid level). Neural network predictions usually result in a tighter fit of the data than is accomplished by regression analysis. As a result, the tighter fit usually leads to better predictions (Ward Systems Group, 1993)

RATON FORMULATION: AN OPPORTUNITY FOR NUTRIENT MANAGEMENT

While the methods for improving nutrient availability and determination have resulted in some success, they have not addressed a basic problem. Almost all livestock feeds are now mixed according to a mathematical recipe with the objective to meet the nutrient requirement of the animal. If these recipes (input) are not optimal, then nutrient waste will result.

Figure 1 shows a flow diagram from 'nutrients in ingredients' to 'nutrients excreted'. A key link in the process is the method of formulation of the recipes.

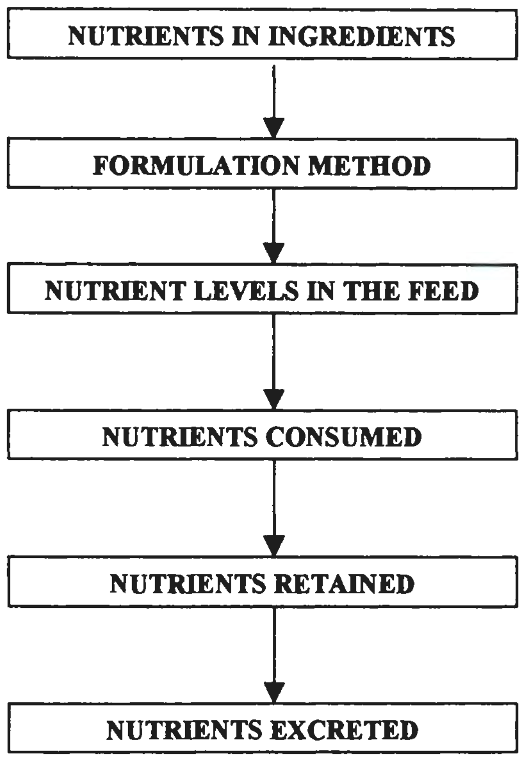

Figure 1. Flow of Nutrients from Ingredients to Excreta

On a commercial level, computer formulation is the method that is used to balance the nutrients in ingredients with nutrient requirements of the animal. Most companies use linear programming which minimizes the cost of the ration by adjusting the levels and combinations of ingredients relative to nutrient and ingredient constraints. Most feed manufacturers want to minimize the risk of not meeting the nutrient requirements of the animal. All nutrients in feed ingredients have variability associated with them. For example, the protein content of soybean meal is commonly stated as 50%. However, when samples are taken of loads of soybean meal, the protein content can vary from 48% to 52%. To minimize risk, nutrient and requirement adjustments have been proposed for the linear program to compensate for the uncertainty of the level of nutrients.

Early in the advent of computer formulation, it was recognized that variability of nutrients was a potential problem in meeting the nutrient requirements of animals. Nott and Combs (1967) suggested a margin of safety adjustment of a fraction of the standard deviation of the nutrient mean. An adjustment of .5 or (1/2) of the standard deviation of the nutrient mean would insure the nutrient mean would be met 69% or more of the time.

However, there is a problem coming from the mathematical assumptions associated with linear programming. One of those assumptions is that the conditions of certainty exist. That is, the numerical values in the objective and constraint equations are known with certainty and do not change during the period being studied. It is assumed there is no variation in the numerical values. We have just pointed out that there is, in fact, variability associated with nutrient levels. The problem of over formulation provides an opportunity for investigation of methods to more accurately meet nutrient requests. One of those opportunities is stochastic nonlinear programming as an alternative to linear programming for feed formulation. Stochastic programming incorporates the nutrient variability in the formulation process.

To illustrate the nutrient management opportunity, Table 1 calculates the difference that linear and stochastic programming can make in generating excess nitrogen. These calculations are based on the findings of Roush *et al.*, (1996).

Table 1. Calculated Nitrogen Levels of Diets Formulated with Linear Programming with a Margin of Safety and Stochastic Programming

Broilers:

Consume 8 lbs feed/ 4 lb broiler.

@ 23.6% CP Feed - linear programming (margin of safety) = 1.888 lbs protein (.236 x 8)

@ 23.2% CP Feed -stochastic program = 1.856 lbs protein (.232 x 8)

Difference = .032 lbs protein
or
= .032 * 0.16 (%N in Protein)
= .00512 lbs nitrogen

In the U.S. (7.8 billion birds)

.00512 x 7.8 billion birds = 37,376,000 lbs (18,688 tons) excess nitrogen per year.

In Pennsylvania (135 million birds)

.00512 x 135,000,000 birds = 691, 200 lbs (346 tons) excess nitrogen per year.

Although the amount of reduction appears to be small in Table 1, it should be pointed out that formulated rations are, in fact, recipes that are given to feed mills. That is, designated amounts of ingredients are proportioned in each mix. Therefore the differences in amounts of excess nutrients (and differences in prices) are real. When taken into context of the number of animals involved, the excess amounts can be significant. Table 1 only includes an estimate for broiler chickens.

Because the statistical adjustment of the nutrients in an ingredient database is a stochastic adjustment, the linear program is an inappropriate tool for this type of formulation. It has been suggested that stochastic programming would be a better tool. In fact, Roush (1994) and Roush *et al.* (1996) have shown that stochastic programming will more accurately meet requested nutrient levels and at a reduced cost.

To gain insight into the way nutrients are adjusted in linear programming and stochastic programming consider the following constraints. The first mathematical program constraint, using protein as an example, adjusts corn and soybean by .5 times the standard deviation and subtraction from the appropriate mean, as follows:

$$\mathbf{(8.7-.5*(.8))*Corn +(48.8-.5*.4))*\ Soybean\ l > 23\%,}$$

where 8.7 and 48.8 are the average values of protein in corn and soybean respectively; .8 and .4 are the standard deviations of protein for corn and soybean, respectively ; .5 is the standard normal deviate for correction, and 23% is the requested level of protein for the ration.

The stochastic program also includes an adjustment. But it is handled a little differently. The following is the constraint as it would be handled by a stochastic programming approach:

$$\mathbf{8.7*Corn +48.8*Soybean -.5*\ ((.8^2*\ Corn^2)+(.4^2\ *\ Soybean^2))^{.5} > 23\%}$$

An intuitive analogy to the comparison of adjustments made by linear and stochastic programs are as follows:

Remembering from math class that,

$$\sqrt{(9)} + \sqrt{(16)} = 7 \quad \text{(the linear programming approach)}$$

does not equal

$$\sqrt{(9+16)} = 5 \quad \text{(the stochastic programming approach).}$$

The linear programming approach makes an over correction and, thus, an over formulation. It is the over formulation that is a potential pollution problem.

For more extensive explanation of the philosophy and use of stochastic nonlinear programming refer to Roush, 1994; and Roush *et al.* 1996.

Table 2 shows another example in which a linear program with a margin of safety will over formulate nutrients. For crude protein, the linear program (LP) had a requested probability of 50%. The linear programming with a margin of safety (LPMS) and the stochastic program (SP) had requested probabilities of 69% to meet the nutrient requirement. Amino acids were formulated at a requested 50% probability. Excesses are shown for a majority of the amino acids when it is considered that a probability above the requested probability would represent nutrient wastage.

Table 2. Over Formulation of Nutrients.

Nutrient	Requirement, (%)	Requested Probability	LP	LPMS	SP
Protein	23.00	69%	23.1 (60)	23.56 (87)	23.24 (69)
Arginine	1.25	50	1.29 (77)	1.34 (94)	1.30 (83)
Glycine	.1	50	1.1 (100)	1.13 (100)	1.12 (100)
Histidine	.35	50	.54 (100)	.55 (100)	.54 (100)
Isolucine	.80	50	.88 (99)	.91 (99)	.88 (99)
Leucine	1.30	50	2.01 (100)	2.05 (100)	2.02 (100)
Lysine	1.10	50	1.10 (50)	1.10 (50)	1.10 (50)
Methionine	.50	50	.54 (97)	.53 (94)	.53 (97)
Met+Cys	.90	50	.90 (50)	.90 (50)	.90 (50)
Phenlyalanine	.72	50	1.04 (100)	1.08 (100)	1.05 (100)
Tyrosine	.10	50	.72 (100)	.74 (100)	.73 (100)
Phe+Tyr	1.34	50	1.44 (92)	1.47 (96)	1.45 (93)
Serine	.10	50	1.03 (100)	1.06 (100)	1.03 (100)
Threonine	.80	50	.80 (50)	.83 (82)	.81 (59)
Tryptophan	.20	50	.25 (100)	.27 (100)	.25 (100)
Valine	.90	50	1.04 (100)	1.06 (100)	1.04 (100)

*Figures (in parentheses) represent the calculated probability of meeting the nutrient requirement. Requested probabilities for protein were 50%, 69% and 69% for linear programming (LP), LP with a margin of safety (LPMS) and stochastic programming (SP), respectively. The amino acids in all of the rations were requested at a 50% probability. Percentages over the requested probability represent over formulation.

SUMMARY

The formulation method is a link between nutrient input and nutrient waste. The commercial industry uses linear programming with databases in which the nutrients are adjusted with a margin of safety. Stochastic programming, a new method of formulating rations, is being explored as an alternative to linear programming with a margin of safety for feed formulation. Results have shown that stochastic programming more accurately meets requested nutrient probabilities. The result is a reduction in nutrient waste.

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ESTIMATED NUTRIENT MOVEMENT WITH ALTERNATIVE POULTRY LITTER APPLICATION RATES ON VARIOUS SOILS, USING DIFFERENT MANAGEMENT SYSTEMS

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The Food and Agricultural Policy Research Institute (FAPRI) at the University of Missouri has devoted significant effort over the past few years examining the interface between production agriculture and the environment at the farm and watershed scales. During the last two years the state of Missouri through an advisory panel, has determined that one area of major interest is the environmental performance of broiler producers. The Missouri Poultry Federation has cooperated in this effort to quantify the environmental and the financial performance of broiler producers.

Producer panels were convened in Lawrence and Barry counties, and McDonald and Newton counties. These two panels provided the data needed to develop the "representative" farm models used to evaluate current and alternative litter management systems.

The objectives of these studies are to

- assess the environmental impacts on surface and ground waters of adopting alternative poultry litter management strategies compared with current practices and
- assess on-farm financial impacts of adopting alternative poultry litter management strategies compared with current practices.

METHODOLOGY

The Agricultural Policy Environmental eXtender (APEX) model was used to simulate the crop production and environmental impacts of the current and alternative crop and management practices. This model is one of a system of models developed by the Grassland Soil and Water Research Laboratory, Agricultural Research Service, United

States Department of Agricultural and the Blackland Research Center, Texas Agricultural Experiment Station in cooperation with other government agencies and universities.

APEX simulations were made to estimate the soil movement and loading of nutrients with

- current management practices,
- pasture forage change and commercial fertilizer instead of poultry litter,
- alternative changes in grazing management and/or pasture forages, and
- alternative forages harvested for hay with no grazing.

The Farm Level Income and Policy Simulation (FLIPSIM) model developed by Dr. James Richardson at Texas A&M University was used to simulate the economic viability of the representative broiler operation over a one to ten-year period. The simulated results include

- income statement,
- balance sheet,
- cash flow,
- income tax summary, and
- risk analysis.

Integration of the environmental and financial analyses helps producers and policymakers compare the environmental and economic benefits and costs of alternative litter management systems.

DESCRIPTION OF KEY NUTRIENT AND TILLAGE PROCESSES

The APEX model contains over 300 equations to simulate many of the physical and environmental processes that impact soil nutrient accumulation and water quality. The following brief description is designed to help the reader understand the farm results that follow.

Nitrogen occurs in the soil in many forms. APEX simulates denitrification, mineralization, volitalization, nitrification, crop uptake, and nitrogen movement with water and sediment. When poultry litter is applied to crops, all of these processes interact to simulate the impacts of poultry litter. For example, 2 tons of poultry litter contain approximately 1 lb of elemental nitrogen in nitrate form, 111 lbs of nitrogen in ammonia form, and 64 lbs of nitrogen in organic form. These contents vary with ration and manure handling. The nitrate form is readily available for crop use, movement with water, or denitrification. The ammonia form may volatize (highly likely if not incorporated in the soil) or may be converted to nitrate form with nitrification. The organic nitrogen may move with sediment or be mineralized to nitrate form. Crop uptake varies from approximately 62 to 214 lbs/ac among the alternatives analyzed. Some of the alternatives require supplemental nitrogen to meet crop needs.

Phosphorus also occurs in the soil in many forms and goes through multiple chemical processes. APEX simulates mineralization, crop uptake, and phosphorus movement with water and sediment. To continue the example, 2 tons of poultry litter contain approximately 29 lbs of phosphorus in soluble form and 45 lbs of phosphorus in organic form. Phosphorus contents also vary with ration and manure handling. The soluble form is readily available for crop use or movement with water. The organic phosphorus may move with sediment or be mineralized to soluble form. Among the alternatives analyzed, crop uptake varies from approximately 9 to 21 lbs/ac.

APEX accounts for livestock grazing by removing biomass from the growing crop, depositing a portion of that biomass as dead crop residue to account for trampled forage, and adding livestock manure each day, all at rates consistent with the stocking rate of the livestock. The harvested crop nitrogen uptake for the grazing alternatives is estimated to be 62 lbs of nitrogen per acre. However, approximately 40 lbs of nitrogen in ammonia form and 17 lbs of nitrogen in organic form are returned to the pasture in the manure. The harvested crop phosphorus uptake is estimated to be 13 lbs of phosphorus per acre. Approximately 5 lbs of soluble phosphorus and 4 lbs of organic phosphorus are also returned in manure. The no-cattle, hay production only alternatives remove 85 to 214 lbs of nitrogen and 9 to 21 lbs of phosphorus with no nitrogen or phosphorus returned in manure.

Runoff water extracts nitrogen and phosphorus from the surface soil (upper centimeter [.4 in] in the APEX model). Incorporating nitrogen and phosphorus into lower soil layers has the potential to reduce nutrient movement with runoff water and sediment. Incorporation is accomplished in two ways, tillage and biological mixing, e.g., earthworms. Plowing before seeding or sprigging are the tillage practices considered in this study. Because so little tillage occurs in pasture and hay production, the surface soil layer builds up phosphorus with manure application. As a result, movement of nitrogen and phosphorus with runoff water and sediment is very sensitive to biological mixing and any tillage that occurs.

Both water and nutrients must be available in a soil layer for the roots to absorb the nutrients. Large amounts of nutrients in the near surface layers may change the crop availability and uptake in dry months when the soil surface lacks the moisture to carry nutrients into the roots.

Environmental data was obtained from the panel members and entered into the APEX model. Soil nutrient concentrations for the top 6 inches are based on panelist management discussions and University of Missouri research. Litter nutrient levels from the APEX fertilizer data were compared to University of Missouri estimates for consistency and then used. The APEX model determines the environmental performance at the representative farm edge of field, accumulates this edge of field data and moves it to the outlet(s) of the representative watershed. The environmental output data was used to validate the representative farms with the panel members.

Financial information obtained from the panel members was entered into the FLIPSIM model and simulated for 1998. The financial output was used to validate the farm with the panel.

Computer simulations for 50 years were used to generate a distribution of yields and environmental impacts across many alternative weather years. Daily rainfall, temperature, relative humidity, radiation, and wind were generated for 50 years based on Springfield, Missouri, weather statistics.

The panelists identified different management alternatives. For each alternative, financial and environmental data was gathered from the panel. Using the 1999 and 2000 FAPRI Baselines and the FLIPSIM model, a 6-year financial outlook for each alternative was developed. Panel members are then able to compare the financial and environmental results for each alternative to the baseline.

REPRESENTATIVE FARMS

Lawrence/Barry Counties Representative Broiler Farm

This farm has 160 acres of land with 130 acres of fescue pasture and 50 cow/calf pairs. It is split into 3 fields of 30, 50, and 50 acres each. Litter is applied at a rate of 2 t/ac annually.

Soil Characteristics: The Tonti silt loam (slope 2%, slope length 250 ft.) soil map unit was the dominant soil for this representative farm. It has a restrictive soil layer, fragipan that inhibits water, and nutrient movement which increases runoff.

Alternative Poultry Litter Management: The farm panel identified five alternatives to their current poultry litter management practice. One was to use no litter, another was to adopt an improved fescue/legume pasture, and the remaining three all converted from cow/calf grazing and hay production to hay production only with either Bermuda grass, alfalfa, or eastern gama grass hay. Hay production recycles more phosphorus than grazing but it does not recycle all the phosphorus currently applied. This results in phosphorus buildup in the soil and movement with water and sediment.

After discussing the results of these alternatives with the farm panel, the panel suggested that we consider another alternative, which was to maintain the current system but apply litter every other year and sell the litter not applied. The environmental and economic impacts of the current management and three alternatives (no litter, eastern gama grass hay production, and applying litter on alternate years with current management) are presented in Figures 1-3. The beginning soil phosphorus levels vary slightly because the 50-year period of simulation begins after 3 years of simulation to allow pasture and hay rotations to be established.

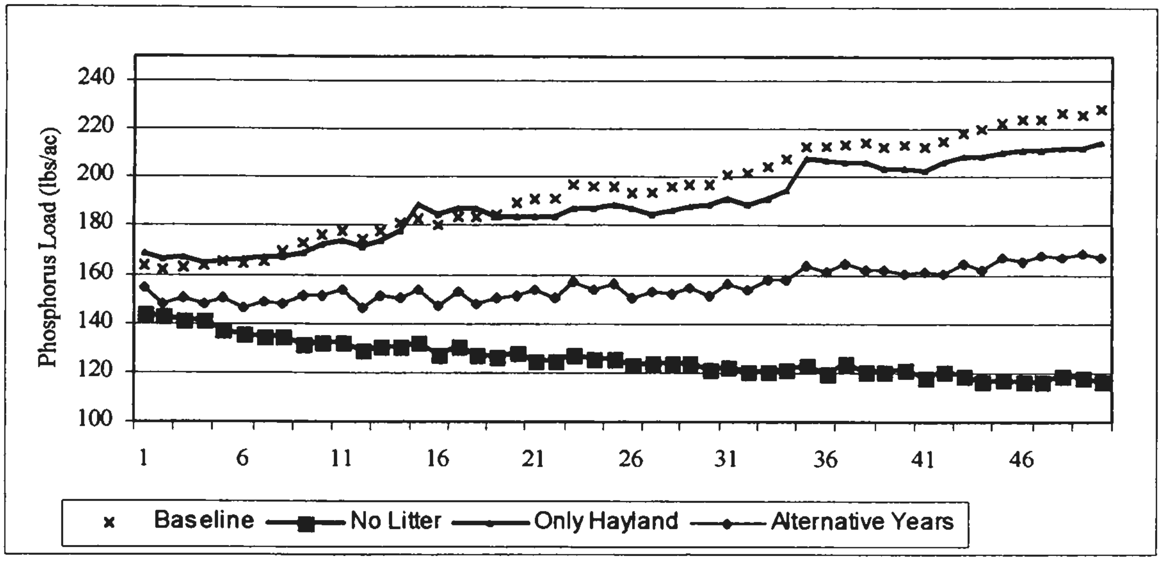

Figure 1. Projected Accumulated Soil Phosphorus Loading in the Top Six Inches of Soil

Soil Phosphorus Accumulations: The soil phosphorus accumulation in the upper six inches of soil relative to the baseline is reduced slightly by the hay production alternative and nearly reduced to zero by alternate year litter application. The no litter management reduces the soil phosphorus.

Annual Phosphorus movement: The annual phosphorus movement in runoff varies greatly from year to year due to the weather variability, particularly rainfall. There is a response to reduced litter application particularly in the later years of the 50-year period because the soil phosphorus available for runoff is much less.

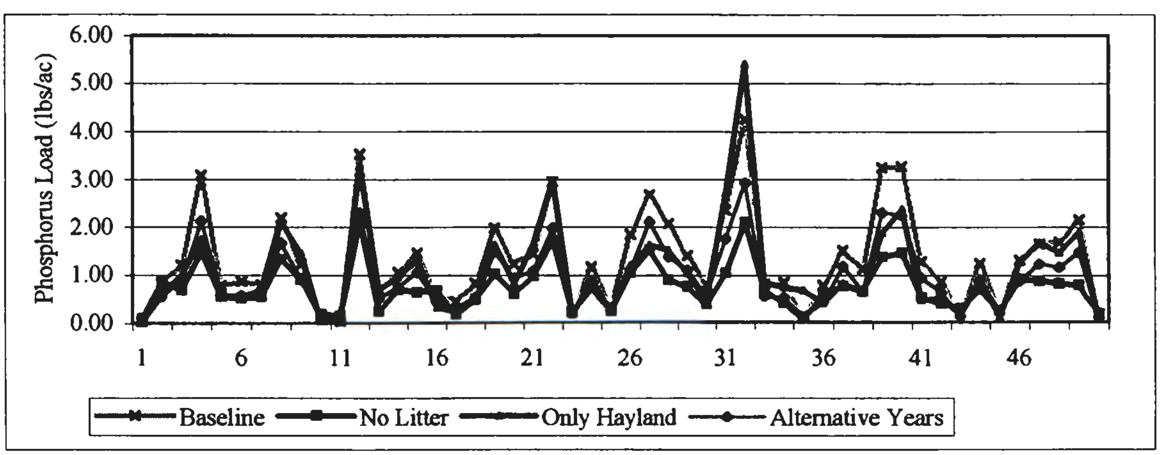

Figure 2. Project Phosphorus Loading in Runoff

Economic Impacts: The hay production alternative is the only scenario that maintains a positive ending cash reserve throughout the simulation period (1998-2003). This is due to the increase in receipts associated with the sale of hay. The other three scenarios build a large deficit cash reserve the first five years (1998-2002). After 2002, all four scenarios show a sharp increase in ending cash reserves because the farm pays off their poultry houses.

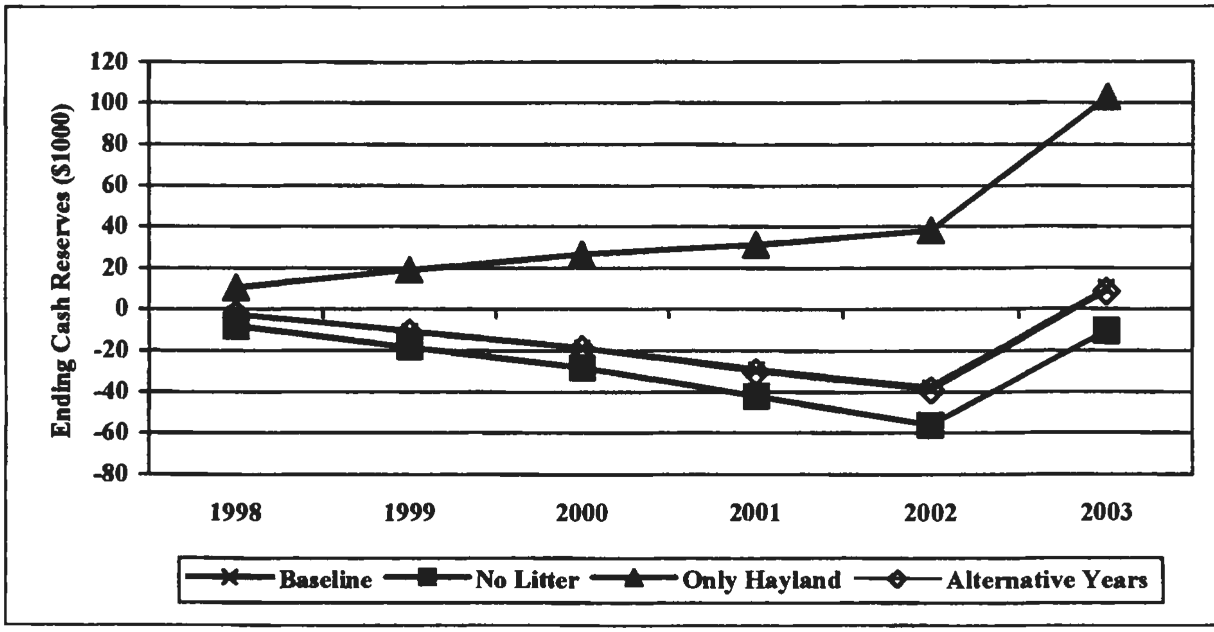

Figure 3. Ending Cash Reserves for Lawrence and Barry Counties Contract Broiler Representative Farm

<u>McDonald/Newton Counties Representative Broiler Farm</u>

This farm has 200 acres (five 40 acre fields) of clover/tall fescue pasture with 50 cow-calf pairs. Hay is harvested once per year in the spring from one field. Litter is applied at a rate of 2 t/ac annually.

<u>Soil Charactistics:</u> Each soil map unit within the following two soil groups is simulated as the dominant soil for the entire field and farm.

- Soil map units Tonti silt loam (slope 2%, slope length 250 ft.), Hoberg silt loam (slope 2%, slope length 250 ft.), and Nixa very gravelly silt loam (slope 5%, slope length 200 ft.) are grouped as having a fragipan.
- Soil map units Clarksville very gravelly silt loam (slope 12%, slope length 200 ft.) and Crackerneck very gravelly silt loam (slope 5%, slope length 200 ft.) are grouped as non-fragipan located in karst regions.

<u>Alternative Poultry Litter Management:</u> The McDonald/Newton counties farm panel initially identified two alternatives to their current poultry litter management practice. The alternatives converted 20 acres of the 40-acre field that was harvested for hay to

Bermuda grass hay or Caucasian bluestem hay production. Litter was applied at a rate of 2 t/ac annually.

After discussing the first two alternatives, a third was proposed that converted all fields to Fescue/clover pasture grazed 150 days each spring and summer by 300 stockers with 2 t/ac of litter applied annually. This alternative increased income, but had a negligible impact on nutrient movement.

Subsequently, the panel proposed two new alternatives. One applied litter every second year at 2 t/ac on Matua bromegrass/clover pasture grazed 150 days annually by 300 stockers. The other applied litter every third year at 2 t/ac on Matua bromegrass/clover pasture grazed 150 days annually by 300 stockers. These alternatives increased income and reduced phosphorus build up in the soil and phosphorus movement.

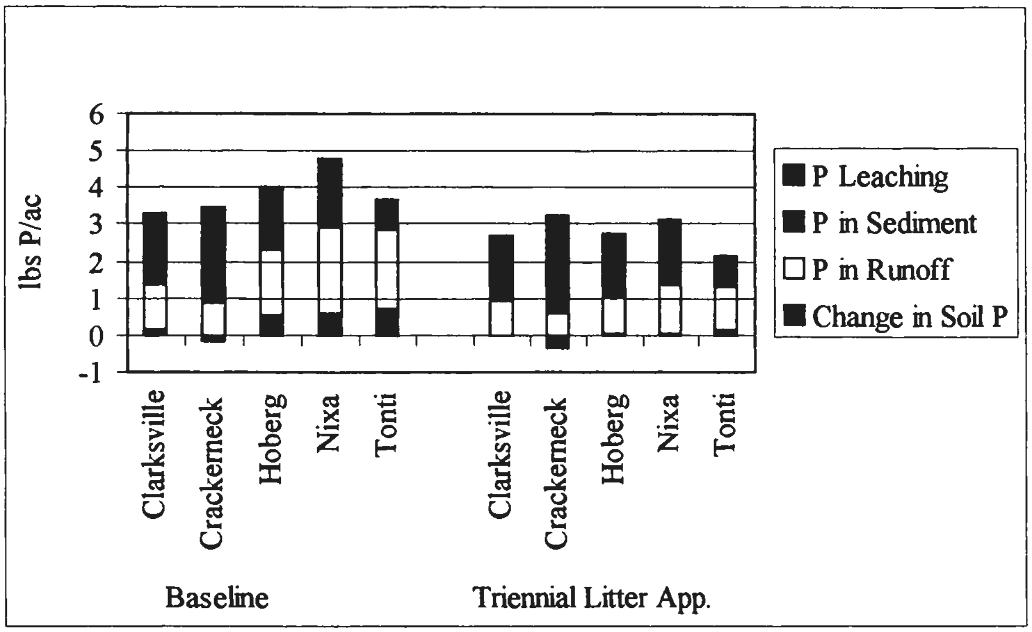

Figure 4. Phosphorus Movement Across Soils: Baseline Versus Triennial Litter Application

<u>**Phosphorus Movement Across Soils:**</u> Differences among the five soil mapping units are greater than the differences among alternatives. Figure 4 reflects the impact of slopes, the presence of restrictive soil layers, and the water storage capabilities of the soil for the baseline management and for the alternative with litter applied every third year. The Clarksville soil has a 12% slope and limited water storage which leads to high runoff, percolation, and sediment loss. The Tonti and Hoberg soils have low slopes (2%), but have fragipans that restrict percolation. The Nixa and Crackerneck soil have moderate slopes (5%). The Nixa soil has a fragipan. The Crackerneck soil has considerable rock and little water storage which results in high percolation.

CONCLUSIONS

Two types of management options appear to have some potential to improve the environmental and/or the economic impacts of poultry litter management. One is to produce forage crops instead of pasture because they recycle more nutrients and increase revenue at current prices. However, the local demand for forage may soon be saturated requiring more distant marketing, and adding transportation costs that may make this alternative economically unfavorable.

The second management option focuses on reducing the amount of litter applied and marketing, or removing, the litter off-site. The challenge with this option is that there may not be many local alternatives available for marketing this litter and what markets do exist may quickly become saturated. Figure 5 is a map of the potential phosphorus available from likely confined animal production and Figure 6 is a map of potential phosphorus needs of harvested crops by county based on the 1997 agricultural census. Many poultry production areas such as southwest Missouri have more phosphorus available than phosphorus needs.

Some combination of new products, new markets, reduction of phosphorus in manure, programs to encourage the development and adoption of new technologies, and research and education can lead to the appropriate solutions region by region. It is important that the discussions of alternatives focus on both the economic and environmental value of manure as a resource, not a waste.

Animal manures are valuable sources of nutrients, organic material, and beneficial organisms. Development of new value added products from poultry litter increases its monetary value directly. The benefits of recycling manures go beyond the direct monetary measures. It may also improve soil quality for future generations, sequester carbon, reduce nitrogen in runoff and leaching due to delayed nitrogen release, and extend the life of our mined phosphorus deposits. The value of these attributes should be included in the discussion.

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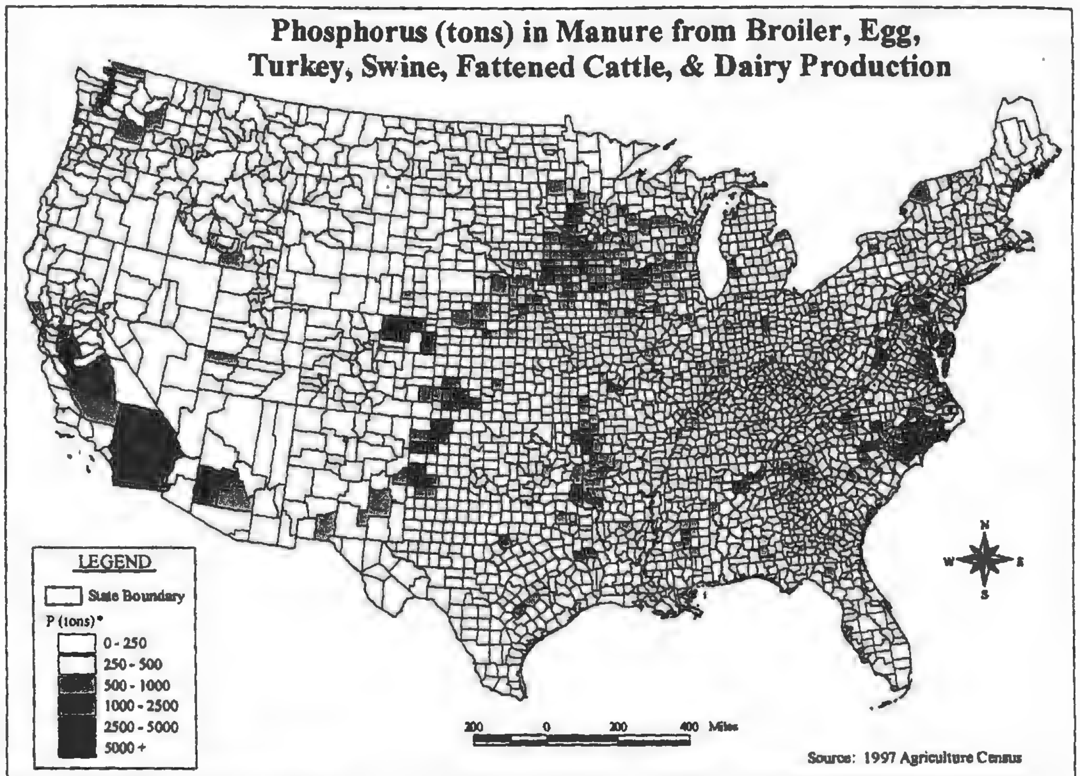
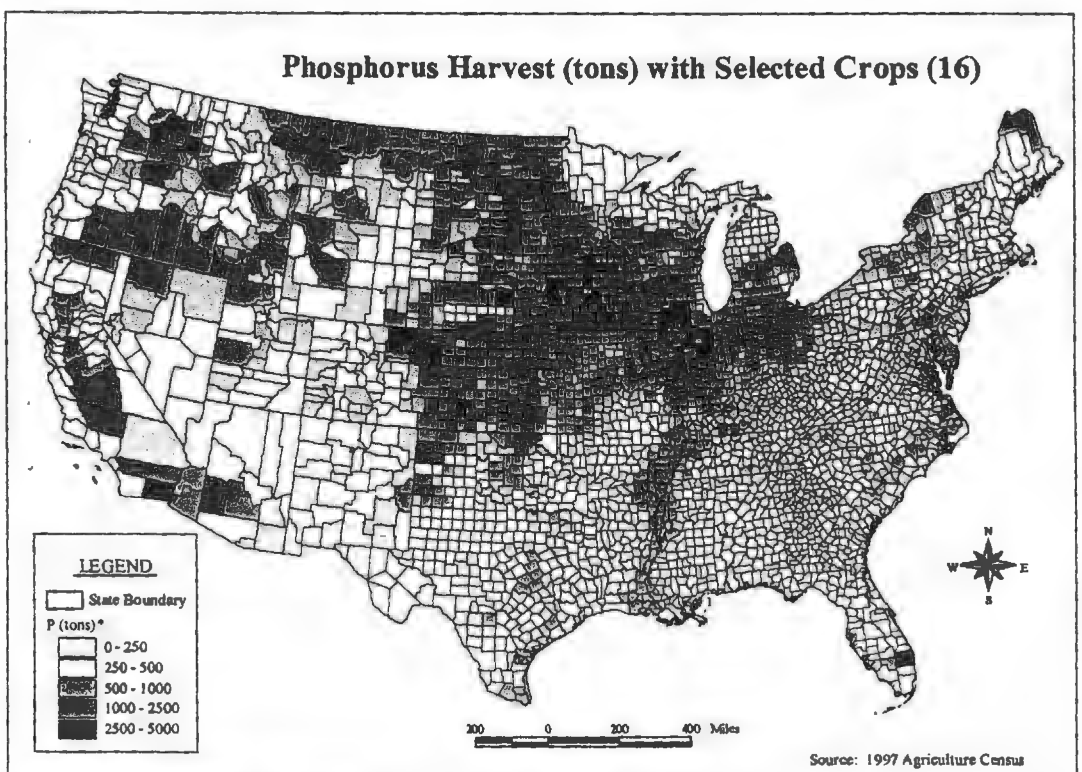


* Counties with missing acreage data were set to 0.

Figure 5. Potential Phosphorus Available from Confined Livestock



* Counties with missing acreage data were set to 0.

Figure 6. Potential Phosphorus Needs of Harvested Crops

WHERE DOES SCIENCE SUPPORT AND NOT SUPPORT PHOSPHORUS REGULATIONS?

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NO PAPER SUBMITTED

OVERVIEW OF PELLETING BROILER LITTER

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NO PAPER SUBMITTED

ECONOMIC AND TECHNICAL FEASIBILITY OF ENERGY PRODUCTION FROM POULTRY LITTER

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The purpose of this paper is to provide an indication of the technical and economic feasibility of producing electricity and/or process steam from poultry litter. This is a rather challenging task because using poultry litter for energy has not yet been implemented commercially in the United States. Electricity is being produced commercially from poultry litter in the United Kingdom, but most details from these operations are not in the public domain. Poultry litter has been tested in several energy conversion technologies, but the results generally are not in the public domain. Therefore, the technical feasibility discussion is based partly on extrapolation from experiences with biomass fuels with properties and challenges similar to those with poultry litter, and partly on test results in the public domain. Assessing economic feasibility is also a difficult task because commercial examples are lacking and because several of the important factors are quite site specific, including (1) competing fuel and electricity prices, (2) delivered poultry litter feedstock prices, and (3) net revenues that can be generated at an energy plant from poultry litter ash. In addition to being site specific, the latter two factors are rather speculative at this point. Prices that an energy plant will have to pay for poultry litter will depend a lot on how much environmental pressure there ultimately is for developing alternatives to local land application of poultry litter. The net revenue that an energy plant can generate from the fertilizer value of the ash depends on several technical and market factors that need further clarification. This paper provides a framework for assessment and a first-approximation assessment of technical and economic feasibility for some potential scenarios.

NUTRIENT MANAGEMENT DRIVER

Concentrated poultry areas generally produce several times more manure phosphorus (P) than is taken up and removed by crops in these areas (Lander *et al.*, 1998). The basic reason for the P imbalances is that large quantities of P are imported into these regions in feedstuffs (grain and inorganic P supplements), resulting in more manure P than is taken up and removed by crops grown in these regions. The surplus P has been building up in soils in concentrated poultry areas for several years, and there is increasing concern about

P runoff from these high-P soils causing surface water quality problems. Of greatest concern are ecological problems and odor and taste problems in drinking water, resulting from excess algae growth due to P enrichment of the water. Because of these water quality concerns, restrictions on local land application of poultry litter are likely, and it is projected that alternatives to local land application will be needed for much of the poultry litter produced in concentrated poultry areas.

This paper makes the case that using poultry litter to produce process steam and/or electricity is a promising, high-volume alternative to local land application. Combusting or gasifying poultry litter concentrates P, K, S, and micronutrients in the ash, thereby facilitating significantly more economical transport of surplus P out of concentrated poultry areas (more details in next paragraph). Furthermore, the fertilizer value of the nutrient rich ash is expected to offset most or all of the delivered poultry litter feedstock costs, resulting in a near net-zero feedstock cost (more details later). The forest products industry has demonstrated that using its by-products for energy is economically viable when the delivered feedstock cost is near zero, and this concept should apply to poultry litter.

The ash content of poultry litter is about 15 percent on an as-received basis. This implies that nutrients, such as P, potassium (K), sulfur (S), and micronutrients, remaining in the ash are 6 to 7 times more concentrated than that for poultry litter. Poultry litter ash has a bulk density about 1.5 to 2.5 times greater than that for poultry litter. The combined effects of greater nutrient concentration and higher bulk density result in nutrient densities (i.e., lb nutrient/ft^3 of material) 10 to 17 times greater for poultry litter ash than for poultry litter. An order of magnitude increase in nutrient density greatly reduces transportation costs for exporting surplus P from concentrated poultry areas.

In addition to nutrient concentration in the ash and enhanced economics of nutrient transport, combustion and gasification provide a year-round use for poultry litter. This contrasts with land application in which most of the litter is applied in the spring and fall and much of the litter is stored for a significant period of time before being applied on the land. Proper storage is costly. Improper storage results in potential for nutrient and pathogen runoff into surface waters. Because of year-round demand, using poultry litter for energy should facilitate a staggered year-round cleanout of houses, minimize the amount of litter that has to be stored, and reduce the potential for nutrient and pathogen runoff from stored litter.

TECHNICAL CHALLENGES AND SOLUTIONS

Poultry litter is a more challenging fuel than wood for several reasons. The ultimate analyses (Table 1) indicate some of the reasons. One reason is that the nitrogen content is about 10 times higher in poultry litter than wood. This increases the potential for fuel NO_X emissions and requires special measures to reduce these emissions. The sulfur content of poultry litter is more than 10 times higher than that of wood. This increases the potential for SO_X emissions and requires special measures to reduce these emissions. Chloride levels are higher in poultry litter than in wood. High chloride levels, in conjunction to high alkali levels, increase the potential for particulate emissions, corrosion problems, and acid gas emissions, and requires special measures. Ash levels are much higher in poultry litter than in wood, requiring higher-volume ash-handling equipment and more attention to particulate removal, slagging, and fouling.

Table 1. Ultimate Analysis (As-Received) of Sawdust and Delmarva Poultry Litter.[a]

	Sawdust	Poultry litter
Carbon, %	24.2	27.2
Hydrogen, %	2.8	3.7
Oxygen (by difference), %	18.3	23.1
Nitrogen, %	0.22	2.7
Sulfur, %	0.02	0.3
Chlorine, %	--	0.7
Ash, %	2.0	15.7
Moisture, %	52.6	27.4
Higher heating value (HHV), Btu/lb	4,150	4,637
HHV (dry), Btu/lb	8,760	6,394

[a]Poultry litter samples from Maryland Department of Environmental Resources (Bock, 1999).

Elemental analyses of the ash (Table 2) indicate additional reasons that poultry litter is a more challenging fuel than wood. The concentration of alkali metals (sodium oxide, Na_2O, and potassium oxide, K_2O) is much higher in poultry litter than in wood. The lb alkali/MBtu is 9.3 for poultry litter vs. 0.4 for wood. High alkali content, especially in conjunction high chloride levels, results in a high potential for slagging, fouling, particulate emissions, and corrosion.

Following are key measures that have been employed for dealing with the challenging fuel properties of poultry litter.

<u>NO_X Emissions:</u> Staged combustion is a widely used option for lowering NO_X emissions from a high-nitrogen fuel such as poultry litter. With staged combustion, combustion conditions are somewhat more reducing and less fuel nitrogen is converted to NO_X. Ammonia injection under appropriate conditions also reduces NO_X emissions, and the naturally occurring ammoniacal nitrogen in poultry litter helps keep NO_X emissions low. In some cases, more rigorous NO_X control measures, such as selective catalytic reduction, may be required for poultry litter.

<u>SO_X Emissions:</u> The naturally occurring calcium and magnesium in poultry litter can trap some SO_X in the form of sulfates. If additional measures are needed, lime injection, either with the fuel or downstream, is the primary option for reducing SO_X emissions.

Table 2. Elemental Analysis (%) of Ash From Sawdust and Delmarva Poultry Litter.[a]

	Sawdust	Poultry litter
SiO_2	35.6	8.1
Al_2O_3	11.5	1.9
TiO_2	0.9	0.2
Fe_2O_3	7.6	1.2
CaO	24.9	17.3
MgO	3.8	5.0
Na_2O	1.7	9.2
K_2O	5.8	16.3
P_2O_5	1.9	24.4
SO_3	0.8	6.7
CO_2/other	5.7	9.7
Total	100.0	100.0
lb alkali/MBtu	0.35	9.3

[a]Poultry litter samples from Maryland Department of Environmental Resources (Bock, 1999).

Alkali Problems: Maintaining low combustion or gasification temperatures is the main line of defense in controlling alkali-related slagging and fouling problems. Lower combustion or gasification temperatures mean that more heat exchange surface area is needed to achieve a given boiler efficiency. In some cases, lime injection also helps alleviate alkali problems. In fluidized-bed systems, lime injection prevents agglomeration of the bed material, and at the same time, alleviates slagging, fouling, corrosion, and acid-gas emission problems. In some cases, lime injection, followed by hot-gas filtration, is a potential option for capturing volatile alkalis before they are deposited on heat exchange surfaces.

Chloride-Related Problems: For electrical power generation, the superheated steam temperature is limited to about 750°F to avoid rapid corrosion of superheater boiler tubes. The high chloride concentrations found in poultry litter requires expensive alloys in the design of superheater boiler tubes to improve longevity. Refractories used in the furnace must be an ultra-low cement material, since refractories containing calcium are rapidly attacked by chlorine. Careful attention to flue gas dewpoint temperatures is necessary to avoid cold-end corrosion in economizers and air heaters. From an air pollution perspective, chloride abatement can be minimally accomplished with the addition of a dry scrubber, depending on the size of the boiler project. Chloride is listed as a hazardous air pollutant under the Clean Air Act, with a 10-ton/year emission limit to avoid major source designation.

Particulate Emissions: In addition to normal fine particulate emissions that occur from burning wood, volatile alkalis (mainly KCl) from poultry litter can carry through to the boiler and increase the particulate load that must be removed from the flue gas. Baghouse capacity may need to be increased relative to that required for wood; in some cases, cloth-to-air ratios have been increased for high-ash fuels to reduce cleaning frequency and increase bag life.

TECHNOLOGY EXAMPLES

Several technologies that have been proposed for using poultry litter for energy were reviewed recently for the Northeast Regional Biomass Energy Program (NRBP, 1999a). Poultry litter test results are not in the public domain for most of these technologies. Two technologies with poultry litter test data in the public domain are discussed below to illustrate the techniques for dealing with the challenging fuel properties of poultry litter. Some additional energy conversion technologies that are scheduled to be used in projects, which have recently been announced, are also briefly described.

Energy Products of Idaho (EPI) Bubbling Fluidized Bed

EPI recently completed poultry litter tests with its bubbling fluidized bed (BFB) technology (Murphy, 2000). These test results illustrate several techniques for dealing with the difficult fuel properties of poultry litter and are very encouraging concerning the technical feasibility for using the EPI BFB technology with poultry litter as a fuel. The BFB technology uses a sand bed that is suspended via combustion air injected at the bottom of the bed. The bed contains a significant store of energy that drives off most of the fuel moisture before igniting the fuel. This allows use of fuels that are wetter and of poorer energy value than other combustion technologies. The turbulent bed also prevents ash residue from building up on fuel particles as they burn, thereby providing virtually complete burnout of high-ash fuels. In addition to improving energy efficiency, complete burnout improves the fertilizer value of the ash. When lime is injected with the fuel, the bed turbulence provides good mixing of the lime and fuel with the bed material, increasing lime effectiveness in reducing SO_X emissions and preventing bed agglomeration from high-alkali fuels. No fuel preparation is required for poultry litter.

In the EPI tests, a relatively low bed temperature of about 1550°F was maintained, and lime was injected with poultry litter to provide a lime Ca to fuel S ratio of 2:1. The injected lime eliminated SO_X emissions, prevented bed agglomeration, and helped alleviate slagging and fouling. Significant ash slagging or accumulation was not observed with these operating conditions. Staged combustion and ammonia injection using selective noncatalytic reduction technology reduced NO_X emissions to 25 ppm, equivalent to 0.08 lb/MBtu. Lime and ammonia injection both helped reduce HCl emissions. More details are provided by Murphy (2000).

Primenergy Gasification/Staged Combustion

Primenergy has conducted several tests of poultry litter, with its gasification/staged combustion technology. A process description and early test results with poultry litter are reported by McQuigg and Scott (1998). The first stage of the Primenergy process occurs in the gasifier that operates at relatively low temperatures (typically 1200°-1500°F) in a low oxygen environment which supplies about 30 percent of the stoichiometric air required for complete combustion of the poultry litter. Slagging generally is not a problem at the low temperatures in the gasifier. Most of the ash that potentially could cause slagging problems is collected at the bottom of the gasifier, and the low Btu gas produced in the gasifier is released to the overfire chamber where the second stage of combustion occurs at 2200°-2400°F using about 15 percent of the stoichiometric air required for complete combustion of the poultry litter. The higher temperatures and reducing atmosphere in the overfire chamber convert much of the fuel bound nitrogen to molecular nitrogen (N_2) rather than NO_X. In some cases, additional reductions in NO_X will be required. Volatile alkalis and small amounts of ash carry over into the overfire chamber. With the higher temperatures in the overfire chamber, the mixture of volatile alkalis and fly ash can yield sticky agglomerates and cause slagging problems. In preliminary tests, lime injection, followed by filtration of the gas between the gasifier and overfire chamber, has been effective in preventing slagging problems in the overfire chamber. Lime injection also holds promise for reducing SO_X emissions. The third, and final, stage of combustion occurs with excess air injection to consume the combustibles from the second stage. No fuel preparation is required for poultry litter, except possibly some breaking up of clumps.

The EPI and Primenergy test results illustrate that combusting or gasifying poultry litter is technically feasible and can be achieved without causing air quality problems.

Technologies in Recently Announced Projects

Earlier this year, Allen Family Foods, Inc., and CHx Engineering Company announced a project that will gasify poultry litter to provide 4 MW of electricity and by-product heat for a poultry processing plant. The gasifier will be provided by Canadian Environmental Energy Solutions (CEES, 2000). The low-Btu gas will be used to indirectly fire a gas turbine coupled with a steam turbine for combined-cycle operation. Poultry litter is blended with other fuels to provide a fuel moisture content of 40 to 50 percent. No other fuel preparation is required for poultry litter. Although testing of these technologies has provided sufficient basis for development of a commercial project, detailed performance data are not available for this paper.

Earlier this year, BG Technologies USA, Inc. (BGT), and Rotary Power International, Inc. (RPI), announced intent to form a joint venture. As part of the joint venture, a demonstration facility will use a BGT gasifier with cubed poultry litter, dried to less than 20 percent moisture as a feedstock. The low-Btu gas will be used to power an RPI rotary engine to drive a generator. More details are provided about these technologies in the BGT web site (BGT, 2000). BGT and associated partners are currently constructing a commercial facility in Maryland to process in excess of 50,000 tons per year of poultry litter into a variety of value-added products (Bioenergy Update, 2000). A BGT gasifier will gasify cubed poultry litter to provide the energy for producing these value-added products. Although testing of these technologies has provided sufficient basis for development of a commercial project, detailed performance data for using poultry litter for energy are not available for this paper.

ECONOMIC FACTORS

In assessing the energy value of poultry litter, electricity production and co-production of electricity and process steam have received the most attention, presumably because electricity provides more added value than does steam. However, opportunities to produce process steam alone should not be overlooked, given the current relatively high prices for natural gas and fuel oil.

Some of the more important factors affecting the economic feasibility of using poultry litter to produce electricity are influenced by the end use for the electricity (Table 3). These factors are rated qualitatively according to how economically favorable they are for the following electricity end uses: utility grid, medium-sized industrial, and small industrial. Typical size ranges, heat input (MBtu/hr) and electricity output (MWe), for supplying these three electricity end uses are presented in Table 3. Other important economic factors are not affected significantly by the electricity end use. These are the farmgate price for poultry litter and fertilizer value of poultry litter ash. After the following qualitative overview of economic factors, more quantitative examples will be presented for illustration.

Table 3. Economic Factor Ratings: Poultry Litter to Energy.

	Electricity end use		
Economic factor	Utility grid >250 MBtu/hr >20 MWe	Medium Industrial 100-250 MBtu/hr 8-20 MWe	Small Industrial <100 MBtu/hr <8 MWe
Utility advantage:			
Economies of scale	H	M	L
Capacity factor	H	M to H	M to H
Industrial advantage:			
Electricity price	L	M	H
Co-production options	L	H	H
Feedstock transportation economics	M	H	H
Air-quality compliance	L	M	H
Vested interest in alternative uses	L to M	H	H

L=low; M=medium; H=high.

The first two factors, economies of scale and capacity factor, are more favorable for the utility grid end use. The high economic rating for capacity factor (percentage of annual capacity produced) assumes that a poultry litter-to-electricity plant would not be built to supply electricity to a utility grid, unless it is sufficiently economical to result in being dispatched a high percentage of the time. Capacity factor for supplying electricity to industrial plants will vary. For example, it is common for poultry processing plants to run 5 days/week with two production shifts/day and one clean-up shift/day, and for electricity demand on weekends to be mainly for refrigeration. This type of demand results in a medium capacity factor. A high capacity factor can be achieved at this type of industrial plant if excess capacity can be sold on the utility grid; however, the grid price will be lower than the price to the industrial customer.

Relative to utility grid applications, economies of scale are significantly lower for most industrial applications, especially those of the size associated with the poultry industry, such as meat processing and rendering plants. Operating and maintenance costs per unit of production often are affected even more adversely than equipment costs, by small economies of scale. In some cases, smaller economies of scale for industrial applications may be offset to some extent by using modules that are factory built, easily transported, and designed for "plug and play" operation.

The rest of the economic factors in Table 3 are more favorable for industrial applications. Wholesale prices for electricity sold on the grid are significantly lower than prices paid by industrial customers such as poultry processing and rendering plants. Therefore, a poultry litter-to-electricity plant could expect to receive a significantly higher price for electricity sold to an industrial customer than if the electricity were sold on the grid.

Co-production of electricity and process steam generally is more economical than production of either electricity or process steam alone. Utility operations usually do not have co-production opportunities, whereas industrial operations often provide co-production opportunities. Poultry processing and rendering plants are examples of industrial plants that use significant quantities of both electricity and process steam, usually 100 to 150 psi saturated steam. With proper configuration, significant quantities of process steam can be produced with little added cost over producing electricity alone. Co-production options are most economical for plants that have a continuous, relatively stable demand for both electricity and process steam.

Generally, the average feedstock transportation distance increases with plant size, indicating that feedstock transportation costs/ton will be higher for utility grid than for industrial end uses. Even though poultry litter supplies tend to be quite concentrated geographically, feedstock transportation costs are expected to be more favorable for industrial than utility scales.

In most states, air quality permits are more stringent for larger plants (e.g., heat inputs>100 MBtu/hr). In some cases, this is expected to result in lower costs for emission controls for smaller plants.

Finally, if an energy customer has a vested interest in facilitating alternative uses for poultry litter, the economic feasibility of converting poultry litter to energy may be improved in some cases. For example, a poultry processing or rendering plant may be willing to purchase energy from poultry litter on a relatively favorable basis (at least a break-even basis relative to current energy contracts) in order to help alleviate regional phosphorus surpluses and improve the environmental sustainability of the poultry industry in its service area. For similar reasons, a poultry processing or rendering plant may be more open to helping facilitate year-round litter clean-out schedules and other aspects of litter acquisition, and may be open to sharing shift workers in some cases. Utilities have vested interests in maintaining and increasing electricity demand, based on the poultry industry and its associated multiplier effect; helping ensure environmental conditions conducive to regional economic development; and using poultry litter as a relatively low-cost source of renewable energy. These vested interests potentially can be of strong economic benefit to poultry litter-to-energy projects.

Financial Incentives

An assessment of off-farm poultry litter management options (Goodwin *et al.*, 2000) concluded that, with current economic conditions, including immature markets for litter and litter-derived markets, market interventions will be required for deployment of alternative litter management enterprises. In the case of energy from poultry litter, financial incentives may be required initially to overcome some of these market impediments.

Because of the environmental, economic development, and energy security benefits of using renewable sources of energy, several financial incentives are currently or potentially applicable to production of electricity from poultry litter. A national tax credit is currently applicable for production of electricity from poultry litter; also, green power premiums, renewable portfolio standard credits, and greenhouse gas credits may be applicable to bioenergy in the near future. These incentives hold promise for improving the economics of producing electricity from poultry litter.

The Section 45 tax code provides a 1.7 cent/kWh tax credit for production of electricity from poultry litter. This financial incentive is available to electricity generating facilities placed in service between December 31, 1999, and January 1, 2002; a poultry litter-to-electricity plant that starts up during this time period is eligible to receive the credit for 10 years. In some cases, state tax credits are also available for electricity produced from poultry litter. For example, Maryland recently implemented a tax credit of 0.85¢/kWh for electricity produced from biomass. The combined national and state tax credit in Maryland is 2.55¢/kWh.

Green power programs are being developed by many electricity providers in response to consumers who are willing to pay a premium for green energy as a means of promoting development and implementation of renewable energy. These consumers are willing to pay a premium for renewable energy because of environmental benefits, such as reduced emissions and conservation of natural resources. So far, green power consumers have supported primarily wind and solar; however, bioenergy generally is a much lower-cost source of renewable energy, and use of biomass wastes and by-products for energy eliminates environmental problems associated with traditional methods of waste disposal, such as open burning, landfills, and land application. With proper marketing and education, some consumers may be willing to pay a green power premium for electricity from poultry litter, because of environmental benefits.

As part of utility restructuring, utilities may be required to provide some percentage of their electricity production from renewable sources. This concept is referred to as a renewable portfolio standard (RPS). Several RPS bills have been proposed. In these bills, the percentage requirement for electricity from renewables typically ranges from 2.5 to 7.5 percent. The administration bill, proposed in 1999, included an RPS of 7.5 percent by 2010, and specified a system for trading renewable credits that, in effect, placed a value of 1.5 ¢/kWh on renewable credits.

Because of concerns about global climate change, markets are emerging for greenhouse gas credits. Biomass is considered a CO_2-neutral fuel because CO_2 is absorbed from the atmosphere when plants grow, and a comparable amount of CO_2 is released back into the atmosphere when the biomass is used for energy, resulting in no net increase of CO_2 in the atmosphere. Therefore, if markets for greenhouse gas credits continue to develop, CO_2 credits from using biomass for energy will have a market value. Projected prices for CO_2 credits generally are at least $10/ton of CO_2, corresponding to about 1¢/kWh.

The Case for Net-Zero Fuel Costs as a First Approximation

One of the economic advantages of using poultry litter for energy is that the nutrient-rich ash is expected to have significant value for use in fertilizers. Phosphorus and potassium are the nutrients present in highest concentration. In the fertilizer industry, these nutrients are expressed on an oxide basis. The mean P_2O_5 and K_2O content of 24 Delmarva broiler litter samples was 24.4 and 16.3 percent, respectively. These values are much higher than for wood ash. Vance (1996) reported median values for wood ash of 0.9 percent P_2O_5 and 3.9 percent K_2O.

The net fertilizer value of poultry litter ash at the energy plant, after accounting for transportation costs, any additional processing costs, and marketing costs that may be required, likely will range from $25 to $75 per ton of ash. Estimated fertilizer replacement values and the major factors affecting the net fertilizer value of the ash at the energy plant were recently reviewed by Bock (1999).

The estimated mid-range net value for poultry litter ash at an energy plant ($50/ton of ash) is roughly equivalent to the following prices associated with using poultry litter for energy:

$50/ton ash ~ $7.50/ton litter ~ 1.0 ¢/kWh ~ $1.00/1000 lb steam

This means that an ash price of $50/ton at the energy plant will offset a delivered poultry litter feedstock price of $7.50/ton litter. Poultry litter cleanout and transportation costs combined are in the neighborhood of $7.50/ton, and significant quantities of poultry litter should be available at this price, or lower, as more restrictions on land application of poultry litter are implemented. These relationships suggest that the fertilizer value of the ash potentially can offset the delivered cost for poultry litter feedstock. As a first approximation, a net-zero fuel cost (ash revenues minus feedstock costs roughly equals zero) is a reasonable assumption in assessing the economics of using poultry litter for energy. This assumption is used in the economic examples presented below; however, one can adjust these estimated costs of electricity production for a range of poultry litter and ash prices (Figure 1). For example, for a given cost of electricity, assuming no ash revenues and no feedstock costs, add 1¢/kWh to the cost of electricity, if the delivered poultry litter price is $15/ton and the ash price is $50/ton at the plant. As another example, subtract 1¢/kWh from the cost of electricity, if the delivered poultry litter price is $0/ton and the ash price is $50/ton at the plant. Comparable adjustments for the cost of producing process steam vs. poultry litter and ash prices are presented in Figure 2.

EXAMPLES OF ECONOMICS

Retrofit Example for Utility-Scale Electricity: Conectiv Vienna Plant

Conectiv Energy Supply recently assessed retrofitting a 155-MW oil-fired power station at Vienna, Maryland, to use poultry litter (NRBP, 1999b). At the time of the assessment, the power station was used for peaking capacity. The proposed retrofit included adding poultry litter receiving and handling equipment and a separate boiler, suitable for poultry litter, and using the existing steam turbine and generator to provide 35 MW of baseload electricity from poultry litter. The proposed configuration allowed for supplemental use of the oil-fired boiler and use of the remaining turbine and generator capacity for peaking capacity. The first approximation of retrofit capital costs is presented in Table 4.

Table 4. First approximation capital costs for proposed retrofit at Vienna, Maryland.

Item	$/kW
Poultry litter receiving and handling	291
Boiler, BFW/deaerator systems	576
Environmental capital	143
Balance of plant	102
General facilities and engineering fee	209
Project and process contingency	180
Total	1,500

Assuming a net-zero fuel cost and no financial incentives, the projected cost of electricity was 5.3¢/kWh, comparable to the projected cost of electricity from new capacity from a natural gas turbine, but was significantly higher than the average 1997 grid market clearing price of 2.1¢/kWh. With the 1.7¢/kWh federal tax credit and the 0.85¢/kWh Maryland tax credit, the cost of electricity from poultry litter would be much lower than for new capacity based on natural gas, but still slightly higher than the average grid price.

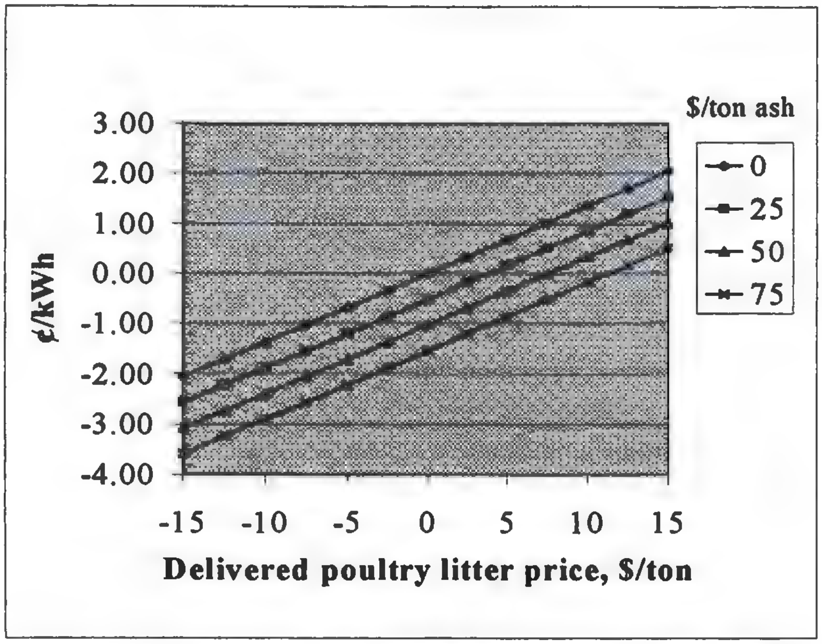

Figure 1. Adjustments for Cost of Producing Electricity.

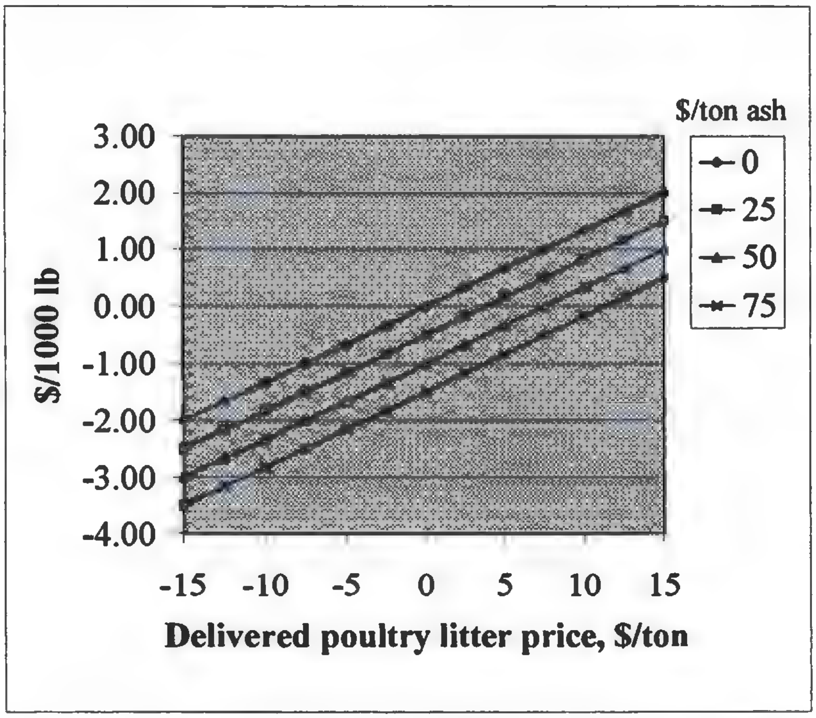

Figure 2. Adjustments for Cost of Producing Process Steam.

The 35-MW proposed retrofit size was selected based on the turn down capacity of the 155-MW turbine/generator. A 35-MW plant would have required about 400,000 tons of poultry litter per year. Acquisition of this much poultry litter on the Delmarva Peninsula may have been difficult, suggesting that supplemental fuels may have been required. Conectiv ultimately sold the Vienna plant, precluding implementation of the retrofit.

Medium-to-Large Industrial

A medium-to-large industrial user of process steam is a candidate for using steam from poultry litter. For example, a large poultry rendering plant may use as much as 250,000 lb steam/hr for 24 hr/day and 5½ days/week. This corresponds to operating 80 percent of the year and would require about 210,000 tons of poultry litter per year. Assuming ash revenues offset delivered poultry litter feedstock costs, annual O&M costs would be about $3.8 million (Table 5). Capital costs, including installation, for a turnkey bubbling fluidized bed plant this size would be about $18.9 million. Assuming a 20-year plant life and an annual percentage interest rate (APR) of 7 percent would result in a levelized cost of producing steam of about $3.30/1000 lb steam. Industrial natural gas prices are $3.50/MBtu, or higher, and projected to remain in this range for the foreseeable future (EIA, 2000). Accounting only for the cost of natural gas used at 80 percent efficiency to produce steam gives a conservative steam cost of $4.40/1000 lb steam ($3.50/0.8 = $4.40). With these assumptions, the simple pay-back period is 4 years, and the process is expected to be competitive with other alternatives to land application of poultry litter. Economics would be even more favorable if the plant could operate more than 5½ days/week, if some of the administrative and labor costs could be shared with the steam customer, or if poultry litter could be obtained at zero cost due to environmental pressures. Using the same operating assumptions, producing process steam from a 100,000 lb steam/hr plant would cost $5.60/1000 lb steam. It will be difficult for a poultry litter steam plant this size, operating 5½ days/week to compete with natural gas or fuel oil.

Table 5. Levelized Cost of Producing Process Steam With Fluidized Bubbling Bed.[a]

	Capital costs		Annual O&M[b]		Total
1000 lb steam/hr	$M	$/1000 lb steam	$M	$/1000 lb steam	
100	10.8	1.50	2.8	4.10	5.60
250	18.9	1.10	3.8	2.20	3.30

[a]Estimates from Energy Products of Idaho.
[b]Assuming that ash revenues offset delivered poultry litter costs.

To carry this example further, 210,000 tons/year of poultry litter could be used to supply a 21-MWe (net) power plant, assuming 25 percent efficiency and a capacity factor of 85 percent. The total capital cost, including installation, would be about $44 million, assuming $2,100 /kW (Table 6). This would correspond to a levelized cost of capital of 2.9 cents/kWh, assuming a 20-year plant life and 7 percent APR. Assuming ash revenues offset delivered poultry litter feedstock costs, a plant this size should have O&M costs of about 3.0 cents/kWh for a total levelized cost of electricity of 5.9 cents/kWh. In many cases, this is comparable to what an industrial customer pays for electricity, and financial incentives would be required for the plant to provide an acceptable rate of return. The 1.7 cents/kWh federal tax credit and possibly other incentives, such as the 0.85 cents/kWh Maryland tax credit, would be required for this plant to provide adequate return.

Table 6. Levelized Cost of Producing Electricity With Fluid Bubbling Bed Technology.[a]

	Capital costs		Annual O&M[b]	Total
	$/kW	¢/kWh	¢/kWh	
12 MWe	2,400	3.3	4.0	7.3
21 MWe	2,100	2.9	3.0	5.9

[a]Estimates from EPI.

[b]Assuming ash revenues offset delivered poultry litter costs.

As discussed earlier, additional incentives may become available, based on renewable portfolio standard credits, CO_2 credits, and green power premiums. The economics can be improved significantly if (1) process steam is co-produced with electricity, (2) the capacity factor is increased beyond 85 percent, (3) administrative and labor costs are shared with the electricity customer, or (4) if poultry litter is obtained at zero cost due to environmental pressures; all four of these options for economic improvements are distinct possibilities in poultry litter-to-energy projects.

CONCLUSIONS

Because of water quality concerns, continued buildup of soil P levels due to land-applied poultry litter will not be a long-term option in most concentrated poultry areas. Alternatives to local land application of poultry litter will be required for a significant portion of the litter produced in concentrated poultry areas.

Export of value-added products produced from poultry litter will be part of the solution, but adding value also adds significant costs, and markets for the value-added products are fairly small. Some unprocessed litter will be exported from concentrated poultry areas to neighboring regions for use as a fertilizer, but transportation costs and handling, application, nutrient ratio, and liability issues will limit this option. Robust and economical high-volume alternative uses for poultry litter are needed. Energy recovery (electricity and/or process steam) with ash export is a promising high-volume alternative use for poultry litter. Because of nutrient concentration and value in the ash, energy options provide a built-in mechanism for economically exporting surplus P and associated nutrients out of concentrated poultry areas. In fact, the economic viability of energy options depends on being able to market poultry litter ash for use in fertilizers outside concentrated poultry areas. Another significant advantage of energy options is that the ash is devoid of any pathogens and odors present in the poultry litter feedstock. These benefits, combined with nutrient concentration, greatly simplify export and use of poultry litter nutrients outside of concentrated poultry areas.

Using poultry litter as a feedstock to produce electricity and/or process steam requires specialized equipment, designs, and practices, but is technically feasible using currently available technology. Because of the environmental, economic development, and energy security benefits of using renewable sources of energy, several financial incentives are currently or potentially applicable to production of electricity from poultry litter. With some of these incentives and cooperation from the poultry industry concerning poultry litter feedstock logistics, production of electricity from poultry litter is economical for medium-to-large industrial end uses, especially if co-production of process steam is a good fit. With current fossil fuel prices, large-scale production of process steam from poultry litter is economical, without financial incentives. Medium-scale production of process steam from poultry litter may be economical, without financial incentives, if some administrative staff and shift labor can be shared between the steam provider and steam customer. Two commercial poultry litter-to-energy projects involving small gasifiers have been announced, suggesting that under some circumstances small-scale, highly integrated poultry litter-to-energy projects may be economical. Biosecurity measures will be required in poultry litter-to-energy projects, and precedents have already been set for achieving biosecurity. There will always be close public scrutiny of plans for centralized energy facilities. The environmental and economic development benefits of using poultry litter for energy are strong and should facilitate gaining public acceptance.

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REGIONALLY COORDINATED LITTER MANAGEMENT STRATEGIES

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POULTRY LITTER APPLICATIONS IN PINE PLANTATIONS

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Forest fertilization in the Southeastern US has increased greatly since the 1960's. In 1998, about one million acres of loblolly pine plantations were fertilized with commercial fertilizers, usually diammonium phosphate (DAP; 18-46-0), urea (46-0-0), or triple super phosphate (TSP; 0-46-0). Currently most pine plantation fertilization is on forest industry land. Loblolly pine is considered to be the southern pine species which is most responsive to fertilization and other cultural practices. Loblolly has a large native range, from Maryland south into Florida and west to Texas. Slash, longleaf pine, and other southern pine stands are also fertilized but not to the extent that loblolly pine plantations are. Pine plantation fertilization rates of return can average 8-12% and can be as high as 25-30% depending on fertilizer cost, extra wood grown, and product class values. Optimal use of any fertilizer material requires that some diagnostic tools are used. These tools include soil and foliage analysis, leaf area index (LAI) estimation, soil classification/grouping, visual symptoms, growth and yield modeling, and stand fertilizer trials (Dickens 1999).

Generally there are four fertilization recommendation "windows" in pine plantations: (1) at planting, (2) at early post-planting to rectify a nutrient deficiency, (3) at mid-rotation after canopy closure (age 5-8 years-old) or after a 1st or 2nd thinning, and (4) in production of pine straw, which is used as a mulch for landscaping. A single application of phosphorus such as TSP @ 200-250 lbs/acre at planting is often applied on poorly to very poorly drained P-deficient Atlantic Coast Flatwoods soils. Nitrogen plus phosphorus such as DAP @ 125-200 lbs/acre is a common application practice at planting where competing vegetation is controlled. Nitrogen plus phosphorus at planting or soon after planting is generally not recommended for most private non-industrial forest landowners. Competing vegetation must be controlled first and seedling/sapling nutrient demand is relatively low the first 2-3 years.

Diammonium phosphate and urea (@ 125-200 lbs DAP and 300-380 lbs urea/acre) are commonly applied to loblolly and slash pine plantations after age 8 years-old or after a thinning. Fertilization to enhance annual pine straw production should occur every 4-8 years to replace the nutrients removed when the straw (fresh brown needles or the litter layer of the forest floor) is raked and taken from the site.

BENEFITS OF FOREST LAND APPLICATION OF POULTRY LITTER

The private non-industrial forest landowner (NIPF) sector has become increasingly interested in using commercial and other fertilizer materials such as poultry litter to fertilize stands. Approximately two-thirds of South Carolina and Georgia are forested and two-thirds of the forest land in these two states are owned by private non-industrial forest landowners. In many instances large pine plantations are in close proximity to poultry growers and the litter.

There are several other advantages to forest land application of poultry litter. Pine plantations can offer sites which have a year-around window to apply poultry litter. This is in contrast to crop and pastureland which have a narrow application window of only weeks to months to optimize nutrient benefits. Forest soils are generally low in plant available phosphorus (P), while many Southeastern pastureland and crop land sites have very high soil levels of P following years of poultry litter applications. Pine stand wood volume and straw production response to a single application of poultry litter can be significant and relatively long lived (4-10 years). Response can be even greater from 2-5 year intervals of application. It is estimated that with a single poultry litter application, timber sale revenues can be increased by $150 to $700/acre depending on extra wood volume production, product classes, and wood prices. Other benefits include: the addition of macro-nutrients other than N and P and micro-nutrients (especially Cu and Zn), adding organic matter to the site (tons/acre), and possibly increasing near-term soil moisture holding capacity. Urea plus DAP fertilization of 8-15 year-old loblolly pine stands will generally increase wood volume by ½ cord/acre per year for 4-10 years (NCSUFNC, 1999). A single biosolids (treated municipal sewage sludge) application in a 10 year-old loblolly pine stand increased wood volume by 5.5 cords after seven years and increased revenues by $700/acre (Dickens, 2000). Initial findings from poultry litter application trials in loblolly and slash pine stands look very promising (Wilhoit *et al.*, 1998, Bush *et al.*, 1999, Samuelson *et al.*, 1999, Dickens and Richardson, 2000).

LIMITATIONS TO FOREST LAND APPLICATION OF POULTRY LITTER

There are some limitations to forest land application of poultry litter. Access is a principal limitation. Tractors and spreaders generally can not maneuver through most young forest stands with current tree spacings: 6 x 10 feet (6 feet between each tree and 10 feet between each row) or 6 x 12 feet are common for southern pines. Typically the first access window is after a pine stand has been row thinned which consists of removing the entire 3rd, 4th or 5th row and selectively thinning between the rows to leave best trees. This occurs when the trees are 10 to 20 years-old in most pine plantations. Some forest landowners intensively prepare their planting sites to have ground access prior to a first thinning by using a planting spacing which consists of 6 x 10 feet with 15 feet between every 5th row for access or 8 x 8 feet with a skip row every 4th row. Many poultry growers who are planting their crop or pastureland with pines are leaving access lanes for ground application of litter.

Only 1-5 acres of forest land may be covered per load of litter due to large application levels, 1-6 tons/acre depending on species, stocking, age, soil type, poultry litter characteristics, and application frequency. Limitations to forest land application of poultry litter include hauling distance, labor and time constraints, spreader availability, and adequate turn-around areas. Most tractor-spreader combinations have a turning radius of approximately 40 feet. Woods roads and good fire breaks can serve as turn-around areas. There may be cases where a few trees need to be sacrificed in order to maneuver a spreader or spreader-tractor combination. Excessive stump height and rutting depth at thinning can reduce the land area where poultry litter is applied. Stump height plus rutting depth in any thinned row should not exceed the lowest clearance of the spreader system used. A rule of thumb is that rutting should not exceed 6" depth and stumps should not exceed 4-6" height for site productivity purposes as well as access. If, for example, a rut is 8" deep, a stump in that rutted area is 7" high and the tractor-spreader clearance needed is 12" then that tractor-spreader combination will not be able to get past that rutted area with a high stump height. A written contract for the thinning to include maximum rutting depth and stump height should take care of these limitations.

CHECKLIST FOR PINE PLANTATION POULTRY LITTER APPLICATION

A willing forest landowner and a suitable stand must be identified and located in close proximity to the poultry grower, generally less than 5-10 miles. A checklist for the candidate stand should include size, species, age, stocking, N and P nutrient needs, access, years to a thinning or final harvest, % hardwoods, % fusiform canker infestation, soils, and proximity to sensitive areas such as churches and developments.

A checklist for the application should include spreader availability, how the litter is to be hauled to the site, and availability of a front-end loader for loading the litter at the farm. The litter that is scheduled to be applied should always be analyzed as close as possible to the actual application dates for total-N, ammonium-N, nitrate-N, total-P, K, Ca, Mg, Cu, and Zn. Nitrate-N analysis may be required on an initial sample to determine whether it is negligible or a significant N contributor.

The tons/acre and total number of tons needed for the stand should be determined. This should be the amount that would result in the target total-N/acre after canopy closure or after a thinning or total-P/acre needs at planting (Table 1 and 2). The spreader should be calibrated using open area, 6-10 plastic tubs with a known open-end surface area, and a field scale that weighs to the nearest gram. Spreader calibration usually takes more than a half day initially and requires several extra tons of the litter. The spreader should be driven at a speed that can be achieved in the woods such as 2 to 2.5 mph. Gear, RPM's, ground speed of the tractor, the PTO RPM's (set to manufacturer's specifications, usually 540 or 1100 RPM for pull behind spreaders), and the port door height must be documented. Place the plastic tubs different distances from the port door of the spreader (0, 3, 6, 9, 12, 15, 18, 21, 24, and 27 feet). A one square foot tub would need 104 grams of litter on average to achieve a 5 tons per acre litter application level.

APPLICATION LEVELS IN SOUTHERN PINE PLANTATIONS

Loblolly pine is the most nutrient demanding of our southern pines. Slash is intermediate in nutrient demands and longleaf is the least nutrient demanding. Too much nitrogen can make young longleaf trees top-heavy due to too much foliage produced in a short period of time. The stem can not support the extra weight and 15-20% of a stand can lean over and never recover (Dickens, 2000). The poultry litter application level should be species, age, stocking, site, and landowner objectives specific due to differences in nutrient demand.

Table 1. Nitrogen (N) and Phosphorus (P) Fertilization Recommendations/Estimations for Single to Repeat Applications Every 4-5 Years by Southern Pine Species in Well Stocked Stands (Broadcast and Surface Applied).

Species	Age (yrs)	N recommendation	P recommendation
		------------------lbs/acre------------------	
Loblolly[a]	1 - 4	40 - 50	25 - 50
	5 - 10	80 - 150	25 - 50
	11 - 35	200	25 - 50
Slash[b]	1 - 4	40 - 50	25 - 50
	5 - 10	70 - 110	25 - 50
	11 - 35	150 - 200	25 - 50
Longleaf	1 - 4	30 - 40	25 - 50
	5 - 10	50 - 80	25 - 50
	11- 35	80[c] - 150	25 - 50

[a] Fusiform stem canker incidence < 30% and hardwood basal area/acre < 10 ft^2
[b] Fusiform stem canker incidence < 25% and hardwood basal area/acre < 10 ft^2
[c] Use less than 100 lbs N/acre when average diameter @ 4.5 feet is < 6-7 inches and up to 150 lbs N/acre when average stem diameter @ 4.5 feet > 7 inches

Table 1 values are derived from a combination of numerous commercial fertilizer and biosolids trials in loblolly, longleaf, and slash pine plantations and are currently "best estimates". Several poultry litter application projects are underway or are being proposed in the Southeastern US. As information is collected and summarized, these N and P application recommendations will be refined. Check with the Cooperative Extension Service and/or the State Forestry Commission for N and P recommendations particular to their state and pine stand factors. Current annual poultry litter application "best estimates" in pine plantations should attempt to achieve approximately 30 - 50 lbs N/acre until age 3-6 years-old and 50-100 lbs N/acre after age 6. The lower number is for longleaf, the higher number for loblolly, an intermediate amount required for slash. Excellent weed control must be achieved prior to applying poultry litter to young stands (4-8 years-old) prior to canopy closure. Initial poultry litter applications in pine plantations will typically be based on N (after canopy closure) or P (at planting) needs.

Tons per acre rate determination may be based on total-N (organic-N + ammonium/ammonia-N + nitrate/nitrite-N) in the poultry litter. Table 2 lists the results of estimating the tons/acre of poultry litter needed to achieve 200 lbs N/acre in a 15 year-old loblolly pine stand. Total-N is much easier to quantify analytically but not all of total-N may be plant available in the first or second growing season. TKN is a good estimate of total-N where nitrate/nitrite-N is negligible.

Table 2. An Example of Estimating Poultry Litter Tons/Acre From a Lab Analysis Based on Total-N and Recommended N Fertilization Level (200 lbs N/acre) for a 15 Year-Old Row Thinned Loblolly Pine Plantation.

Nutrient	Conc. (%)	lbs/ton (as sampled)
total-N	2.70	54
org-N	1.50	30
NH_4-N	1.18	23.6
NO_3-N	0.02	0.4
total-P	1.24	24.8
total-K	1.86	37.2
total-Ca	1.94	38.8
	(ppm)	
B	37.8	0.076
Cu	266	0.53
Zn	287	0.57

To achieve 200 lbs N/acre using the total-N value from the above analysis then divide 200 lbs N/acre by 54 lbs total-N/ton in the poultry litter resulting in 3.7 tons poultry litter/acre. The 3.7 tons/acre poultry litter application level would also have 92 lbs total-P (210 lbs P_2O_5), 138 lbs total-K (166 lbs K_2O), 144 lbs Ca, 0.28 lbs B, 2 lbs Cu, and 2 lbs Zn per acre.

A second, frequently used N rate determination basis for crop and pastureland is plant available-N or PAN. Generally 100% of nitrate/nitrite-N, 50-60% of ammonium/ammonia-N (when surface applied), and 40-50% of organic-N (total Kjeldahl-N minus ammonium-N) are estimated to be plant available in the first growing season. Ammonium can be converted to nitrate or transformed to ammonia. Ammonia is a gas that can be readily lost to the atmosphere. Ammonia losses are dependent on temperature, moisture, relative humidity, wind speed, and micro-environment pH. If a 1/4 inch or more rain occurs within 24 hours of surface applied poultry litter application, ammonia-N losses can be minimal. Often PAN is estimated to be 50% of total-N when surface applied. At least initially, it is recommended that the analyzed total-N lbs/ton in the poultry litter be used to determine tons/acre needed for application for pine plantations.

Special care should be taken in a pine stand in regions such as loblolly's and longleaf's northern range where ice and snow are common and can weigh down crowns or where stem fusiform cankers are relatively high (> 25-30%). As much as 50-75% more crown weight can be added with a single poultry litter application. A forest landowner does not want to loose 15-20% of his/her stand due to producing top-heavy trees that lean over and never recover. This has happened in more than one case in young longleaf stands with over application of N from organic and inorganic fertilizers (Dickens 2000). Long-term repeat application rates may have to be reduced and based on P needs in pine plantations depending on P build-up levels in the soil.

Fertilization to enhance pine straw should occur every 4-8 years using poultry litter. The Table 1 nitrogen and P fertilizer recommendations for each species should be used when determining periodic poultry litter application tons/acre needs. Fertilization using poultry litter, other organic fertilizer materials, and commercial fertilizers will generally increase pine straw production by 40-50% starting 15-24 months after application and last 3-5 years (Dickens, 2000). Wood volume should also increase, generally by 15-40% during this same period (Dickens and Miller, 1998; Dickens, 2000). A current 5 year poultry litter application regime to enhance pine straw production would have the following schedule: Year 1: Rake, herbicide where needed, fertilize. Year 2: Leave (Let the litter break down. Increased needle production is not on the ground yet). Years 3 and 4: Rake. Year 5: Do as in year 1.

For forest land application of poultry litter, the recommended water table depth at time of application should be greater than 20 inches for sandy soils and 30 inches for loamy to clayey soils. With a higher water table growth can be reduced for a number of years by damage to perennial tree root systems and by soil compaction. Also, anaerobic soil environments can increase ammonium-N levels and reduce seedling survival. Heavy equipment should not be used to apply poultry litter at a site where water can be squeezed out of a handful of soil.

PRELIMINARY RESEARCH FINDINGS

At Planting

Bush *et al.* (1999) studied loblolly pine survival after two growing seasons in the lower Coastal Plain of Georgia on Bladen, Chipley, Albany, and Blanton soils. All plots had weed control the first year. They found that survival was 97% using 125 lbs DAP/acre applied at planting, 95% for the 1 ton broadcast pelletized (4.5-4-3) poultry litter/acre applied at planting, and 91% for the controls. In years one and two on the Chipley soil (Aquic Quartzipsamment), mean total height and groundline diameter of the trees in the poultry litter plots were significantly greater than the mean total height and groundline diameter of DAP treated trees and the controls. The poultry litter pine groundline diameter was significantly greater than the control in year one on the Blanton and Albany soils, both of which are loamy, Grossarenic Paleudults.

A similar "at planting" trial was performed in a slash pine stand in the upper Coastal Plain of Georgia on a Fuquay soil (loamy, Arenic Plinthic Kandiudults). Treatments were 1) poultry litter (4-3-2) at 1 and 2 tons/acre, 2) 125 lbs DAP/acre, and 3) untreated controls (Bush *et al.*, 1999). All plots had weed control the first year. Root collar diameter and total heights of the pines treated with 1 and 2 tons/acre poultry litter and the 125 lbs DAP/acre were significantly greater than the controls after the first growing season. Height was also greater after the 2nd growing season, but year 2 root collar diameter was not reported.

Wilhoit *et al.* (1998) reported that poultry litter applications of 2-8 tons/acre at pine establishment, without weed control, decreased height one to two years after treatment. When the weeds were controlled, there was a significant growth response.

Mid-Rotation

Samuelson *et al.* (1999) found that 2-4 tons poultry litter/acre applied in an 18 year-old loblolly pine stand increased stem diameter growth after 18 months. Dickens and Richardson (2000) studied the effects of broiler litter applied at 7 tons/acre (450 lbs total-N, 240 lbs PAN, and 170 lbs elemental-P) versus DAP+Urea and no fertilizer treatment in an old-field row thinned loblolly pine plantation (treatments applied at age 11 years-old) on an eroded upper Coastal Plain Norfolk soil (fine-loamy, Typic Paleudults). They found that the broiler litter application increased 2-year diameter and height growth by 1/4 to 1/3 inch and 1 to 1.8 feet, respectively over the untreated controls and DAP+Urea (200 N + 50 P) plots (Table 3).

Table 3. Old-Field, Row-Thinned Loblolly Pine Mean dbh (diameter @ 4.5') and Total Height Prior to and 2 Growing Seasons After Poultry Litter (7 tons/acre) and DAP+urea (250 lbs DAP+335 lbs urea/acre) Application (900 trees/acre prior to thinning and 250/acre after thinning) in the Upper Coastal Plain of SC (Norfolk soil).

Treatment[a]	Dbh (in)		Dbh growth	Ht (ft)		Ht growth
	------year-----			------year-----		
	1998	2000	increment	1998	2000	increment
control	6.16	7.16	1.00	32.47	37.07	4.60
DAP+urea	6.05	7.16	1.11	35.44	38.88	3.44
broiler litter	6.32	7.68	1.36	33.35	38.79	5.44

[a] stand was starting 11th growing season at time of fertilizer and litter treatment

SUMMARY AND CONCLUSIONS

There are environmental, growth, pine straw production, increased revenue, and cost reduction benefits to poultry litter applications in pine plantations when applied properly. The principle limitation is pine stand access. Other limiting factors include hauling distance and number of acres applied/day. Poultry litter application rate/level determination depends upon pine species, age, stocking, current site fertility, poultry litter characteristics, frequency of application, and soil test-P levels over time. Pine stands where poultry litter is to be applied should have low (<25-30%) stem fusiform canker incidence and low hardwood stocking (<10 ft^2 BA/acre) to maximize the growth benefit to the crop pine trees. Preliminary research has shown that large growth increases occur when poultry litter is applied to pine plantations.

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DEVELOPMENT OF A PHOSPHORUS INDEX FOR PASTURES

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Non-point phosphorus (P) runoff from pastures fertilized with animal manures plays an important role in eutrophication of nearby water bodies. Edwards and Daniel (1993) have shown that poultry litter applications to pastures result in relatively high P runoff at recommended rates with as much as 90% of the P runoff being in the soluble form. Because P is normally the limiting nutrient for eutrophication, concerns have arisen over animal waste applications. Several researchers have studied the relationship between soil test P and soluble reactive P (SRP) concentrations in runoff. These studies have shown that SRP concentrations in runoff water increase as soil test P increases (Pote *et al.*, 1996; Sharpley *et al.*, 1994; Sharpley, 1995). Currently several states are attempting to determine threshold soil test P levels above which animal manures may not be applied due to increased risk of P runoff. An alternative approach to managing P applications to lands is using the Phosphorus Index (PI). The PI is a risk assessment tool that combines the effects of both P sources and P transport mechanisms in determining the risk of P runoff. However, weighting factors used in the original PI were based on professional opinion rather than actual data. The objectives of this study were to determine the effects of soil test P, poultry litter application rates, P reductions in diets, soluble P in litter, fertilizer type, and weather on P runoff. Results from this research were then used to develop weighting factors for a PI for pastures.

MATERIALS AND METHODS

The first phase of the study was conducted on 72 small plots (5' x 20') located at the University of Arkansas Agricultural Research Station. The plots were constructed on a Captina silt loam soil (fine-silty, siliceous, mesic Typic Fragiudult). After initial construction of the plots were completed, soil test P was augmented on 24 plots. Triple super phosphate (0-46-0) was incorporated into the soil at rates of 0, 150, 300, 600, 900, and 1200 lb P/acre. After augmentation of soil test P, all of the plots were seeded with tall fescue (Festuca arundinacea Schreb.) in the fall of 1998. Beginning in June (1999), rainfall simulators were used to produce at least three runoff events on each plot to determine the effects of the following treatments on P runoff:

1. effect of soil test P (6 levels of soil test P)
2. effect of soluble P in poultry litter (4 levels of soluble P)

3. effect of P in diet (normal diet, phytase, HAP, and phytase + HAP)
4. effect of fertilizer type (triple super phosphate vs. poultry or swine manure)
5. effect of poultry litter application rate (4 rates of litter)
6. effect of timing (first runoff event after fertilization occurs at 1,7,21, and 49 days)

The litter from diet manipulation studies was from Delaware (courtesy of Bud Malone and Tom Sims) whereas all other litter was collected in northwest Arkansas. The litter from Delaware had been deep stacked for several months. Soil samples were taken from 0-2" for water soluble P (WSP) and 0-6" for Mehlich III P (MIII). Soil samples were taken before treatments were applied and the day before each simulation. Water soluble P was determined using an autoanalyzer after extracting 2.5 g of soil with 25 ml of DDI water (modified Pote et al., 1996; 1:10 dilution). Mehlich III P was analyzed using ICP after extracting 2 g of soil with 14 ml of Mehlich III extracting solution (Mehlich, 1984). Rainfall simulators were used to produce a 5 cm hr^{-1} intensity with sufficient duration to cause 30 minutes of continuous runoff. Composite samples from each plot was filtered through 0.45 um filter membrane and acidified to pH 2 using HCl. Soluble reactive P was determined using a Technichon auto-analyzer II using the Murphy-Riley method (APHA, 1992).

RESULTS AND DISCUSSION

Average soil test P (Mehlich III) levels were 233, 318, 439, 609, 737, and 946 lb ac^{-1} for additions of 0, 150, 300, 600, 900, and 1200 lb P ac^{-1}, respectively. Runoff P concentrations were well correlated to soil test P levels as seen by Pote *et al.* (1996) and Sauer *et al.* (2000). A positive relationship between SRP and Mehlich III P was found for the first rainfall simulation ($r^2 = 0.86$, Figure 1a) and the second rainfall simulation ($r^2 = 0.52$). However, once manure was applied to these plots, a poor relationship between SRP and soil test P (STP) was found (Figure 1b). A poor relationship also existed between total P in the manure and SRP runoff concentrations. However, a good relationship was found between soluble P in the litter and SRP in the runoff water ($R^2 = 0.76$) (Figure 1c). There were no significant differences in SRP runoff concentrations among various soil test P levels after manure was applied. Furthermore, the amount of P in runoff from soils fertilized with manure was much higher than observed from soil alone. This data agrees with that of Sauer *et al.* (2000) which shows that manure applications overwhelmed soil test P in runoff concentration.

Litter from the diet manipulation studies resulted in the highest SRP concentrations in runoff water of all the manure treatments. When the different manure types were applied at the same application rate (2.5 tons/acre), the amount of total P applied to pasture was lower from the diet manipulated litter (i.e. - HAP corn and phytase) than normal litter (Figure 2a). However, SRP in runoff water was highest from plots fertilized with litter derived from HAP corn or phytase diets even though the amount of total P applied to the plots was lowered (Figure 2b).

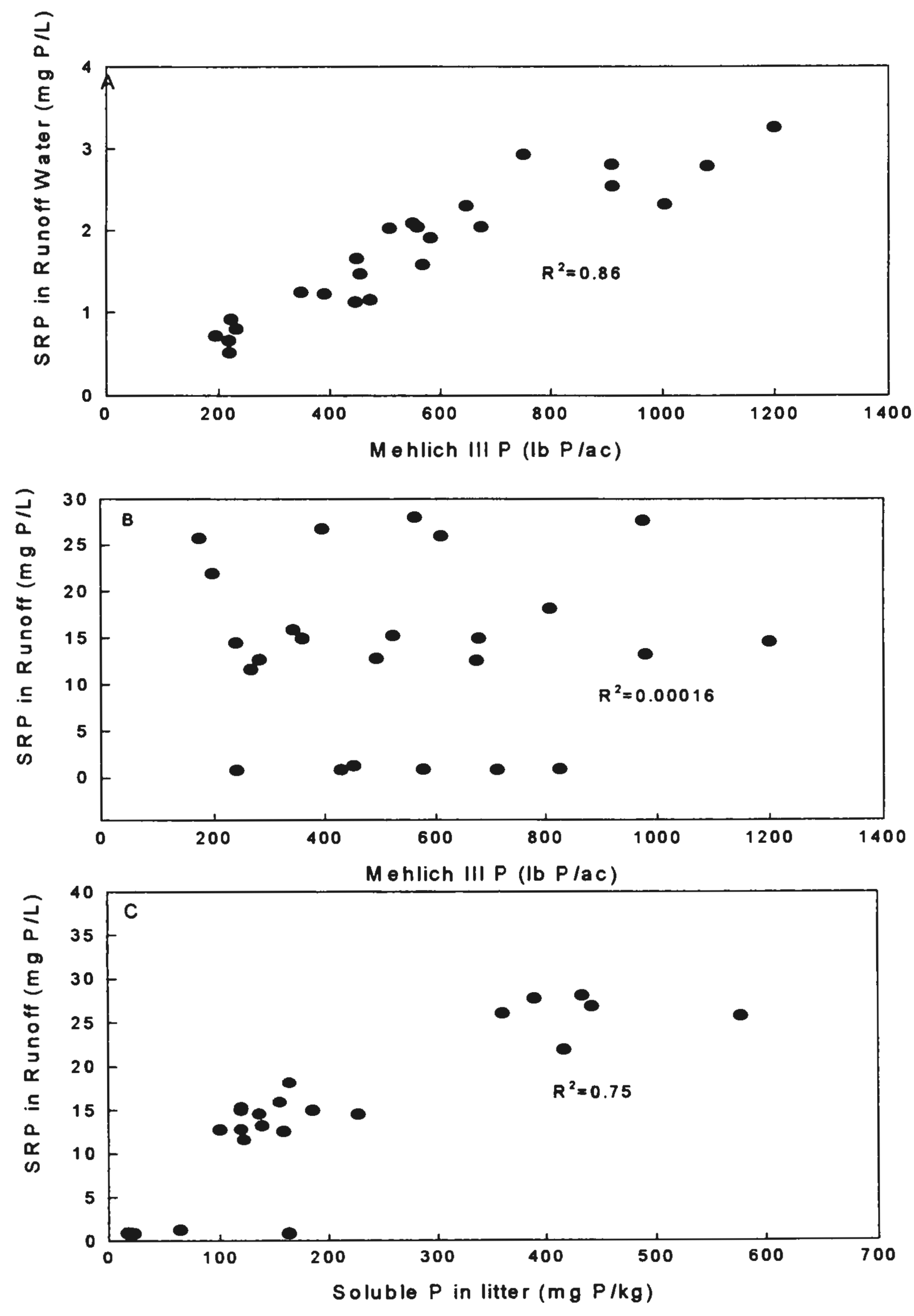

Figure 1. Effect of soil test P on SRP runoff concentrations with (a) no manure applied; (b) manure application; and © effect of manure P solubility of SRP runoff.

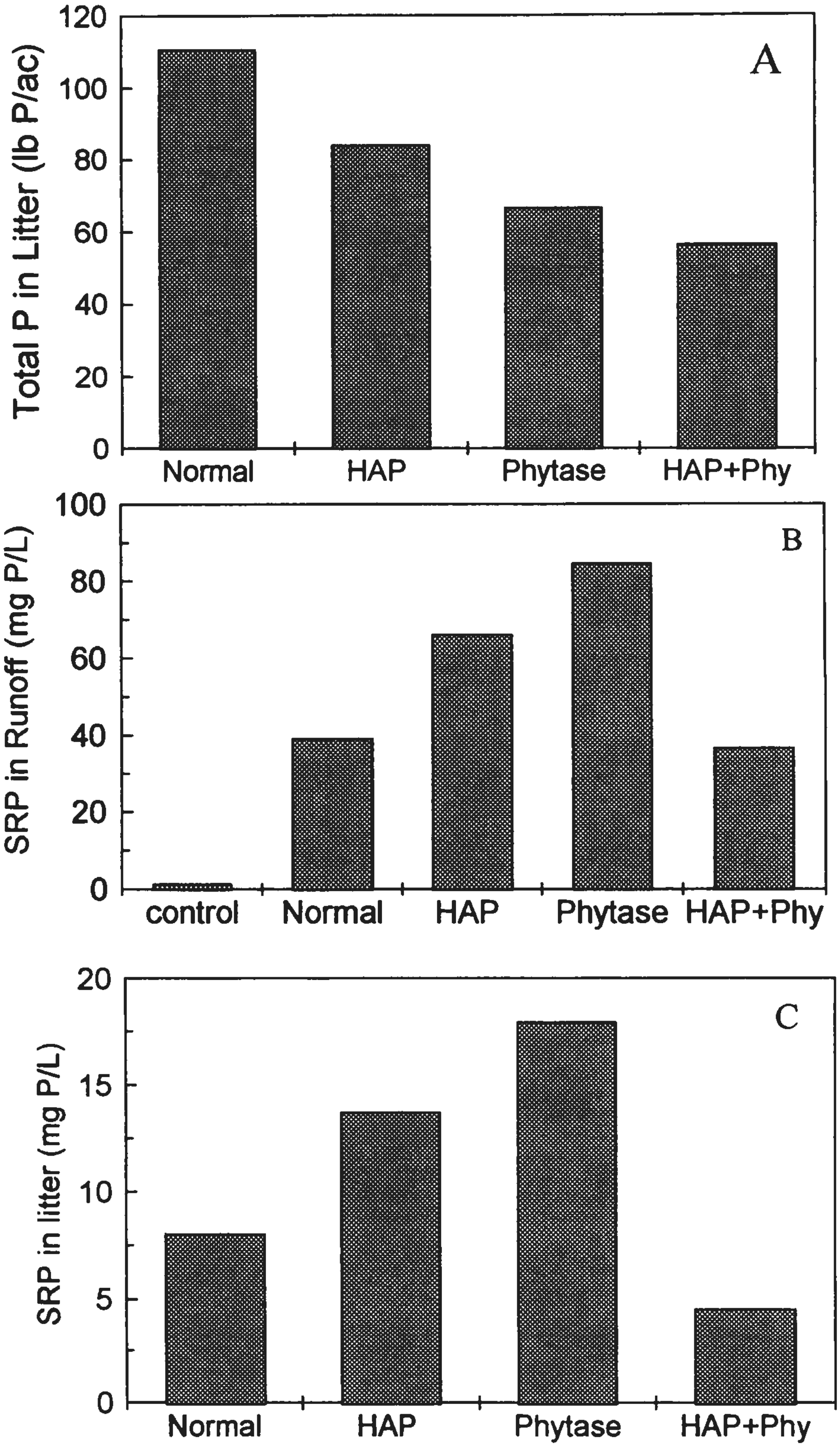

Figure 2. Effect of diet on (a) total P applied; (b) runoff SRP, and © litter SRP.

The reason HAP and phytase diets increased runoff was because the SRP level in the manure was increased with these treatments (Figure 2c). This may or may not be typical for these treatments. The litter had been deep stacked in Delaware for 6-8 months before shipping. In an earlier study, Moore *et al.* (1998) found that HAP corn and phytase had no effect on soluble P or P runoff.

Mean runoff SRP concentrations in runoff water were 26.0, 15.1, 13.4, and 0.88 mg L^{-1} for untreated litter, litter treated with 5% alum, litter treated with 10% alum, and litter treated with 20% alum, respectively (Figure 3a). Soluble reactive P concentrations in runoff water were reduced by 49% and 97%, respectively, with 10% and 20% rates of alum. Reductions in SRP in runoff water were due to reductions in SRP in the litter.

Commercial fertilizer resulted in five times higher P concentrations in runoff water than both swine and poultry manure, even though all of these were applied at the same P rate (Figure 3b). This would be expected since the solubility of commercial fertilizer is much higher than that of organic fertilizers (94% of the P in triple superphosphate is water soluble). These findings demonstrate that inorganic P fertilizers, when applied at the same P rate as manure, result in more P runoff from pastures. This was also demonstrated by Nichols et al. (1994). These data also demonstrate P solubility in the fertilizer determines the amount of runoff.

Phosphorus runoff increased linearly as the phosphorus application rate increased. Runoff concentrations were 33.0, 27.7, 16.6, and 8.8 mg L^{-1} for applications of 1, 2, 3, and 4 tons/acre, respectively. The same positive linear relationship was seen for the second and third rainfall simulation (Figure 3c). The soil test P levels for these plots and the unfertilized controls were relatively the same. The mean SRP runoff concentration of 4.75 mg L^{-1} from litter applications equivalent to 1 ton ac^{-1} after the third rainfall simulation was still higher than that of unfertilized controls. Even after three runoff events, soluble P applied in manure is still a very important factor in regulating P runoff.

Development of the Phosphorus Index

The data from the runoff studies described above were used to develop weighting factors for the Phosphorus Index for pastures. Multiple regression analysis (proc stepwise) was used to obtain the weighting factors (P loads were modeled with the parameters that were varied, such as soil test P, poultry litter application rates, P reductions in diets, soluble P in litter, etc. Results of this analysis showed the weighting factors for the source factors were as follows: 0.404 for soluble P application rate and 0.000666 for soil test P (Mehlich III). Two other important parameters of the index are P transport and best management practices (BMPs). The Phosphorus index is calculated from all three terms as follows:

P.I. = (P sources) * (P Transport) * (BMPs)

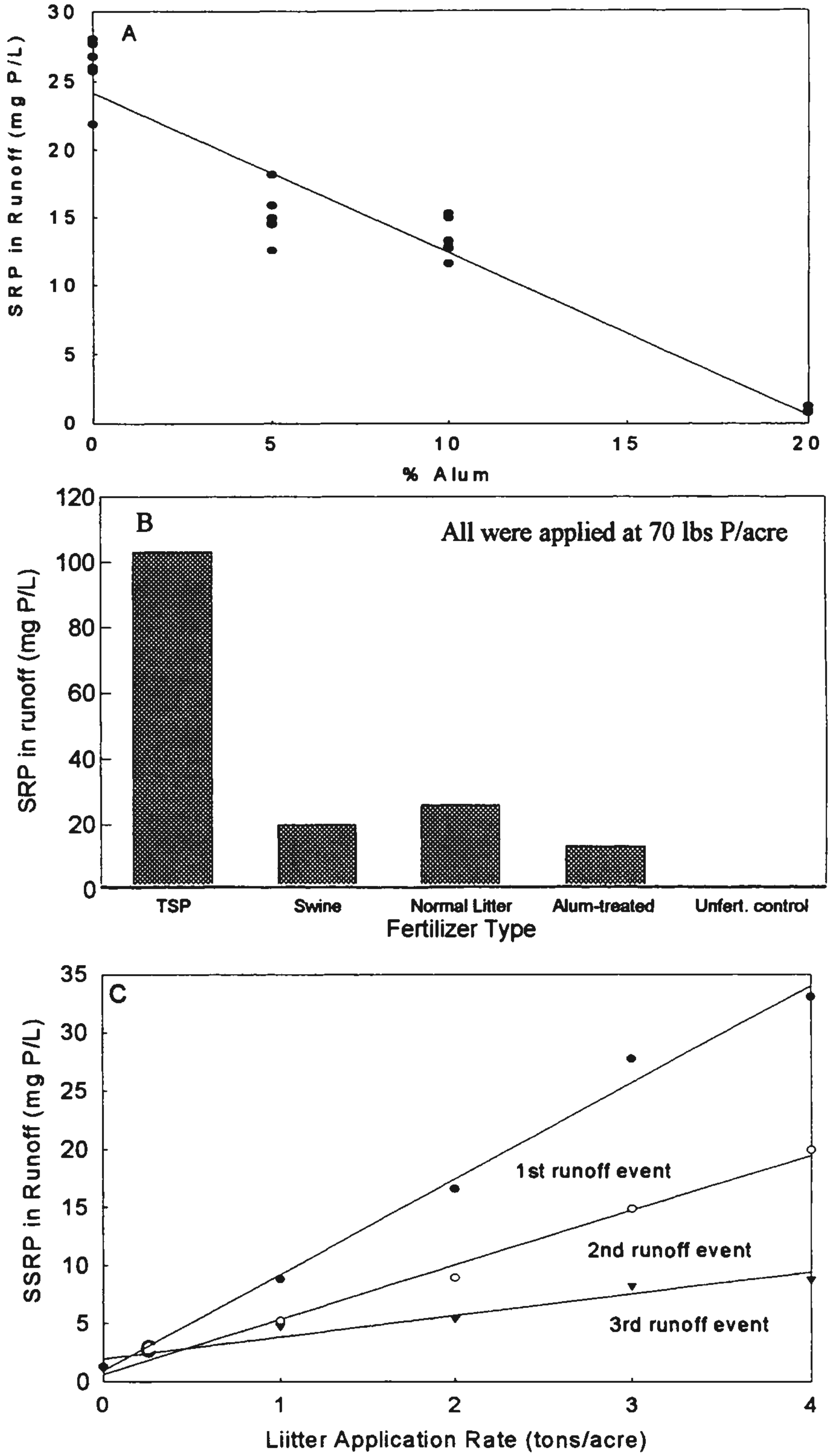

Figure 3. Effect of (a) alum; (b) fertilizer type; and (c) application rate on SRP runoff.

Eight site characteristics are included in the PI for pastures; they are grouped into P source and P transport categories. As mentioned earlier the P source term is comprised of soil test P and soluble P application rate. The P transport term is comprised of soil erosion, soil runoff class, method of application, flooding frequency, timing of P application, and grazing management. This P Index is the first to use actual runoff data to derive weighting factors. Based on the P Index, fields are assigned a P index class of low, medium, high, or very high. Each class is associated with interpretations and recommendations (Table 1).

Table 1. Phosphorus index for pastures interpretation and recommendations.

P Index	Site Interpretations and Recommendations
< 0.6	**Low** potential for P movement from site. Apply nutrients based on crop needs, normally nitrogen. Caution against long term buildup.
0.6 to 1.2	**Medium** potential for P movement from site. Evaluate the Index and determine any areas that could cause long-term concerns. Consider adding conservation practices or reduced P application to maintain the risk at 1.2 or less.
1.2 to 1.8	**High** potential for P movement from site. Evaluate the Index and determine elevation cause. Add appropriate conservation practices and/or reduce P application. Your immediate planning target is a PI value of 1.2 or less. If this cannot be achieved with realistic conservation practices and/or reduced P rates in the short term, then a management plan needs to be developed with the long-term goal of a PI less than 1.2.
> 1.8	**Very High** potential for P movement from site. No litter application. Add conservation practices to decrease this value below 1.8 in the short term and develop a conservation plan that would reduce the PI value to 1.2 or below during the next 5 years.

When the PI is low or medium, manure applications can be based on the N needs of the crop. When the PI reaches the high level, manure applications should be made based on P removal by the crop. At the very high level, manure should not be applied.

CONCLUSIONS

Results from this study show that soil test P levels and manure P solubility are both important factors affecting P runoff from pastures. When no manure has been applied, soil test P values are well correlated to SRP runoff concentrations. However, once manure is applied, SRP concentrations are better correlated to the SRP concentrations in the manure applied. Throughout this study, it was clearly evident that concentrations of SRP in runoff water increased with greater fertilizer P solubility. Lowest runoff concentrations were observed from alum-treated litter which has the lowest SRP concentrations in the litter. Treatments containing the highest P solubility, commercial fertilizer and HAP or phytase litter, resulted in the highest SRP runoff concentrations. Results of this study were used in the development of a P Index for pastures. The source factors (soil test P and manure P solubility) have weighting factors based on annual P loads from runoff plots.

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IMPLEMENTING A PHOSPHORUS SITE INDEX: THE DELMARVA EXPERIENCE

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AGRICULTURE AND ENVIRONMENTAL QUALITY: ISSUES ON THE DELMARVA PENINSULA

Agriculture is the predominant land use on Delmarva. Of the15,500 km^2 total land area on the peninsula about 48% is in agriculture (soybeans, corn, small grains grain sorghum, hay/alfalfa, commercial vegetables, and fruits), 31% is in woodlands, 13% is in wetlands (fresh and tidal), 7% is in urban and residential use, and 1% is in barrier beaches and islands. Economically, Delmarva's agriculture is dominated by a large and geographically concentrated poultry industry that is vital to the overall economy of the region. Approximately 600 million broiler chickens are produced each year on Delmarva and the total value of broilers "processed and delivered" in 1999 was $1.63 billion; the industry as a whole had an annual payroll of > $350 million (DPI, 1999). Poultry production increased markedly on Delmarva from the 1960's to early 1990's but has stabilized in recent years. Today on Delmarva, there are about 2,700 contract poultry growers working with five integrated poultry companies. On average, each grower has 2.1 poultry houses and each house has a production capacity of ~23,000 broilers.

Poultry production is not uniformly distributed on Delmarva, rather it is localized in eight counties in close proximity to each other (Sussex, DE; Caroline, Talbot, Dorchester, Somerset, Wicomico, and Worcester, MD; and Accomack, VA). Seven of the eight counties have < 40,000 ha of cropland; Sussex County, DE has the largest agricultural land base (~100,000 ha) and the largest annual production of broilers by far (~220 million per year). The land base on Delmarva is not adequate to produce the grain needed by the poultry industry, which imports large quantities of corn and soybeans from other regions for use in feed. Approximately 69 million bushels of corn and 35 million bushels of soybeans are used by the poultry industry each year. Based on recent (1993-1998) average yields for corn and soybeans grown in Delaware (115 and 30 bu/acre, respectively; DDA, 1998) and cropland data for Delmarva as a whole, about 20 million bushels of corn and 15 million bushels of soybeans must be imported to meet the nutritional requirements of Delmarva's poultry industry. These feed imports, which also represent nutrient imports, have major implications for regional nutrient management and water quality issues. In particular, there has been serious concern that the geographic intensification of the poultry industry, which has in turn resulted in farm, county, state, and regional nutrient surpluses has created an agricultural setting that is prone to non-point source pollution (Cabrera and Sims, 2000). Simply put, the agricultural land base on Delmarva is not adequate to support the environmentally efficient use of the by-products of the poultry industry (manures, litters, composts) if land application of these by-products is the only option. There are several reasons for this. Nutrient surpluses on farms (or at larger scales) primarily result from the fact that nutrient inputs in feed and fertilizers exceed outputs in animal products and crops. Note that these surpluses do not result from animal agriculture alone; commercial fertilizer use is also a significant contributor. The surplus nutrients from feed are concentrated in animal manures which are heterogeneous in composition and have somewhat unpredictable rates of release once incorporated into soils. Poultry manures also have an unfavorable N:P ratio relative to most grain crops, resulting in over-application of P when manures are applied to meet crop N requirements, the long-standing agronomic practice in this region. Many soils in the poultry producing region of Delmarva are now considered "excessive" in P relative to crop P needs and are sufficiently saturated with P to be of concern for soluble P losses in leaching and runoff (Pautler and Sims, 2000). Manures and other animal wastes (e.g. composts) are also difficult to store properly and apply uniformly in a timely manner that is well-synchronized with plant uptake patterns. This combination of nutrient surpluses and logistical constraints to efficient use of manure nutrients has created a situation where nonpoint source pollution is prone to occur. The likelihood of ground and surface water pollution by agricultural nutrients is further enhanced by the nature of the topography, soils, hydrology, and climate on Delmarva. Abundant rainfall, easily leached or ditch-drained soils, and shallow aquifers that are interconnected with surface waters (streams, rivers, and estuaries) form a setting that facilitates nutrient transport from land to water.

PHOSPHORUS MANAGEMENT ISSUES ON DELMARVA

Phosphorus (P) losses by erosion and surface runoff or subsurface drainage from agricultural fields have been implicated in the degradation of water quality in the Chesapeake Bay, its tributaries, and other surface waters in the mid-Atlantic region (e.g. Delaware's Inland Bays). Most recently P in erosion and runoff has been identified as one of the possible causative factors of the water quality and human health problems presumed to be associated with the accelerated growth of *Pfiesteria spp.* in eutrophic waters. In the past three years a series of events have led to the passage of nutrient management laws in Delaware, Maryland, and Virginia and to increased federal involvement in the regulation of confined animal agriculture in the region. Each of these state laws contains elements that address the need for more intensive P management by agriculture. The first significant step of relevance to Delmarva was a lawsuit filed in1996 by a consortium of environmental groups that sued the U.S. Environmental Protection Agency (USEPA) for "failure to perform its mandatory duties under the Clean Water Act to identify and then improve water quality" in Delaware. In 1997 the state of Delaware, through the Department of Natural Resources and Environmental Control (DNREC), negotiated a Total Maximum Daily Load (TMDL) agreement with USEPA. This agreement established a 10-year schedule to develop TMDLs for affected waterbodies and to then promulgate "pollution control strategies" to ensure that pollutant loadings are below TMDL values. Virginia entered into a TMDL agreement with USEPA in 1998, adopting a 12-year schedule to set TMDLs and, subsequent to this, to implement plans to reduce pollutant inputs to levels needed to meet the desired water quality. Maryland does not have a TMDL agreement but a lawsuit has been filed to compel USEPA to establish TMDLs for impaired water bodies in that state.

The first state water quality legislation that impacted Delmarva was Maryland's Water Quality Improvement Act of 1998. Passage of this act was stimulated by public concerns over fish kills in the summer of 1997 that were reportedly caused by *Pfiesteria spp.* a toxic dinoflagellate that had been implicated in earlier, massive fish kills in North Carolina and also in human health problems. Detailed information on the events that led to Maryland's law are provided by Simpson (1998). However, it is fair to say that the Maryland law, which passed in a politically-charged atmosphere, stimulated similar efforts in Virginia and Delaware, under pressure from the USEPA, to move away from the voluntary nutrient management practices advocated in the past and in the direction of regulated programs, especially for large confined animal feeding operations (CAFOs, usually those operations with >1000 animal units). The states of Delaware and Virginia worked throughout 1998 and into 1999 to draft legislation addressing nutrient management and water quality. Virginia was the next state to pass legislation, in the form of a poultry waste management bill approved in January of 1999 (see Table 3 for details). In Delaware the Governor appointed an Agricultural Industry Advisory Committee on Nutrient Management, consisting of ten farmers, to develop recommendations for state actions. The efforts of this committee led to the passage in June of 1999 of Delaware's state nutrient management act. Subsequent to the passage of these state laws, committees or commission were appointed to draft the regulations required by each state's legislation. For example, in Delaware a Nutrient Management Commission (DNMC) has been established to develop and implement a state nutrient management program that will protect and improve water quality. Specific information on Delaware's act and the responsibilities of the DNMC is provided by Sims (1999) and Sims (2000).

National policy initiatives are also underway that impact animal agriculture on Delmarva. By far the most significant is the USEPA-USDA Unified National Strategy for Animal Feeding Operations (AFOs), adopted in March of 1999 after lengthy discussion and public review. This document contains nine "guiding principles" for the joint effort between the nation's lead regulatory agency (USEPA) and its lead technical agency for agriculture (USDA) to "..address the water quality and public health impacts associated with AFOs". The recently adopted "national nutrient policy" of the USDA Natural Resources Conservation Service will also have an impact because, as discussed below, it requires the development of P-based nutrient management plans for some agricultural operations.

PHOSPHORUS MANAGEMENT OPTIONS FOR DELMARVA

As nutrient management planning efforts shift in the direction of mandating controls on P management, a systematic assessment of the risks of P losses to water becomes essential if we are to design best management practices (BMPs) to reduce P losses and effectively prioritize the locations where their implementation will have the greatest water quality benefits. Recently, the USDA-NRCS adopted a national nutrient policy that recommended three options to use in identifying appropriate P application rates (Table 1):

Table 1. Phosphorus Management Options Established by USDA-NRCS.

Phosphorus Management Option	Rating Scale	Recommended Approach
Phosphorus Site Index: Integrates transport, source and management factors to identify areas in the landscape with greatest risk of P loss to water.	Low risk	Nitrogen-based
	Medium risk	Nitrogen-based
	High risk	P-based (e.g., crop P removal)
	Very high risk	P-based (e.g., no P application)
Soil Phosphorus Threshold (TH) Value: An upper limit for soil P, as measured by an agronomic soil test or other appropriate method (e.g. degree of P saturation, water soluble P), above which more intensive P management practices are needed.	< ¾ TH	Nitrogen-based
	> ¾ TH to < 1½ TH	P-based (e.g., crop P removal)
	> 1½ TH to < 2 TH	P-based (e.g., 0.5X crop P removal)
	> 2 TH	P-based (e.g., no P application)
Soil Test Phosphorus: Agronomic soil test P ratings (i.e., likelihood of economic response of crop to P inputs) are used to identify when P-based management should occur.	Low	Nitrogen-based
	Medium	Nitrogen-based
	High	P-based (e.g., 1.5X crop P removal)
	Very high	P-based (e.g., crop P removal)
	Excessive	P-based (e.g., no P application)

On Delmarva a concerted multi-state, multi-agency effort (University of Delaware, University of Maryland, Pennsylvania State University, Virginia Tech University, USDA-ARS, and USDA-NRCS) has been underway since 1998 to develop and implement the *P Site Index* as the preferred approach to P management. We believe that, in terms of an accurate risk assessment for P loss to water, it is not logical, nor supported by past research, to develop plans that treat all P sources alike, or to focus strictly on a single measure of P, such as an agronomic soil test P value, to accurately characterize P risks to water quality. A broader, multi-disciplinary approach is needed, one that recognizes that P loss will vary among watersheds and soils, due to the rate and type of soil amendments used, and to the wide diversity in soils, crop management practices, topography, and hydrology (Sims, *et al.*, 2000).

THE DELMARVA PHOSPHORUS SITE INDEX

Evolution of the Phosphorus Site Index

We recognized the importance of managing soil P and developing risk assessment tools for Delaware nearly a decade ago. In the early 1990's, in conjunction with USDA-NRCS and scientists from other universities and governmental agencies a national work group was formed to develop a simple, field-based, planning tool (the *Phosphorus Site Index*) that could assess, in a relative way, the risk of P movement from soil to water. The initial objectives of this national work group, which has since evolved into an international, interdisciplinary research and management project focusing on minimizing the impacts of agricultural P on water quality (SERA-IEG 17: Southern Extension-Research Activity Information Exchange Group on *Minimizing Agricultural Phosphorus Losses for Protection of the Water Resource*; http://ces.soil.ncsu.edu/sera17), were as follows:

- To develop an easily used field rating system (the *Phosphorus Site Index*) for Cooperative Extension, NRCS technical staff, crop consultants, farmers or others that rates soils according to the relative potential for P loss to surface waters.

- To relate the *P Site Index* to the sensitivity of receiving waters to eutrophication. This is a vital task because soil P is primarily an environmental concern if a transport process exists that can carry particulate or soluble P to surface waters where eutrophication is limited by P.

- To facilitate adaptation of the *P Site Index* to site specific situations. The variability in soils, crops, climates and surface waters makes it essential that each state or region modify the parameters and interpretation in the original *P Site Index* for local conditions.

- To develop agricultural management practices that will minimize the buildup of soil P to excessive levels and the transport of P from soils to sensitive water bodies.

Shortly after the formation of this work group, we conducted an evaluation of the initial version of the *P Site Index* under "on-farm" conditions in Delaware's Inland Bays watershed in 1992-93 and drew the following conclusions (Sims and Ritter, 1993):

- "The *P Site Index* is a readily used, inexpensive way to identify areas on a farm that have the greatest potential to contribute to nonpoint source pollution of surface waters by soil P. Our study suggests that an evaluation of the *P Site Index* for the entire Inland Bays watershed would be relatively easy task, one that should be given serious consideration in the near future. The most difficult information to obtain would be soil test P; however the reasonably similar topography, soil types, and crop management practices used in the Inland Bays means that limited field-scale observations would be needed to obtain the other site characteristics for *P Site Index* for a site or farm (erosion, runoff, drainage). Farmers could then work with extension agronomists or soil conservation specialists to determine not only where the most critical areas for P loss are located, but how changes in their management practices would improve (or make worse) the current situation."

- "The P Site Index should be modified to include soil drainage. This is probably the main process for P transport in the Inland Bays watershed due to the flat topography in most of the area. We need to know more about the hydrology of agricultural drainage, the role of subsoils and sediments in retaining or releasing P to drainage waters, and the influence of land use on the entire process (e.g. will riparian or wetland vegetation act as a "sink" for P being transported in drainage waters)".

- "A greater educational effort is needed, not only to inform farmers of the possible effects current agricultural management practices may have on P losses to surface waters, but to provide them with practical, short-term alternatives to minimize P losses. Integral to this educational program is the need for a long-term, "watershed-wide" approach to P management that addresses the realities of animal-based agriculture in the region. The nitrogen-based management program used for animal manures will undoubtedly increase soil P levels even higher in the future. We should address this issue now, at all scales (field, farm, watershed, state), to determine the importance that should be placed on P management and the most efficient solutions needed at each scale".

The Current Delmarva Phosphorus Site Index

The first version of the *P Site Index* used on Delmarva was published in1996 (Sims, 1996). However, until passage of state legislation in Maryland, Delaware, and Virginia the *P Site Index* was rarely used in nutrient management planning efforts. Today, however, regulations promulgated under Maryland's Water Quality Improvement Act of 1998 require that a *P Site Index* assessment be conducted for soils where soil test P (Mehlich 1 soil test) values exceed 75 mg P/kg. In Delaware, the state's Nutrient Management Commission is considering the use of the *P Site Index* to identify "high P" soils (those soils where P applications in manures and fertilizers cannot exceed P removal in the harvested portion of the crop). Because the *P Site Index* is still in development on Delmarva, we only provide here an overview of the approach that will be used. The Delmarva *P Site Index* will have two major components:

Part A: Phosphorus Loss Potential Due to Site and Transport Characteristics: This involves an assessment of soil erosion, soil runoff class, subsurface drainage, leaching potential, distance from edge of field to surface water (also including the influence of a "no-P application zone"), and the priority of the receiving water body. A weighted matrix is used to determine the overall site and transport value using these site characteristics.

Part B: Phosphorus Loss Potential Due to Management Practice and Source Characteristics: This involves an assessment of agronomic soil test P, P fertilizer application rate and method/timing of fertilizer application, organic P application rate and method/timing of organic P application. We also include a "phosphorus availability coefficient" (PAC) that will be used to weight the organic P application rate based on the type of organic material applied (e.g, beef vs. dairy vs. poultry vs. swine manures vs. municipal biosolids). A weighted matrix is used to determine the overall management and source value from these characteristics.

Overall P Site Index:: To determine the *P Site Index* for a site, multiply the overall site and transport value from Part A by the overall management and source value from Part B. The following scale is then used to guide P management at that site (Table 2):

Table 2. Generalized Interpretation of the *P Site Index* for Delmarva.

P Site Index	Generalized Interpretation of *P Site Index*
0-50	**LOW** potential for P movement from this site given current management practices and site characteristics. There is a low probability of an adverse impact to surface waters from P losses from this site. Nitrogen-based nutrient management planning is satisfactory for this site. Soil P levels and P loss potential may increase in the future due to N-based nutrient management.
51-75	**MEDIUM** potential for P movement from this site given current management practices and site characteristics. Practices should be implemented to reduce P losses by surface runoff, subsurface flow, and erosion. Nitrogen-based nutrient management should be implemented no more than one year out of three. Phosphorus-based nutrient management planning should be implemented two years out of three during which time P applications should be limited to the amount expected to be removed from the field by crop harvest or soil test-based P application recommendations, whichever is greater.
76-100	**HIGH** potential for P movement from this site, given current management practices and site characteristics. Phosphorus-based nutrient management planning should be used for this site. Phosphorus applications should be limited to the amount expected to be removed from the field by crop harvest or soil test-based P application recommendations. All practical management practices for reducing P losses by surface runoff, subsurface flow, or erosion should be implemented.
>100	**VERY HIGH** potential for P movement from this site given current management practices and site characteristics. No phosphorus should be applied to this site. Active remediation techniques should be implemented in an effort to reduce the P loss potential from this site.

Implementation and Evaluation of the Phosphorus Site Index on Delmarva

During 1999 and 2000 we have determined *P Site Index* values for hundreds of fields in Delaware and Maryland, using related but slightly different approaches. In Maryland regional and county nutrient consultants worked with farmers to conduct P Site Index assessments on ~600 fields throughout the state, from the coastal lowlands to the Piedmont, to the mountainous areas in western Maryland. The goals were to assess the logistical aspects of conducting *P Site Index* evaluations under a wide range of conditions (crops, topography, management practices) and to obtain a large, diverse data base for use in refining the P Site Index. In Delaware, we have conducted complete evaluations of the *P Site Index* on four farms that represent the diversity of soils, topography, hydrology, crops, and agricultural production systems present. Our goal has been to develop economic and environmental analyses of the impact of P-based management (using either the *P Site Index*, soil P thresholds, or soil test P) on Delaware farmers. Combining the two efforts (easily done since there are many similarities between the two states) gives us both the broad overview and the detailed, site specific perspective needed to fully evaluate the merits of the *P Site Index* for Delmarva. We anticipate that, based on these efforts, a reliable, workable *P Site Index* will be in place and in use on Delmarva by 2001. Future research and extension efforts will focus on the environmental benefits of the *P Site Index* and the economic costs associated with implementing this approach to P management.

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ENVIRONMENTAL BENEFIT OF USING PHYTASE AND LOW PHYTIC ACID GRAINS

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FEEDING STRATEGIES TO REDUCE PHOSPHORUS OUTPUT

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Recent events in the US have brought the issue of phosphorus (P) content in poultry litter to the forefront among legislators, the public, poultry growers, and integrators. In Delmarva, new legislation will limit the use of litter application to soil (based, in part, on soil P content). Given limited land for litter application in certain areas of the U.S.A. where the greatest concentration of poultry production exists today, the poultry industry and poultry producers must find strategies that reduce P in litter with the least impact on income. The challenge of minimizing excreta P is one, that sooner or later, will have to be faced by the poultry industry nationwide. Different strategies exist to reduce excreta P but the most effective strategies will be those that are multi-facetted.

Not one single strategy will solve the problem of excess P associated with poultry litter. Pre- and post-production strategies must be integrated if a comprehensive and economically feasible solution is to be found. Pre-production strategies refer to strategies that are implemented before the excreta is generated by the bird. These strategies include feed formulation changes (including use of feed additives, ingredient choices, levels of minerals in the diet), genetic improvements to increase the bird's efficiency of nutrient use, and bird management changes that improve feed efficiency. These pre-production strategies can greatly influence the nutrient content of poultry litter. Post-production strategies refer to strategies that are implemented after the excreta is produced. These strategies include litter treatments that change the solubility of P, composting, shipping litter out of areas with excess soil P, burning poultry litter for fuel, etc.

This paper focuses on pre-production strategies that are related to feed changes. Diet changes can have a great impact on the amount of P that is excreted by broilers and accumulate in litter. Several feed and management related strategies will be discussed that have the potential for decreasing excreta P. 1) Formulating feeds and feeding birds closer to their P requirements. To do this, several issues must be addressed which would include: establishing P and calcium (Ca) requirements under commercial management systems; use of phase feeding systems with a maximum number of phases within practical and economic constraints; use of ingredient knowledge on nutrient content and variability; use of rapid analytical techniques at feed mills to determine actual P and Ca content in ingredients; etc. 2) Use of feed additives that maximize the availability of P for broilers. These feed additives would include enzymes (such as phytase), and/or enzyme "cocktails", organic acids, and vitamin D_3 metabolites. Feed formulated with enzyme(s) addition must take into account the increased availability of nutrients when feed additives are used. 3) Use novel ingredients that are low in phytate P (PP) (high available phosphorus (HAP) corns and soybeans) currently being developed and tested.

FEED FORMULATION

In formulation of commercial diets, several factors have to be considered: ingredient variability; availability of nutrients within an ingredient and changes in that availability due to processing, growing season, soil where ingredients were grown or where ingredients were mined; specific plant genotype; bird strain; physiological factors such as sex and age; environmental factors or stressors such as heat or density; and the mixing accuracy within a specific system in a feed mill. Formulators need to have these factors in mind when determining the nutrient levels to use in practical diets. If not considered, these factors can result in low dietary levels and deficiencies. Safety margins in formulation are in place to prevent deficiencies from occurring. The challenge is to increase our knowledge such that safety margins can "safely" be reduced.

Minimizing formulation safety margins will lead to feed formulation that is closer to the bird's requirements. Formulators will need better information on ingredient nutrient content and its variability. Use of near infrared reflectance (NIR) technology or other analysis techniques at the feed mill for rapid analysis of ingredients, would allow for "real time" formulation and large decreases in safety margins. Other strategies such as minimizing mixing "errors" through changes in ingredient delivery systems; seasonal formulations, and diet formulation for specific strains would also help decrease these safety margins. Implementation cost, information and technology availability, and previous lack of economic or legislative incentives to overcome implementation costs have resulted in limited use of new technologies to minimize safety margins. This situation will change rapidly once legislation is implemented and the economic consequences can be measured and used as part of formulation systems.

Ingredient Selection and Variability

It is important to clarify terms (related to P) before continuing. "Book" values, such as those found in NRC (1994) for non-phytate P (nPP) levels in plant ingredients are often referred to as being available P (aP). This misuse of the aP term has led to confusion as to the meaning of terms. Available P refers to the P that is absorbed from the diet into the animal while nPP refers to total P minus phytate P. Both total and phytate P can be determined through chemical analysis. Retained P refers to the P that stays in the body (i.e., feed P minus excreta P).

Ingredient selection can play an important role in decreasing excess dietary levels of most nutrients. This is the case with P. In most formulation systems inorganic sources of P are generally assumed to be 100% available by poultry. This belief is not correct since inorganic sources of P are clearly not 100% available. Inorganic sources of P vary greatly in availability (Weibel *et al.*, 1984; Potter *et al.*, 1995; De Groote and Huyghebaert, 1996; Van Der Klis and Versteegh, 1996). Monocalcium phosphate has a relatively higher bioavailability than dicalcium phosphate, with deflourinated phosphate having the lowest bioavailability regardless of reference. This is consistent among experimental trials done in the same research unit (Weibel et al., 1984) as well as among researchers (Weibel *et al.*, 1984; Potchanakorn and Potter, 1987; Potter *et al.*, 1987; De Groote and Huyghebaert, 1996) and bioavailability assays (Potter *et al.*, 1995). Researchers have found that the experimental conditions under which P availabilities are determined affect absolute P availability results (De Groote and Huyghebaert, 1996) and thus commercial application of these data must be done carefully. This can be explained, in part, through decreases in seed endogenous phytase activity brought about by enzyme inactivation due to the heat associated with pelleting. The extensive use of absolute P bioavailabilty data (CVB, 1994) in commercial feed formulation in Europe should be questioned and perhaps a relative bioavailability system should be applied instead (De Goote and Huyghebeart, 1996). Data presented by Van Der Klis and Versteegh (1996) demonstrates that nonphytate P and available P are not synonymous. These authors found that of the total P in corn, 24% was nPP but 29% was available to broilers. Similarly, of the total P in SBM, 39% was nPP but 61% was available to broilers.

Actual P and phytate P content in different ingredients vary between different references (NRC, 1994; Van Der Klis and Versteegh, 1996; Nelson *et al.*, 1968). Data are still limited as to the variability in phytate P content within an ingredient and how soil and environmental factors may affect this content (Cossa *et al.*, 1997). Work done by Cossa *et al.* (1997) showed, in 54 corn samples, a total P content of 3.11g/kg on a dry matter basis and reported a standard deviation (SD) of 0.28 with low and high values of 2.55 and 3.83 g/kg, respectively. Average phytate P was 2.66 mg/kg (SD of 0.34) with low and high values of 1.92 and 3.54 g/kg DM, respectively. These researchers found no apparent differences between locations and early, medium and late varieties of corn on the phytate P content of the corn. There is also limited information on potential variability in the availability of phytate P (Van Der Klis and Versteegh, 1996; Cossa *et al.*, 1997) within an ingredient and on how diet manufacturing process may affect this availability (De Goote and Huyghebeart, 1996).

Another strategy to maximize P retention from feeds is the selection of plant-based ingredients. New plant genotypes are being developed that contain lower levels of phytate P, as is the case in the new high available phosphorus (HAP) corn (Stillborn, 1998). This new genotype contains the same level of total P as normal corn varieties. In HAP corn only 35% of the total P is phytate P versus 75 to 80% in other corn varieties. Chick studies have shown that the P in HAP corn is indeed more available (Kersey *et al.*, 1998; Huff *et al.*, 1998).

Other key ingredients are currently being selected for high availability of P. Soybean phytic acid content could be reduced (Raboy and Dickinson, 1993) with a concomitant decrease in PP from 70% to 24% of total P through breeding efforts (Raboy *et al.*, 1985). Another strategy being implemented is the incorporation of fungal phytase gene(s) into plants such that phytase is expressed in the seed at high levels (Stillborn, 1998). Results from chick trials (Denbow *et al.*, 1998) showed that soybean meal with phytase transgenically inserted and added supplemental phytase were effective in improving PP utilization. Processing is still a concern in terms of inactivation of phytase regardless of how it is added to the diet. Post-expansion and/or pelleting application of exogenous phytase to feed can be done (Aicher, 1998) thus avoiding heat inactivation of the enzyme. This would not be possible with transgenically incorporated phytase. Practically, the use of new ingredients in commercial diets poses some challenges. New ingredients must be identified from planting to actual incorporation into diets. The logistics and economics of accomplishing this are still being worked out. The simplest solution so far is for feed manufacturers to contract fields for planting specific genotypes. This solution leaves some of the logistical and economic challenges unanswered. In a feed mill, bin space for ingredients is always at a premium and thus new ingredients would displace other ingredients.

NIR technology for quick determination of protein, fat, and fiber exists and has been in place in some commercial mills in the U.S. for several years. Application of NIR for digestable and total amino acid predictions has been developed (van Kempen and Simmins, 1997, Ruiz *et al.*, 2000) but so far it is not used extensively in US commercial mills. Other potential applications for NIR are determinations of organically bound Ca and P and determination of feed mixing uniformity (Mendez *et al.*, 1999). This technology has the potential to allow for feed formulation based on real time ingredient nutrient content beyond protein, fat, and fiber and thus closer formulation, under commercial mills situations, to actual requirements. This would result in smaller formulation safety margins.

PHOSPHORUS REQUIREMENTS

There is limited information on the P requirements of the broilers of today (NRC, 1994; Van Der Klis and Versteegh, 1996; Van Der Klis and Versteegh, 1997a) and no conclusive values have been established apart from those published by NRC (1994). The values proposed by NRC (1994) are recommended levels and reflect only information published through the peer review process up to 1983. Thus, it does not include levels used with success commercially or reflect the changing needs as broilers are selectively breed. NRC (1994) recommendations for nPP from hatch to 3 weeks of age appear to be well supported both under controlled experimental conditions as well as under commercial conditions. It is in the grower and finisher phases that NRC (1994) recommended levels for Ca and nPP exceed those used successfully in the field and shown to be adequate under experimental conditions (1992; Waldroup, 1998, Angel *et al.*, 2000a, Angel *et al.*, 2000b, Dhandu *et al.*, 2000, Ling *et al.*, 2000). Although NRC (1994) recommends a level of nPP of 0.30% from 42 to 56 days of age, commercial use levels during this age period (42 to 50 days of age) can be 0.17% or lower. Establishing minimum adequate levels for nPP under defined conditions is a necessity if one is to maximize the effect of feed additives in decreasing excreta P.

It is imperative that certain factors be defined when requirements are being determined. The factors that most affect P requirements are dietary Ca level (and Ca:P ratio), level and type of vitamin D in the diet, and amount of PP in the diet (Van Der Klis and Versteegh, 1997a; Van Der Klis and Versteegh, 1997b). Plant P in the diet should be at least defined by analysis as total P, and PP. Age (Van Der Klis and Versteegh, 1997b) and strain of birds also have an effect on P requirements. The more closely diets are formulated for poultry of specific ages, the lower the P excretion will be. Phase feeding systems should be implemented that maximize, within economic and logistical constrains, the number of feeding phases.

Preliminary Results on Phosphorus Requirements in a Four Phase Feeding System

Several trials have been done at the University of Maryland to determine more accurately the nPP needs of broilers in a four phase feeding system (Angel *et al.*, 2000, Angel *et al.*, 2000b, Dhandu *et al.*, 2000; Ling *et al.*,2000). The four phases studied were: starter, hatch to 18 d of age; grower, 18 to 32 d of age; finisher, 32 to 42 d of age; and withdrawal, 42 to 49 d of age.

This research has shown that nPP can be reduced (versus average commercial usage levels) by 5% in the grower diet and by 15% in the finisher diet without affecting bone strength or performance. Withdrawal phase nPP levels can be reduced by 40%. Requirements for all phases need to be confirmed under commercial conditions. A study was done to determine the effects of decreasing the level of nPP in the diet of broilers in the grower, finisher, and withdrawal phases on bone breakage at the processing plant. Results show that 0.45%, 0.36%, 0.18% and 0.14% nPP in the starter, grower, finisher, and withdrawal phases, respectively, resulted in no increase in the number of birds with broken wings or legs at processing versus birds fed industry-average nPP levels. The commercial levels tested were 0.43, 0.36, 0.32, and 0.28% nPP in the starter, grower, finisher, and withdrawal phases, respectively.

Having more accurate nPP requirement information has a profound consequence in terms of P nutrient management. Given the results to date, we can potentially see a reduction of at least 10% in the amount of nPP we feed broilers. This would mean at least a 10% decrease in litter P. Having more accurate P requirement information will also allow us to more fully use feed additives, such as phytase, to decrease P in poultry litter.

Feed Additives that Maximize Phosphorus Retention

Poultry diets contain plant seed-based ingredients and a high proportion of P from seeds occurs as PP. Phytate chelates other minerals and binds to proteins and starches making them unavailable to birds. Extensive information is available on phytate and phytase (Kornegay, 1998, Nelson, 1967). Phytase and factors affecting its activity and efficiency have been extensively discussed (Nelson *et al.*, 1971; Simons *et al.*, 1990; Biehl *et al.*, 1995; Ravindran *et al.*, 1995; Van Der Klis *et al.*, 1997; Mitchell and Edwards, 1996; Van Der Klis *et al.*, 1997d; Kornegay, 1998) and thus, the focus in this section will be on the potential use of several feed additives ("cocktails") together.

Work done by Zyla *et al.* (1997) demonstrated that, under *in vitro* conditions simulating turkey intestinal conditions, the use of an enzymatic "cocktails" could release 100% of the PP contained in a corn-soy diet. The enzymatic "cocktail" contained a microbial phytase, acid phosphatase, acid protease, citric acid, and *A. niger* pectinase. From their work, it was clear that phytase alone could not release 100% of the PP present in a corn-soy diet. These researchers (Zyla *et al.*, 1995a; Zyla *et al.*, 1995b) found that phytase preparations (both commercial and laboratory derived sources) are not "pure" phytase and that they generally contain, acid phosphatases, acid proteases, and pectinase. These researchers found a negative correlation between purity of the phytate preparation and its capacity to release PP. Only when the right balance between the different components of the "cocktail" was obtained did 100% release of PP from the corn-soy diet occur.

To determine whether the enzymatic "cocktail" developed *in vitro* would work as effectively *in vivo* an experiment was done with 7 to 21 day-old turkeys (Zyla *et al.*, 1996). These researchers fed a corn-soy-meat meal diet with a Ca level of 1.2% and an aP level of 0.6% which met NRC (1994) recommendations, a positive control diet containing 0.42% aP and 0.84% Ca (positive control), and diets containing 0.84% Ca and 0.16% aP to which enzyme preparations (phytase (1000 u/kg of diet), an enzyme cocktail, or *A. niger* mycelium) were added. They found P retention from 31.0% in the NRC (1994) based diet, 42.8% in the positive control diet, 66.8% in the diet with phytase, 77.0% in the diet with the enzyme "cocktail", and 79.5% in the diet with the *A. niger* mycelium. Addition of acid phosphatase, pectinase, and citric acid to phytase (enzyme cocktail) also increased P retention ($P<.05$).

Other feed "additives" that need to be considered are vitamin D_3 and its metabolites. Not only does vitamin D stimulate P transport mechanisms in the intestine but it also appears to enhance phytase activity (Mohammed *et al.*, 1991). Vitamin D as well as its metabolites, 25-hydroxycholecalciferol and 1,25-dihydroxycholecalciferol ($1,25(OH)_2D_3$) (Edwards, 1993; Mitchell and Edwards, 1996) have been shown to enhance phytase activity. $1,25(OH)_2D_3$ and phytase appear to act in an additive manner rather than a synergistic one (Mitchell and Edwards, 1996; Biehl *et al.*, 1995). Mitchell and Edwards (1996) found that the addition of $1,25(OH)_2D_3$ and phytase could replace 0.2% of the inorganic P addition in the diet in 21 day-old chicks. Phytase and $1,25(OH)_2D_3$ alone could each only substitute for close to 0.1% of added inorganic P. Vitamin D metabolites have a clear role in improving P retention and their use in conjunction with other feed additives (phytase and/or enzyme "cocktails") is indicated.

PRELIMINARY RESULTS ON THE USE OF A *LACTOBACILUS*-BASED PRO-BIOTIC IN BROILER FEED ON PHOSPHORUS AND NITROGEN CONTENT OF LITTER

Some *lactobacillus*-based pro-biotics have been shown to improve growth and feed conversion in poultry. Research was done to determine if broilers fed low P, Ca, and protein in a diet containing a *lactobacillus*-based pro-biotic would perform similarly to broilers fed a control (commercial levels of P, Ca, and protein) diet. Excreta P and nitrogen (N) were analyzed to determine the effect of adding the pro-biotic. Data from the two studies (Angel, *et al.*, 1999a; and Angel *et al.*, 1999b) indicates that broilers fed control diets (grower; 19.3% protein, 0.37% nPP: finisher; 17% protein, 0.30% nPP) and low nutrient diets (where protein was decrease 12% and nPP and Ca 18%) from 18 to 28 d (grower) and 28 to 42 d (finisher) of age had similar performance when the pro-biotic was included. In the absence of pro-biotic, broilers fed the low nutrient diet had a poorer ($P<.05$) performance than those fed the control and those fed the low nutrient plus pro-biotic. Tibia breaking strength and ash were affected in a similar manner as performance. Birds fed the low nutrient diets with pro-biotic were able to overcome the deficiency exhibited by birds fed the low nutrient diet with no pro-biotic.

Nutrient retention was improved when the pro-biotic was added to the diet. P retention was 22% higher and N retention was 10% higher in birds fed the low nutrient plus pro-biotic diet than in the birds fed the control diet. The addition of the pro-biotic to the low nutrient diet allowed broilers to grow as well as those fed a control diet in part because they were more efficient in retaining nutrients. Feeding a low nutrient diet with pro-biotic decreased excreta P by 33% without adversely affecting performance or bone strength. This decrease would also be seen in litter P content.

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PRACTICAL ISSUES AND OPPORTUNITIES IN ENZYME APPLICATION TO FEED

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Although some plant geneticists may disagree, it appears that the practice of adding enzymes to poultry feed is here to stay. The primary reasons for this include: 1) remaining competitive in the market place through the use of alternative feedstuffs during times of high corn/soy price, 2) Working with key suppliers of corn and soy for various rotational crops, 3) maximizing genetic potential of birds while using alternative feedstuffs, 4) ensuring minimal nutrient output into the environment.

Feed enzymes are used in four major areas: 1) removal of anti-nutritional factors, 2) increasing digestibility of existing nutrients, 3) increasing digestibility of non-starch polysaccharides (NSP's) and 4) supplementing host endogenous enzymes (Classen, 2000).

There will continue to be competition between plant geneticists and enzyme producers. Current feed mill bin space availability and grain identity preservation issues may limit, in the near term, the number of possible new ingredients to inventory at a feed mill. However, heat instability is the real challenge for enzyme manufacturers. Method and consistency of application of the enzymes to the feed is absolutely critial to success.

ENZYME SUPPLY

The variety of enzyme products on the market is large and growing rapidly. There are enzymes for small grain usage (barley, wheat, milo), enzymes for animal by-products, enzymes for corn and soy and there are enzymes to break down the phytate molecule in plants. Enzymes come in both dry and liquid forms.

Design of your enzyme addition system is important from the type of containers your enzyme should come in, how and where the containers should be stored, the stability of the enzyme and consideration of what should happen with any excess ordered, as normal amounts of shipment are in container quantities. Designing the "day-tank" for enzyme usage is an important consideration. Normal storage amount for the "day tank" is at least two days. Accurate measurement of the enzyme in the tank, at any time is critical and load cells are a must. Sight glasses on the side can assist in visible confirmation of level of enzyme in the "day tank."

Ensure that there are many places along the pathway, from your supply to finished feed, to sample both pure enzyme and enzyme/water mixture.

TEMPERATURE IS YOUR WORST ENEMY

Strong consideration should be given to where and when the enzyme is to be stored. Failure to keep the enzyme in a warm location during the winter could result in the enzyme gelling up and clogging filters. Storage in the summer heat can shorten enzyme activity life.

In many feed mill installations, the addition of water or other carrier with an enzyme is mandatory to ensure accurate application of the enzyme on the feed. Failure to insulate or heat trace your lines in cold rooms could result in the enzyme mixture never being applied to the feed or not being applied accurately.

CONSISTENT CLEAN WATER AND DRY AIR SUPPLY ARE IMPORTANT

Ensure that incoming water supply to be mixed with the enzyme is under constant pressure. Another "day tank" just for the water is another important consideration to ensure consistency of water pressure. The use of hard water is unacceptable, filters and/or water may be necessary. As with the enzyme, the water supply must be kept from freezing to ensure proper dilution and distribution of the enzyme to the feed.

Consistent flow of dry air is important for a consistent spray pattern of the enzyme on the feed. Air filters as close to the application point as possible need to be installed to allow removal of moisture and other contaminants.

ACCURATE DRY FLOW MEASUREMENT IS KEY

The accurate measurement of dry finished feed flow prior to enzyme addition is the foundation for accurate enzyme application. If dry flow measurement is incorrect, the entire process will be negatively affected. Both gravimetric and volumetric measurements are currently available. Surge bins are critical to maximize the accuracy of any dry flow device.

BLENDING SCREW DESIGN

After liquid application, a blending/mixing device will enhance distribution. The most common is a blending screw. There can be many variations in design of a blending screw. How long and wide should it be? What should be the distance between flights of the screw? Are bars needed between the flights to "fluff up" the feed to ensure complete enzyme coverage?

SAFETY IS PARAMOUNT

While each enzyme should have a Material Safety Data Sheet, enzymes can affect human health if not used properly or if inhaled as a straight enzyme. Dilution of the enzyme with water is important from a human health standpoint. Full awareness of when the enzyme is being applied to the feed through the use of easily observed lights is an important safety consideration in the feed mill. Use extreme caution if atomizing an enzyme without a carrier.

COMPATIBILITY OF CONTROL SYSTEMS

To ensure accurate enzyme application, it is essential that the batching and/or pelleting process control system communicate accurately with the enzyme application system. The liquid application can also have its own stand alone control system. Each feed mill installation is unique, both options can be successful with proper standard operating procedures (SOP's) in place.

ENZYME APPLICATION

Although there may be more than one location where the enzyme can be applied, it is important that the dilution of the enzyme with water be done as close to the application point as possible. Easy access to the spray nozzles is a good idea for routine observation and maintenance.

Critical decisions need to be made as to where the enzyme should be applied to the feed. Should it be added before or after the fat application? Both have been successful. What is the best spray pattern necessary to ensure the lowest coefficients of variation in enzyme application.

Generally speaking, coefficients of variation (CV's) of enzyme application tend to improve with greater mixing of the liquid enzyme and the finished feed. Improvements in CV's have been seen from the mixing screw to load out to the bin on the farm to the feed hopper in the poultry house. Sampling finished feed with applied enzyme immediately after blending/mixing is recommended to determine how the feed mill is doing in terms of enzyme application. Quantity of enzyme as well as consistency of application are equally important. Good field performance has been seen with 15-20% CV's.

WHAT IS THE DEFINITION OF SUCCESS?

For a poultry integrator, success for enzyme addition to the feed is measured by no visible performance loss (weights, feed conversion, leg problems, etc.) on flocks settled on the enzyme compared to prior to enzyme addition. With typical week-to-week biological variation, grower profile, etc., this is not always easy to do. The addition of wheat, barley and milo can come under intense scrutiny because the feed is not as yellow as it once was. Sometimes pellet quality in the feed mill can deteriorate with barley inclusion in particular.

In the case of phytase use in the integrated poultry feeds, it is the first time that nutritionists knowingly formulate diets that can be deficient in available phosphorous. Nutritionists have to completely depend on the accurate addition of the enzyme and have to depend on the enzyme activity to do what it is supposed to do in terms of making more nutrients available to the chicken, turkey or laying hen.

ENZYME ASSAY AND ACTIVITY DETERMINATION

Each enzyme has its own assay and mode of action. This has become an industry problem. Assay methodology is not uniform for a variety of reasons. Attempts are being made to standardize assay procedures which is an important first step. Because of the small quantity of enzyme in feeds as well as the possibilities of soluble inhibitors and enzyme binding to substrate can make complete feed levels somewhat suspect (Classen, 2000). As previously mentioned, the primary method of determining the quality of an enzyme product is biological testing under commercial feed manufacturing and animal production conditions.

PEOPLE ARE YOUR GREATEST ASSET

Teamwork is required to make everything come together. People from purchasing, research, nutrition, formulation, quality control, lab analysis, feed mill design and function as well as growout are all needed to make accurate enzyme addition a reality.

CONCLUSIONS

The practice of the addition of enzymes to animal feed is here to stay. Consistency and accuracy of addition of enzymes to the feed is essential to maximize animal performance, minimize input costs and minimize environmental impact. Carefully monitoring the finished feed dry flow mix, the temperature control of stored enzymes, the dilution and application of raw enzymes to the feed are all important components to ensure success in the use of enzymes to the feed.

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PERSPECTIVES ON NUTRIENT POLLUTION IN THE LAST HALF OF THE 20TH CENTURY

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There is currently much debate about sources of pollution, particularly nutrient pollution of surface and groundwaters. It frequently appears that everyone is quite confident everyone else is contributing far more than they are. The reality, particularly for nutrient pollution, is that we all are part of the problem and must be part of the solution. This paper offers a science-based perspective on nutrient pollution and how changes in technology, resource consumption and personal life style choices have accelerated nutrient pollution. I try to be objective but state my policy preferences for sustaining agriculture and addressing nutrient pollution.

Humans have clearly had some impact on the environment throughout their existence. This impact increased as we moved from hunter-gatherers to a less nomadic agrarian society, centered around villages.

The industrial revolution of the late nineteenth and early twentieth centuries started a period of rapid population growth and concentration in urban centers that continues today. This accelerated environmental degradation, particularly near urban centers. Mechanization of agriculture allowed cultivation of much greater expanses of land than ever before which resulted in severe erosion that impacted soil productivity. Sedimentation caused major physical changes in rivers and lakes and destroyed or altered habitat for many living resources. Most of these impacts were acute and somewhat localized.

There were also localized "hot spots" resulting from disposal or misuse of toxic compounds by industry. From before World War II through the 1960s, there was widespread application of toxic compounds in pesticides with little evaluation of ecosystem or human impacts. The effect of DDT and its metabolites on raptors (and other near shore birds) provides one well documented example of an unintended consequence of using compounds without evaluating impacts.

It was not until well after World War II that nutrient pollution was considered a major water quality issue. Nutrient pollution, and its consequences (low dissolved oxygen and poor water clarity) are now deemed the leading cause of degradation of lakes, rivers, streams, and coastal waters (US EPA, 1999). Nutrient pollution of surface waters causes excessive growth of algae and is commonly termed eutrophication, or "overenrichment." The most common problem is low or no dissolved oxygen as a result of the oxygen demand generated by decaying algae. The algae can also reduce water clarity thus making it difficult for underwater grasses to grow in the shallows. Nutrient pollution manifests itself in slow-flowing coastal areas, lakes and reservoirs and portions of some rivers.

The rapid growth in nutrient pollution that began after World War II was largely the result of major changes in science and technology, and lifestyles, particularly in the United States. New technologies meant we were able to create large quantities of readily available fertilizers from previously inert materials. It also meant we could generate new materials such as nylon that use nitrogen rich amino acids as a primary building block. New cleansers and detergents made shirts and dishes cleaner than ever, but contained large amounts of phosphorus. The ability to convert "inert" nutrient compounds into bioavailable forms for many uses began to grow exponentially.

Agriculture also began a change that has accelerated in the last two decades. Specialization, intensification, and concentration increased dramatically. In animal agriculture, particularly poultry, production concentrated into major production centers or regions.

The lifestyle change was no less significant. The combination of new fertilizers, improved genetics and rapid mechanization meant that more food could be grown with fewer people. Rural areas, that had lost population due to industrialization and the Depression, saw an ever greater migration to factory and office jobs in the city. Many people did not stay in the city but moved to "the new place" between the city and the country, the suburb. Nonproductive consumption of both land (for housing and commercial uses) and natural resources accelerated to per capita rates unprecedented in human history.

PERSONAL NUTRIENT POLLUTION

People frequently ask "what is the source of nutrient pollution?" The answer is simple: people and their consumption choices and habits. One of the major issues facing the Chesapeake Bay is the rapidly expanding population due to people moving to the watershed, not childbirth. Each person brings with them a nutrient load that I term their personal nutrient pollution. There are obvious personal nutrient pollution sources like sewage and how we fertilize our home landscapes. A little less obvious are the products we use in our home. Ammonia as a cleaner and phosphate containing detergents are good examples.

Air pollution from our cars (and lawn mowers) is a major source of nitrogen pollution of water bodies. We own more cars and drive more miles every year with all projections for that trend to increase. Sports utility vehicles (SUVs) perhaps best illustrate our attitude about pollution in general (or nutrient pollution specifically). These large, gas-guzzling vehicles meet the qualification of a "truck" and are thus excluded from "fleet average" gas consumption requirements designed to improve energy efficiency in the US. These vehicles also have different pollution control requirements than automobiles. As a result, our most popular type of vehicle is really a "loophole" for car manufacturers to avoid environmental requirements. Belatedly, it appears the loophole will be closed.

We generate substantial nutrient pollution at the marketplace. Whether it is food waste, packaging wastes or the bright lights and signs, many types of nutrient pollution occur at the market place. Nutrient pollution also occurs at the workplace. It can be through electrical consumption, production inefficiencies or wasting office products (eg. paper).

Finally, we all demand certain levels of community service that generate nutrient pollution. Highway and street construction, ditches, stream channeling, school buses, schools and county seats are all sources of nutrient pollution that are there for us.

LAND CONSUMPTION

There is another type of consumption, that nearly all groups agree is detrimental to the environment: land consumption. The per capita rate at which we convert land from a resource use of forestry or agriculture to a nonproductive commercial or residential use has been steadily increased since World War II. A few places are trying to slow the rate of land conversion but few are succeeding and none have stopped the loss of resource lands.

As of today, once we develop land, we only know how to make it more developed. It is lost from the resource base "forever." I argue with my forester and environmental friends that they should work diligently to preserve both farm and forest land. There is a "purist" view that we should preserve forest land and let them develop the farm land. "Farm land is a major source of nutrient pollution while forests are our least polluting land use. Farm land is better than developed land but it can be sacrificed to protect forest."

This argument is not necessarily based on false information but it would seem to be terribly short sighted. I argue that we must preserve as much farm land as possible for two good reasons. First, as long as land is in agriculture, it can be converted to forest, if society deems that appropriate. If we are producing too much food, we can selectively remove small to large amounts of land from production (a different version of the Conservation Reserve Program) and plant it to trees or other less polluting resource uses. We can selectively remove land that provides the greatest environmental benefit and/or are marginal for crop production. We may even wish to remove large tracts of agricultural lands in certain important watersheds.

The second reason to preserve both forest and farm land is that, globally, as many environmental nay-sayers like to point out, we must produce enough crops to feed a growing world. The more farm land, particularly prime land, that we preserve from development, the less marginal land must "be brought under the plow" and alternatively, the more forest/native lands that can be preserved.

I do not subscribe to the notions being put forward that we must feed all the world on an American diet, or that our rates of food (or resource) consumption can continue to increase at present rates. Residents of the United States currently represent less than 5% of the global population but are responsible for about one quarter of the consumption of natural resources (including food). I also do not believe that all alternative or "sustainable" agricultural production systems will necessarily result in drastic yield reductions.

I clearly disagree with the assumptions of those who argue that we cannot have both environmental protection and an agricultural production system to feed an expanding population. The global glut of agricultural products also suggests these assumptions are not valid in the short term. However, it must be recognized that global population will expand and agricultural production must meet whatever the food (diet) and fiber needs are for that population to exist reasonably.
The best way to be ready to feed that population while addressing environmental concerns, including nutrient pollution, is to minimize the loss of all resource lands, including farm land.

ENVIRONMENTAL ETHICS AND RESPONSIBILITY

The popularity of SUVs, discussed earlier, raises the question of personal/corporate ethics and responsibility as opposed to government regulation. During the last 30 years, it has been far too common for those who decry government regulation to also exploit every loophole available to avoid addressing environmental issues.

It can be argued that many individuals and corporations have used government requirements as a substitute for ethics and responsibility. If the government does not say it cannot be done, then it is acceptable. This is usually rationalized by the need to remain competitive and to produce at the lowest possible unit price. What is not explained is that we are not paying the real cost of many products, including food, but are avoiding, externalizing and subsidizing costs through environmental (and social) government programs and corporate decisions.

It is clear to me that individuals and corporations must act ethically and accept responsibility for environmental actions beyond government dictates. If not, the dire prognostications about unsustainable rates of resource consumption and impacts of (nutrient) pollution on our ecosystem may prove true.

We must recognize our role as a member of the ecosystem and our ethical responsibility to respect the air, water, soil, and biotic members of that ecosystem. Aldo Leopold (1949) described this as a "land ethic." Leopold said that "a land ethic changes the role of *Homo sapiens* from conqueror of the land-community to plain member and citizen of it. It implies respect for his fellow-members, and also respect for the community as such."

Somewhat ironically, Leopold's essay was written at the beginning of the resource consumption binge we are still on today. It is equally interesting that Leopold, who died in 1948 prior to publication of *The Land Ethic* in *A Sand County Almanac*, has become so widely popular in the conservation community in the last two decades. Perhaps it has taken thirty to fifty years to recognize the lack of respect given to water, air, soil, and biotic as other rightful members of the "land-community."

AGRICULTURE AND NUTRIENT POLLUTION

Research conducted during the last three decades have consistently suggested substantial losses of nutrients from agriculture to surface and ground waters (Logan, 1990). The increase in nutrient impacts appears to relate to both increases in fertilizer use and intensification and concentration of animal agriculture. In Iowa, Libra *et al.* (1987) found a good relationship between increases in fertilizer and manure use and groundwater nitrogen discharged from Big Spring.

The US Geologic Survey synthesized all monitoring data in the Chesapeake Bay watershed (Langland *et al.*, 1995). This included analysis of 126 sites for which nutrient load data was available for more than three consecutive years. They found a strong positive relationship between high nitrogen and phosphorus loads and the amount of agricultural lands. Estimates of nitrogen loads to the Gulf of Mexico by the Mississippi River indicate that agriculture is the dominant source (Giattina, personal communication).

The abundance of data indicating that agriculture is a major source of nutrient pollution of surface and ground waters should not be a scientific surprise or an indictment of the American farmer. We have seen an enormous increase in the use of nitrogen and phosphorus in agricultural production in the last 50 years. During the same period, there has been intensification and concentration of confined animal operations, particularly in poultry.

Basic principles of plant growth, and economics, have taught us that as we approach maximum biomass production (crop yield), we get small yield increases for each additional unit of nutrient input. In fact, most still advocate that we increase fertilizer application as long as the revenue generated from yield increases is greater than the cost of the additional fertilizer.

I am not prepared to argue with the law of diminishing returns but I will argue that there may be more costs, particularly environmental, than just the cost of the additional fertilizer. We have clearly been aiming for yields on the "flat" upper end of the yield response curve. Plant nutrient use efficiency is not very high so substantial quantities of nutrients are left in the environment. This is further complicated by the "no risk" philosophy regarding nutrient use espoused by both the fertilizer industry and land grant university. This approach argues that since nutrients are inexpensive and crop yields are unpredictable, we should always apply enough nutrients to produce maximum possible yields. There are both economic and environmental consequences to this approach. Obviously, there will always be excesses in the environment following this philosophy. Economically if nutrients are purchased, or valued, we always lose money on over application of nutrients to avoid any risks of losing money to nutrient-limited yields.

It can be correctly stated that excess nutrients in the environment (in soils), do not necessarily result in nutrient pollution. However, at least in a humid climate, we farm in a naturally leaky system. Nitrogen, dominantly in the nitrate form for plant uptake, is highly mobile and leaches below the root zone and eventually through groundwater to surface waters. Many transformations could occur between root zone and river but the elevated levels of nitrogen in streams flowing from agricultural watersheds suggest much of it is surviving the trip.

Phosphorus was considered the easy nutrient to control until the last two decades. If we controlled erosion, we could control phosphorus loss, since most phosphorus was attached to sediment. Research in the 1970's (Sharpley *et al.*, 1978) began to suggest that, at levels above agronomic optimum, substantial amounts dissolved phosphorus could be lost in runoff.

As the research base expanded, it became apparent that we would need to limit nutrient applications based on phosphorus. This was particularly critical for animal manures, where we were just succeeding at getting farmers to base manure application on nitrogen which resulted in over application of phosphorus. Poultry scientists were advised of the probability of the change to phosphorus based nutrient management a decade ago (Simpson, 1991).

There is now extensive data indicating that phosphorus losses to surface waters increase with increasing soil phosphorus levels (Sharpley, 2000). Areas receiving animal manures over a long period are most likely to have extremely high soil phosphorus levels. Thus, in our naturally "leaky" system, applications of both nitrogen and phosphorus at "maximum yield" levels result in substantial nutrient losses to surface waters.

Why is this not an indictment of the American farmer? To the extent that he did what science and society told him to do, it is. Society told the farmer we wanted a cheap, high quality and abundant food supply produced by a few people. Society did not emphasize (or perhaps recognize) environmental impacts until recently but now wants the farmer to address the environment without affecting the other three. A colleague, who works for a poultry processor, likes to say "pick three, any three, but not all four" with the implication that the environmental component cannot be one of the three. I argue it must be one of the four or we will eventually pay the true ecologic and economic costs of our "cheap" food policy. The real question is how cheap is too cheap?

Agricultural scientists provided the best knowledge available for the farmer to meet society's challenge. We recommended nutrient rates that would not limit yield. Concentration and intensification were seen as progress by the scientific community with most public agricultural research geared to promote both. Much research had a principal focus on maximizing yields with no evaluation of environmental impacts. It did not always consider the economic well being of individual farmers and failed to evaluate the impacts of low profit margin agriculture on the net worth of rural communities. The farmer has responded well to science and society's direction but has found himself with declining income, influence and respect, and increasing blame for environmental concerns, particularly nutrient pollution.

It is important to recognize that farmers had adopted many practices to reduce both erosion and nutrient pollution. Farmers were given financial and technical incentives to overcome the costs of such practices. For the most part, only practices that had no positive impact on income were recommended. It was difficult to ask a "downsizing" group with limited income potential to take on costly new practices. I am afraid that we may have reinforced an observation Aldo Leopold (1949) made more than 50 years ago: "In our attempt to make conservation easy, we have made it trivial." It is now difficult to ask farmers to meet some very challenging demands, particularly in this time of low prices and surplus commodities. Balancing nutrient use based on phosphorus and finding alternative uses for excess manure must be considered a part of the true costs of our food production system.

Ultimately, the costs must either be subsidized or paid directly by consumers. Environmental impacts are one of many concerns being raised about our "cheap food" policy that are likely to be debated during development of the next farm bill. Perhaps we need a formal national food policy that includes environmental impacts. I feel we must address agricultural nutrient pollution but, as we in Maryland know, it is difficult to do on a state by state basis.

CONCENTRATION AND INTENSIFICATION IN ANIMAL AGRICULTURE

There has been tremendous concentration of confined animal production, particularly poultry, in regional centers during the last fifty years. The number of animals per operation has also grown dramatically. Data adapted by Coffey (1996) shows a relatively constant number of hogs produced from 1900 to 1993 but the number of farms raising hogs declined by nearly 20 fold. Poultry has seen major growth in total production and was the first animal industry to concentrate production in relatively small geographic regions. The concentration is driven by integration and efficiencies of locating production near processing and feed mill facilities.

Regional concentration has provided production efficiencies but it has also created regional nutrient imbalances. For example, a large part of the grain fed to poultry on Delmarva is grown outside the production area. The result is that we have a surplus of waste nutrients in litter that were imported in feed grains. It may be possible to use all the litter for crop production on all of Delmarva, not just the poultry region, if application is based on nitrogen. It is clear that there will be substantial excess litter when we go to phosphorus based applications. This appears to be common in concentrated production.

Regional nutrient imbalances have principally developed since World War II. As farms have become less diverse, we have substantially changed the nutrient cycle from a more local, farm based cycle to a distant one directional path. Lanyon (2000) suggested that "the supply of balanced nutrients from off-farm following World War II shifted farm organization from an emphasis on biological feedback to other considerations, primarily economic incentives based on market transactions, and encouraged specialization in agricultural production."

If waste nutrients were of sufficient value to return to the crop production region, there might not be a problem. If there were local high value alternative uses, there would be no problem. However, most animal waste nutrients are used on cropland near the production areas. High nutrient levels are common in both surface and ground waters in these areas (Logan, 1990, Langland *et al.*, 1995).

Thus it is apparent to many in and out of agriculture that regional nutrient imbalances are an issue in concentrated animal production areas. Keith Rinehart (1996), recently retired poultry executive and nutritionist, known for his objectivity, said "Water pollution is the most damaging and widespread concern in regard to production agriculture, including the poultry industry... While the individual bird has become more efficient in the conversion of nutrients to meat or eggs, the large increase in animal units has led to an overall increase in environmental burden." Regional nutrient imbalances are an environmental concern because we have not fully included the cost of waste management as part of the cost of animal production..

SUMMARY

Technology and life styles have combined to immensely increase nutrient pollution in the U.S., and the developed world, during the last fifty years. Population growth and development and increased per capita resource consumption are the long term factors that influence nutrient pollution.

Modern agricultural production systems are major sources of nutrient pollution due to both their domination of the landscape in many watersheds and inefficiency of nutrient use in a "leaky" natural system. Concentration and intensification of animal production has created on-farm and regional nutrient imbalances. Monitoring and soil test data suggest the regional production centers are substantial sources of nutrient pollution.

Farmers have implemented many practices to address sediment and nutrient pollution. However, these practices must be acceptable to farmers within current production systems and economic conditions. The costs of waste management and environmental control have not been fully included in the cost of our food system. It is difficult to extract these costs from farmer/producers without passing these costs up the food system.

Every person who lives in or visits a watershed contributes to nutrient pollution of its waters. We also each contribute to nutrient pollution through lifestyle choices and resource consumption. Agriculture is just one part of the problem, and solution, for nutrient pollution but an important one. It is critical that we work to address water quality issues so we can expect the same responsibility from all others.

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CURRENT CONDITIONS AND FUTURE NEEDS OF PROCESSING AND FURTHER PROCESSING INDUSTRIES

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In 1998, the poultry industry produced a total of 33,667 million pounds with sales of greater than $30 billion dollars and a water usage of more than 88.7 billion gallons. Food safety, environmental and other regulatory issues along with profitability are among the key concerns for poultry processing and further processing industries for the present and into the 21st Century.

CURRENT CONDITIONS

Cleaner Technologies

The focus of these concerns is related to Cleaner Technologies that link environmental and food safety issues. Cleaner Technologies are any system or process that reduces adverse effects on the environment during the manufacture of food products by increasing yield and/or decreasing the amount of water used, the amount of wastewater discharged, the amount of pollutants in the wastewater, the amount of solid waste generated, or the pollutants emitted to the atmosphere, while ensuring sustainable development. The development and adaptation of cleaner technologies in the poultry processing industry is more complicated than in other industries in that there is a need to help assure a safe food supply while reducing the existing or potential impact on the environment.

Food Safety

Detection of Foodborne Pathogens: Foodborne pathogens rank at the top of the list in terms of food safety; however, physical and chemical hazards also have to be controlled. Methods for detecting important foodborne pathogens such as *E. coli* O157:H7, *Salmonella, Campylobacter,* and *Listeria* are variable and not applicable across food matrices. Manufacturers of detection systems are trying to meet the industry' need for fast, reliable and cost effective analyses.

Hazard Analysis Critical Control Point (HACCP): HACCP implementation has significantly increased water use and water use ratios (gallons per bird). Prior to HACCP implementation in 1998, some broiler plants were using less than 4 gallons per broiler. After initial implementation of HACCP in 1998, average water usage increased to 9.5 gallons per bird. A similar trend has been observed in processing other poultry species. Much of this additional water use appears to be directed at resolving problems with current processing procedures that allow fecal contamination and interventions used to address this problem. Intervention strategies utilized include washers, irradiation and antimicrobials.

Sanitation: Sanitation is one of the largest water users and wastewater sources in a processing plant. A systematic approach to sanitation should be established to ensure proper sanitation is achieved with minimum water use. Employee understanding of their role and an appreciation for food safety, the need for water conservation and pollution prevention is essential.

ENVIRONMENTAL

The success or failure of some companies may not depend solely on their bottom-line profitability but on their ability to manage water usage and wastewater treatment issues. Environmental issues have an increasing impact on profits and balance sheets and the impact differs significantly from one company to another.

Water Conservation: Processors must look to increase the yield per unit of water used and water must be managed for maximum yield. The less water used, the less to be treated for disposal. These are simple concepts yet are frequently overlooked.

Pollution Prevention: Pollution prevention (P2) is the use of materials, processes or practices that reduce or eliminate the creation of pollutants or wastes at the source. It also includes practices to reduce the use of materials, energy, water and other resources. P2 is an effective approach to environmental protection when compared to other forms of waste management. "Pollution prevention makes economic sense. We'll save money on raw materials, we'll have less waste to dispose of, and we'll protect American citizens and our own environment" (Carol M. Browner, EPA Administrator).

Water Reuse/ Renovated Process Water: Two swine processors have effectively utilized renovated process water resulting in approximately 35% reduction in water use and wastewater discharged and significant annual savings. This has not been extended into the poultry industry. Possible uses for renovated process water in poultry processing include inedible water flume system, scalders, pickers, blood room and blood collection system and receiving bay cleanup. Additional potential uses are cooling towers, vacuum pump seals, initial cleanup and boiler feed. There are at least two systems that are being utilized to recycle process water streams using ozone.

Fats, Oils and Grease (FOG)/ Sanitary Sewer Overflows (SSOs): Sanitary Sewer Overflows result in the spill raw (untreated) sewage and pose a substantial health risk and environmental challenge. SSOs can be the result of storm water infiltration; sewers too small; blocked, broken or cracked pipes; or a deteriorating sewer system. Consequences of SSOs include violation of water quality laws, increased civil penalties (up to $25,000), required publication and press release notices of discharges of untreated wastewater, an annual report to citizens of treatment works performance and extent of violations of water quality laws, and increased expense to the municipality. FOG can block sewers and require increased time and cost to treat wastes at the POTW. In North Carolina, approximately 90% of the SSOs are due to fats, oils and grease from food plants or food service operations.

Residue Disposal or Utilization: Increasing diversion of food residuals from disposal by identifying environmentally beneficial and economically viable uses is important. Current options for utilization include direct use as animal feed (including pet food), dry for animal feed, incinerate for energy, contact recoverers to dry and blend for animal food and spread for fertilizer. Virtually all of these materials decompose in landfills and contribute more to global warming than when composted. Food residuals in landfills are a major source of leachate formation that can lead to groundwater contamination.

Several new technologies have been introduced in the last several years. They are now being tested in several plants to prove their value and assure that pilot success can be replicated in the "real world". First, is the Novus CLARADIGM™ process for on-site separation of fat and solids from DAF floats. This system helps address the concern of hauling water to rendering facilities and then having to separate the fat and solids. Second, is the DuPont Specialty Chemicals Particlear™ that provides removal of suspended solids and dissolved material in aqueous streams using in-situ production of highly active silica microgel. This system was developed to help address the concern that renders do not want metallic salt recovered DAF floats and the concerns about using polyacrylamide and other flocculants for recovering fat and/ or proteins for feeding to animals that will ultimately be for human consumption.

Legal Liability: Some companies are facing or have faced lawsuits and potential multi-million dollar fines while others are trying to ensure that they are ready to address these types of issues if they arise. There is a trend towards environmental issues and regulatory enforcement actions are becoming much more prevalent.

FUTURE NEEDS

Food safety; environmental and other regulatory concerns; new technology; and global economic integration will continue to be critical issues for the poultry processors in the 21st Century.

Irradiation

Irradiation is one of the challenges for the near future. The primary challenge is to properly position and market irradiated products and gain consumer acceptance. The industry will have to educate consumers about the safety of irradiated products.

Water Use and Waste Management

The issues of water usage and waste management aren't ones that will disappear in the near future. How much water the industry uses and what producers and processors do with it after use will continue to be an issue. Industry is facing ever-more stringent local, state and federal regulations.

Total Maximum Daily Load Program (TMDLs): TMDL is an estimate of the maximum amount of a given pollutant a water body can assimilate without violating water quality standards. The Clean Water Act (CWA) requires states to identify waters not meeting water quality standards, set priorities for TMDL development, and develop a TMDL for each pollutant for each listed water. EPA will approve or disapprove State submissions. All 56 states and territories submitted lists in 1998 that included approximately 21,000 listed waters and approximately 40,000 TMDLs. TMDLs represent a potential concern to industry if non-point source loads cannot be reduced to allocated levels, point source allocations may need to be reduced and point source allocation can cause more stringent control and treatment requirements for discharge to POTWs.

Compliance and Liability: Efforts to protect creeks, rivers and lakes located around processing facilities have placed some producers and processors in a precarious situation. The key to future success is achieving a balance between operational needs and community demands. Companies must invest the time and resources to understand what they must do to remain in compliance with the law. Managers who do not take environmental considerations seriously will not be successful in the future and may even be treated as criminals.

Employee training: Employee training will continue to be a critical and a first step towards water conservation and pollution prevention. Employees that understand their role and how it affects their employment are more apt to follow suggested guidelines.

Sustainable Development

Sustainability has a goal of conserving irreplaceable resources and maintaining the environment for future generations. P2 has been around for decades; however, today the basic tenets of pollution prevention are the building blocks of sustainable development. Corporations have elected to lead the way in preparing for a sustainable future and can do so more efficiently than governments and legislation.

Management Systems: Many of the major international corporations are adopting environmental management systems (EMS). The intent is to insure that operational processes are consistent, that they are designed to achieve stated environmental policy and objectives, and that they represent a commitment to continued improvement of environmental performance. An EMS is important to businesses worldwide for the following reasons:

- ***Visibility***. Environmental performance is being given increasing attention.
- ***Requirement to do business***. Compliance with environmental standards may become a condition of doing business in a larger share of the world markets.
- ***Public pressure***. There is increasing public pressure for improved environmental performance and for open demonstrations that companies have heard the will of the people for greater corporate responsibility. A company's image and the acceptability of their products may be favorably influenced to the degree that they can demonstrate their adoption of acceptable environmental safeguards.
- ***Regulatory liability***. There are an increasing number of international initiatives, only voluntary in the United States, for companies to adopt management systems that provide a systematic approach to controlling environmental impacts.
- ***Sound business practice***. An EMS introduces more efficient business processes to a company and can lead to enhanced operational effectiveness.
- ***Environmental improvement***. Implementation of a management system will give corporate and the subsidiaries the satisfaction of helping to address local environmental issues.

ISO 14001 Certification: Many of these EMS systems are being developed with the intent to seek ISO 14001 certification when clients or customers require this step. Some multinational corporations such as H.J. Heinz have begun doing this at all their facilities globally and Dole Foods has even addressed farming operations in a number of countries.

Genetically Modified Organisms (GMOs)

Products of agricultural biotechnology are not coming to market as expected. Critics in Europe have been very successful in delaying acceptance of genetically modified foods. US consumers tend to trust the government to insure food safety and are generally less fearful of biotech foods. What does the future hold for GMOs in the international marketplace? Current opinion indicates that critics will damage and delay acceptance of this agricultural technology; however, ultimately the biotech revolution will go forward without them. The National Food Processors Association (NFPA) believes food biotechnology is extremely important for improving the nutrient content of foods, enhancing food safety by removing undesirable components in food (i.e. allergens), and providing better processing properties and storage characteristics of foods.

New Plant Locations and Expansions

At a Focus Group of key environmental leaders in the food industry held at North Carolina State University several years ago, the consensus was that the environmental concerns of availability of quality water supply, the ability to economically treat and dispose of wastewater and the ability to get rid of residuals economically was either the first or second most important concern in locating new food plants or expanding existing facilities. This is exacerbated by management decisions to get 80 percent or more utilization of facilities when 20-35 percent used to be acceptable and considered profitable. This means that the production from 5 facilities is being merged into 2 or 3 plants.

CONCLUSIONS

In closing, the poultry processing and further processing industries will continue to face a myriad of challenges in the 21st Century. Many of these are extensions of ones faced previously and continued profitability of processors will depend on how they respond to these opportunities. We can be assured that:

- Food safety is critical.
- A company's success can depend on its water and wastewater management system. It is important for poultry processors to take action now to be prepared for increasing limitations on water use and waste loads.
- Environmental regulations and costs will continue to rise.
- Management will be legally responsible for their actions.
- Processors need to think globally.

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RENDERING ISSUES

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SPN (SELECT PROTEIN NUTRIENTS)

History

1. American proteins was, and is, a service organization. We have always found a way to process any allied product generated the poultry industry.

2. In 1994 SPN was 6% of our non-feather/non-blood volume. Today it is 14%.

3. In 1996 we entered the pet food market. The removal of SPN in pet food poultry protein meal effectively doubled the percentage of SPN in meat allied products.

4. In January of 1998 we established SPN criteria for poultry processors.

   a. Moisture must be less than 75%.
   b. Age must be less than 24 hours.
   c. Ethoxyquin must be applied at a rate of 250 ppm during the winter and 500 ppm during the summer.
   d. Removal of iron salts in pre-treatment by March of 1999. Certain extensions were granted to those showing good faith effort and for circumstances such as TSP.

5. Water consumption has increased from an average of 5 gallons per bird to almost 10 gallons per bird at Southeastern processing plants in an effort to meet zero fecal tolerance regulations.

Variation

1. The criteria established in 1998 reduced moisture variation dramatically. Historical moisture range was 60%-90%. Current average moisture level is 70% with a very tight range.

2. SPN variability is influenced by processor operations (kill only, kill and cut up, kill and debone, cook, marinate, etc.).

Composition

1. At harvest moisture is ~90%, fat is ~6% and non-fat solids are ~4%.

2. Post decant moisture is ~75%, fat is ~15% and non-fat solids are ~10%.

Pre-Treatment Options

1. Metal salts catalyze oxidation.
   Fat + 02 + Metal Salt → Peroxides → Aldehydes and Ketone Bodies → Low Nutritional Value and Malodors Metal salts also form a residual catalyst in the meal which can, and will, result in auto-oxidation leading to combustion.

2. Various polymer systems; single, dual and triple.

3. Particlear, which is a new non-oxidizing coagulant manufactured by DuPont

4. Sorin, which utilizes a magnetic field and polymers.

Processing Options

1. Render with meat allied products.

2. SPN can be processed separately using coagulation and centrifugation. Solids can be rendered with meat allied products, processed with hydrolyzed feathers or dried separately. Stick water can be processed in an evaporator or sent to pre-treatment.

MALODORS

Georgia Malodor CAP (Control & Assessment Program)

1. This program is administered by the Georgia Department of Agriculture. It is modeled after Hazard Analysis Critical Control Point (HACCP) and has proven to be very effective.

Research

1. Odor Source Evaluation and Site Characterization at Rendering Plants
   K.C. Das and J. Kastner
   University of Georgia
   $125,000

Funded Poultry Protein and Fats council, United States Poultry and Egg Association

2. Wet Scrubber Process Enhancements and Monitoring for Odor and VOC Control in the Food Processing Industry
   K.C. Das
   University of Georgia
   John Pierson
   Georgia Tech Research Institute
   $239,078
   Funded by Food PAC, American Proteins, Inc., Gold Kist, Fieldale Farms and Tiberian Technologies

BIOSECURITY

No. controlled, peer reviewed, research exists validating the rendering processing pathogen elimination

Research

1. Prevalence of Selected Foodborne Pathogens in Final Rendered Products: Pilot Study
   H. Fred Troutt
   University of Illinois
   $79,656
   Funded by Fats and Proteins Research Foundation

2. Thermal Death time Values for Rendered Products
   Annel K. Greene
   Clemson University
   $16,650
   Funded by Fats and Proteins Research Foundation

THE CRIMINALIZATION OF ENVIRONMENTAL LAW
YEAR 2000

John D. Copeland
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Springdale, AR

ENVIRONMENTAL COMPLIANCE

- Complying with environmental regulation is the duty of every Tyson Foods team member.
- It can be expensive, but not complying is more expensive – for the Company and the people involved.

SEVEN FACTORS WHICH MAKE ENVIRONMENTAL LAWS PUNITITIVE

1. Laws are extraordinarily broad
2. Laws are extraordinarily complicated
3. Constantly expanding through creative interpretation
4. Sanitations are inclusive
5. Criminal sanctions require mere "general knowledge" instead of specific
6. Parallel civil and criminal proceedings
7. FBI has 500 pending investigations of environmental wrongdoing.

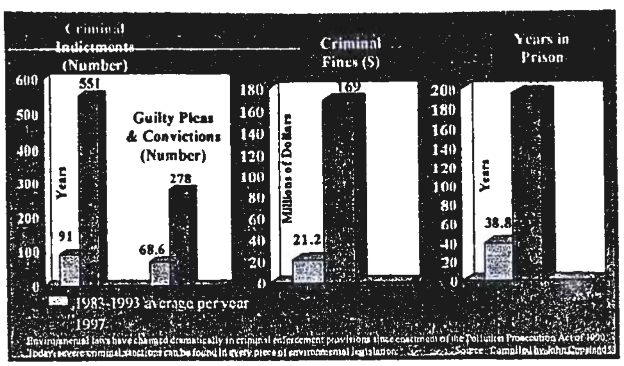

Chart 1. The Explosion in Environmental Law Criminal Prosecutions (1983-93 average) Versus 1997

FY 1998 EPA Action Led to $184 Million in Criminal, Civil, Administrative Penalties

Dollar Value of FY 1998 EPA Enforcement Actions

Criminal Penalties Assessed	Civil Judicial Penalties Assessed	Administrative Penalties Assessed	Value of Injunctive Relief	Value of Supplemental Environmental Projects
$92.8 million	$63.5 million	$28.2 million	$1.9 billion	$90 million

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FY 1999 EPA Action Led to $228.3 Million in Criminal, Civil, Administrative Penalties

Dollar Value of FY 1999 EPA Enforcement Actions

Criminal Penalties Assessed	Civil Judicial Penalties Assessed	Administrative Penalties Assessed	Value of Injunctive Relief	Value of Supplemental Environmental Projects
$61.6 million	$142.7 million	$24 million	$3.4 billion	$236.8 million

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PEISON TIME

1998	1999
196 years	208 years

Federation prosecution of Corporations – Whether to Indict a Corporation

- The nature and seriousness of the offense
- The pervasiveness of wrongdoing within the corporation, including the complicity in, or condemnation of, the wrongdoing by corporate management
- The corporation's history of similar conduct, including prior criminal, civil and regulatory enforcement actions against it

**Federal prosecution of Corporations –
Whether to Indict a Corporation**

- The corporation's timely and voluntary disclosure of wrongdoing and its willingness to cooperate in the investigation of its agents, including, if necessary, the waiver of the corporate attorney-client and work product privileges
- Collateral consequences, including disproportionate harm to shareholders and employees not proven personally culpable

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**Federal Prosecution of Corporations –
Whether to Indict a Corporation**

- The adequacy of non-criminal remedies, such as civil or regulatory enforcement actions
- The existence and adequacy of the corporation's compliance program at the time of the offense
- The corporation's remedial actions after the offense, including any efforts to implement an effective corporate compliance program or to improve an existing one

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**The Sentencing Guidelines Create Four (4) Categories of
Environmental Violations**

1. Knowing endangerment of human life;
2. Offenses involving hazardous or toxic substances;
3. Offenses involving other pollutants;
4. Conservation and wildlife

Penalty Determination

Each category has a base penalty level for knowingly violating the law. Penalties increase if pollutants are released into the environment and for ongoing or continuous violations. A prior history of criminal violations can also increase a penalty. Reduced penalties are provided for acts of negligence, record keeping, and reporting violations.

<u>John Pozsgai – 27 Months</u>

6 points – for discharging pollutant without a permit
6 points – for discharging the pollutant
4 points – for not having permit
----
16 points = prison sentence of 21 to 27 months

Justice or Extortion?

Taung Ming-Lin: For violation of the ESA, the government demanded 363 acres of his 720-acre farm. The land was to be used for a wildlife preserve and Lin was to pay $172,425.00 to fund the preserve's operation.

Paul Tudor Jones: In exchange for probation after violating the CWA, Jones had to make a $1 million contribution to the National Fish and Wildlife Foundation.

Emmet Runde: After polluting a Wisconsin stream, he was forced to write and publish a confession and apology.

1996 United States vs. Ahmad 101 F.3d 386 (5th Cir. 1996)

The defendant owned a convenience store. The store had two underground gasoline storage tanks. One tank had water in it. The defendant's employees attempted to pump out the water – results was over 5,000 gallons of gasoline was pumped into the street. Gasoline went down the manhole into a creek that feeds Lake Houston. Conro'e city sewage treatment plant was forced to evacuate non-essential personnel. Two schools were evacuated.

The jury found the defendant storeowner guilty of two CWA violations:

1 Knowingly discharging a pollutant from a point source without a permit.
2 Knowingly operating point source in violation of pretreatment standards.

There was a deadlock on whether the defendant knowingly placed anyone in imminent danger of death or serious bodily injury.

Defendant's two defenses were:

1. Did not knowingly discharge a pollutant
2. Did not knowingly discharge the pollutant. Employees did it. He was only negligent. (Trial Court refused to allow evidence to be admitted)

Reversed on Appeal – Fifth Court held:

1 CWA's language is less than clear as to application of knowingly
2 Does it modify "discharge" or also "pollutant"
3 Held government had to prove that defendant knew he was discharging a pollutant
4 Also held that he should have been able to present evidence of negligence

<u>1997 United States vs. Wilson</u> **133 F.3d 251 (4th Cir. 1997)**

The defendant the convicted for knowingly discharging fill and excavated matter into wetlands without a permit. Was given 21 month's jail term with a $1 million fine. Two partnerships were fined $3 million.

Reversed on Appeal – Fourth Circuit held that the criminal intent element required the government to prove:

1 The defendant knew the substance he was discharging was a pollutant.
2 The defendant knew the method used to discharge the pollutant.

The defendant knew the physical characteristics of the property into which the pollutant was discharged and that the land was a wetland. The defendant was also aware of facts establishing the required length between a wetland and waters of the United States. The defendant knew he did not have a permit for such a discharge. The appellate court found that the lower court's jury instructions did not adequately impose on the government the burden of proving knowledge with regard to each statutory element.

AUDIT PRIVILEGE STATUES

"Audit Privilege" statutes are designed to encourage voluntary compliance by providing confidentiality for the results of environmental self-audits.

State Audit Privilege legislation has slowed because of EPA opposition.

STATES WITH ENVIRONMENTAL AUDIT PRIVILEGE LAWS

Arkansas	Kansas	Texas
Colorado	Kentucky	Utah
Idaho	Minnesota	Virginia
Illinois	Mississippi	Wyoming
Indiana	Oregon	

ENVIRONMENTAL CRIMES BILLS

- Fines up to $1 million and sentences of up to 20 years for individuals
- Fines up to $2 million for corporations
- Attempt to commit crime carries same penalty as actual offense
- Reimburse state for cost of investigation and prosecution
- Pay for removal, remediation and environmental damage
- Pre-judgment odors to secure payment

Of all tyrannies, a tyranny exercised for the good of its victims may be the most oppressive. It may be better to live under robber barons than under omnipotent moral busybodies. The robber baron's cruelty may sometimes sleep, his cupidity may at some point be satiated; but those who torment us for our own good will torment us without end, for they do with the approval of their own consciences.

ADVANCES IN SPENT HEN UTILIZATION

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The productive life of a commercial laying hen is limited. Approximately 50% of the layers in production at any time will be scheduled for removal throughout the year (Lyons and Vandepopulieree, 1996). As a result, over 160,347,000 "spent" laying hens require disposal annually in the United States. Unfortunately, this volume of spent laying hens exceeds the demand and disposal of spent hens is becoming increasingly difficult (Bachman, 1995). While a number of options are available for the utilization of spent hens, unique challenges are associated with each method. This paper will discuss issues relative to the recycling of spent hens.

DISPOSAL OPTIONS FOR SPENT HENS

Processing for Human Consumption

Spent hens have historically been sold to processors for approximately $0.10/lb (live weight) for use in soups and pies (Lyons and Vandepopulieree, 1996 and Aho, 1999). However, genetic selection for egg production has resulted in smaller body weights and a reduced amount of edible meat on these birds. The average white meat deboning yield of today's spent laying hen is only 0.37 lbs (5.92 ozs). In addition, the realities of increased egg production have resulted in a decrease in bone strength that can further complicate processing spent hens and increase the risk of consumer injury due to bone fragments in products (Kersey *et al.*, 1997). As a result of these changes, the economics of spent hen processing are no longer favorable. The costs associated with catching, hauling, and processing spent hens average $0.68/bird. At a white meat value of $0.59, plus a $0.10 residual value for the remainder of the carcass, the return to the processor would be expected to be only $0.69/bird. Because of this, Campbell's in 1990 and Stouffer's in 1995 sharply reduced their use of spent hen meat in their products; instead relying on the use of broiler and roaster type birds for production (Lyons and Vandepopulieree, 1996 and Aho, 1999). As a result, the on-farm prices paid for spent hens in 1996 dropped to essentially $0.00/lb (Aho, 1999).

Recent government involvement in both the United States and Canada has somewhat improved the status of the spent hen market. With the exit of major processors from the market, the USDA has been purchasing cooked diced spent hen meat for school and institutional programs at prices and quantities that have allowed the survival of the spent hen processing industry. In addition, the Broiler Market Order in Canada has resulted in an artificially high price for spent hens in that country. As a result, many US spent hens are making their way north of the border. On-farm returns for spent hens with access to these markets now currently average $0.02/lb, live weight (Aho, 1999). However, neither price support is expected to be long lived. With the increasingly global economy, white meat from broilers can be obtained for less than the processing costs for spent hens. The long-term viability of the spent hen processing industry is therefore questionable.

Rendering

Rendering is another option for the disposal of spent hens; but, a number of difficulties are encountered when rendering spent hens by traditional methods. Whole feathers tend to plug screens and grinders and to absorb fats, interfering with the fat extraction process. The resulting protein by-product meals are therefore higher in fat and more difficult to handle (Anonymous, 1995). Furthermore, the meals produced can actually absorb some of the oils used in the cooking process and further reduce revenues (Hamm, 1976; Anonymous, 1995). In addition, rendering yields for spent hens average only 27% (*versus* 35-38% for other products). Finally, the unhydrolyzed feathers remaining reduce the nutritional value of the protein. Consequently, this meal is not considered for use by pet food markets, leaving only the lower profit livestock and poultry feeding markets as available options (Anonymous, 1995).

Darling International (West Point, NB 68788) outfitted a rendering plant in Nebraska with a proprietary process to transform spent hens into hydrolyzed poultry meal (HPM) with meal yields of 25% and fat yields of approximately 5% (Aho, 1999). The cooking variables of the rendering process were adjusted to obtain a balance that provided maximum processing of the feather portion while minimizing the decrease in lysine availability in the meat portion of the meal (Lyons and Vandepopulieree, 1997). The nutritional quality of the meal has been evaluated by a number or researchers and found to be substantial, yet variable (Douglas *et al.*, 1997 and Kersey *et al.*, 1998). Crude protein levels in the meals ranged from 56-71% and crude fat levels of from 8.78-13.79 were reported (Douglas *et al.*, 1997; Lyons and Vandepopulieree, 1997; Kersey *et al.*, 1997). Pepsin digestibilities (0.2%) of 82.35-94.29% have been observed with lysine, methionine, and cysteine digestibilities averaging 78.5, 84.7, and 62.6, respectively (Kersey *et al.*, 1997). Unfortunately, the economics of production of hydrolyzed poultry meal are currently not favorable. During the late 1990's, when the value of spent hens reached their lowest point and the economic value of the HPM approached $310/ton, this form of rendering was viable. With current product values hovering near $220/ton and the value of spent hens being supported by government programs, this process is no longer viable and the Nebraska plant is currently being dismantled (Aho, 1999).

Mechanical Deboning

Because the presence of feathers in the meats and meals produced from spent hens reduces their value, Beehive Inc. (Sandy, UT 84091) has developed a mechanical deboning system specifically designed to address this issue. This mechanical deboning system for spend hens results in two distinct products: mechanically deboned meat (MDM) containing meat, viscera, and skin and the residue consisting primarily of bones and feathers (B+F). While the white meat yield for spent hens by conventional processing is only 11%, a 70% yield of MDM is obtained by mechanical deboning (Lyons and Vandepopulieree, 1997; Aho, 1999). MDM, while inedible to humans, has potential value as an ingredient in premium poultry and livestock feeds as well as in cat and dog foods. The B+F fraction also has potential as a feed ingredient for animals following further processing (Lyons and Vandepopuliere, 1997; Aho, 1999). Lyons and Vandepopuliere (1997) evaluated the feeding value of each of these products. Body weight, feed consumption, and feed conversion were unaffected ($p > 0.05$) when autoclaved/dehydrated MDM was included at up to 6% and autoclaved/dehydrated B+F meal was included at 2.75% in the diets of broilers.

A predicted value of $340/ton ($0.17/lb) was reported for pet food uses of MDM in 1997 based on the market values of soybean meal, corn, and animal fat at that time (Lyons and Vandepopuliere, 1997). At this value, mechanical deboning of spent hens would be a very profitable enterprise. However, with soybean meal prices at a 23-year low, the value of MDM is currently estimated at $220/ton ($0.11/lb) for premium markets such as pet food manufacturing. Fortunately, even at this value, plants employing this technology would still be expected to make a small profit and be able to compensate growers at $0.03/bird for their hens (Aho, 1999).

One issue currently clouds the viability of mechanically deboning spent hens. All ingredients used in the manufacture of pet foods and animal feeds are required to have an official definition from the American Association of Feed Control Officials (AAFCO) in order for the products to be marketed commercially. Unfortunately, there is no specific official definition for MDM from spent hens. Therefore, the default definition for any product containing viscera is "by-product." This definition is considered unacceptable by many pet food manufacturers who do not want these words included on their labels. While a number of individuals are cooperating with AAFCO and the FDA to develop a suitable definition, no progress has been reported and the marketability of this product as a premium pet food ingredient remains limited. Until an AAFCO definition can be developed that is suitable to all parties involved or the price of soybean meal rises substantially, only lower value, rendered products for livestock and poultry feeding are potential end products resulting from this material. Therefore, the mechanical deboning of spent hens is currently not an economically viable option for their disposal.

Co-Processing with Grain Products to Produce Animal Feeds

The blending of ground poultry with grain products reduces the overall moisture and fat levels in the material and allows the mixture to be co-processed by a number of different methods. Three commercial co-processing options have been evaluated for the production of feed ingredients for poultry and livestock. Both fluidized bed drying and flash dehydration have been shown to be valuable for co-processing of poultry by-products. Body weight and feed conversion were significantly better ($p < 0.05$) when a product manufactured by co-processing spent hens with wheat middlings using a Jet Pro fluidized bed dehydrator (Atchison, Kansas 66002) was included in the diets of broilers at up to 12% of a complete ration (Lyons and Vandepopulieree, 1996). Questions still remain relative to the microbiological safety of the products resulting from these technologies (Lyons and Vandepopuliere, 1996). Dry extrusion has also been demonstrated to produce nutritionally valuable feed ingredients from the co-processing of poultry products with grains (Reynolds *et al.*, 1990; Blake *et al.*, 1991). Diets formulated using turkey and broiler mortalities co-extruded with soybean meal resulted in similar feed conversion and higher body weights in broilers than in the birds fed an isocaloric, isonitrogenous corn/soy diet (Tadtiyantant *et al.*, 1993). However, in contrast to fluidized bed drying and flash dehydration, feed ingredients subjected to extrusion cooking are sterile and pose no risk of transmitting infectious agents (Council for Agricultural Science and Technology, 1995). One manufacturer, Insta-Pro International (Des Moines, IA 51322), has been a leader in promoting extrusion technology for the processing of spent hens.

When spent hens are co-extruded with soybean meal, the resulting product has the energy value of corn and nearly the protein level of soybean meal (Aho, 1999). Aho (1999) recently estimated the value of this meal to be $130/ton ($0.065/lb). As with the price of MDM, this value is tied to historically low soybean meal prices and is expected to increase over time. Never the less, at this value the return to producers for live hens processed in this manner would be expected to approach $0.02/lb. Estimated annual return to capital for a 338,000 bird capacity facility is estimated at $762,000 (Aho, 1999).

In January of this year, AAFCO modified its definition of "HYDROLYZED WHOLE POULTRY" (HWP) as follows to include processing by dry extrusion as an acceptable method of co-processing to make the material suitable as an animal food:

> T9.58 Hydrolyzed Whole Poultry is the product resulting from the hydrolyzation of whole carcasses of culled or dead, undecomposed, poultry including feather, heads, feet, viscera, blood and any other specific portions of the carcass. The product must be consistent with the actual proportions of whole poultry and must be free of added parts; including, but not limited to viscera, blood or feathers. The poultry may be fermented as a part of the manufacturing process. The product shall be processed in such a fashion as to make it suitable for animal food, including heating (boiling at 212 degrees F or 100 degrees C at sea level for 30 minutes; dry extrusion at a minimum temperature of 284 degrees F or 140 degrees C for 30 seconds with a pressure differential of approximately 40 atmospheres as the product exits the extruder; or their equivalents) and agitating (except in steam cooking equipment). The product may, if acid or alkaline treated, be subsequently neutralized. If the product bears a name descriptive of its kind, the name must correspond thereto. (Proposed 1995, Adopted 1997, Amended 2000)

Prior to this point, extruded poultry co-products were similar to MDM in that they could not be marketed commercially and were prohibited from interstate transport. With the adoption of dry extrusion as an accepted method to produce HWP, AAFCO has cleared the way for widespread adoption of this method of utilization of spent hens and the commercial marketing of the resulting products.

UNIQUE CHALLENGES ASSOCIATED WITH SPENT HEN CO-PROCESSING INTO FEED INGREDIENTS

Commercial Viability

In order for a spent hen co-processing facility to be successful, it must have a consistent supply of raw materials (spent hens) as well as a consistent market for the manufactured feed ingredients. Therefore, producer/processor cooperation is mandatory for the success of this type of enterprise. Corporate farms and/or farmer's cooperatives can provide this sort of cooperation internally and therefore have the highest probability of success with a co-processing facility (Smith, 1995). This type of arrangement provides a ready supply of raw materials, an established market for products, quality control of the materials, and cooperation in scheduling to prevent excesses or deficiencies in spent hens for processing (Anonymous, 1995). While commercial co-processing ventures could be viable, seasonal fluctuations in raw material and/or ingredient prices have the potential to create serious problems in production and/or profitability. In addition, only one co-processing option, extrusion, is approved for the co-processing of spent hens to produce a commercially marketable product. Therefore, options for commercial operations are limited.

Nature of Input of Raw Materials into the Facility

Extrusion processing is generally the rate limiting operation in a spent hen co-processing facility. Even with the best producer/processor cooperation, the quantity of spent hens coming into a spent hen co-processing facility is at times likely to exceed that facility's extrusion capacity. The perishable nature of this raw material therefore necessitates that preservation options be available. While refrigeration/freezing is possible, lactic acid fermentation or phosphoric acid preservation are more likely options for this function. A great deal of information is available in the literature on the advantages and disadvantages of each of these preservative systems, so they will not be addressed here (Divakaran and Sawa, 1986; Blake *et al.*, 1992; Murphy and Silbert, 1992; Cai *et al.*, 1995; Middleton and Ferket, 1998). However, to avoid investing in excess extrusion capacity that would likely often remain idle, some method of preservation should be incorporated into any spent hen co-processing facility.

Regulatory

Spent hens and mortality products have been classified by various government agencies both as animal wastes and as garbage. Therefore, a variety of state and federal regulations apply to their reuse as feed ingredients. Unfortunately, the new technologies that have made spent hen co-processing possible were unforeseen when the regulations regarding the feeding of wastes and garbage were drafted. This has resulted in uncertainties over jurisdiction and a situation in which the requirements vary state by state. A number of recent clarifications on the national level have reduced the confusion associated with these new technologies. Let's review the regulatory issues involved.

National/Federal: Taken literally, there are few federal restrictions that prevent the feeding of co-processed spent hen products back to birds owned by the originators of the raw materials. The practice does not constitute commercial sale and the materials produced are therefore exempt from commercial feed laws and regulations. Moreover, in 1980, following a review relative to the feeding of broiler litter to cattle, the FDA issued a statement in which it declared the feeding of animal wastes to be primarily a local matter and therefore subject to individual state control (Federal Register, Vol 45, No. 251. Pages 86271-86278). Jurisdiction relative to the feeding of animal wastes was therefore assigned to the individual states.

If the feed ingredient is to be fed to swine species within the cooperative or corporation, the Federal Swine Health Protection Act (9 CFR Part 166) clearly restricts the feeding of improperly cooked waste materials to swine. Section 166.7 of this act (Cooking Standards) specifies that "garbage" (such as are classified mortality carcasses and spent hens) must be "heated throughout at boiling (212°F or 100°C at sea level) for 30 (thirty) minutes." Rendered materials are exempt from these cooking standards and are defined in this act (9 CFR Part 166.1) as follows:

> "Rendered product. Waste material derived in whole or in part from the meat of any animal (including fish and poultry) or other animal material, and other refuse of any character whatsoever that has been associated with any such material, resulting from the handling, preparation, cooking, or consumption of food that has been ground and heated to a minimum temperature of 230°F to make products such as, but not limited to, animal, poultry, or fish protein meal, grease or tallow."

Recent communications from the office of USDA Emergency Programs confirm that extruded products that achieve 230°F fulfill the definition of "rendered product". Therefore, properly extruded products are exempt from the cooking requirements of the Act and can therefore be fed to swine.

As cited previously, AAFCO recently modified its definition of "HYDROLYZED WHOLE POULTRY" to include heating by dry extrusion as a suitable method of processing. This modification was enacted following receipt of an FDA "letter of no objection" to this practice dated December 7, 1999. Therefore, extrusion co-processed spent hens can not only be classified as rendered, but also can be marketed commercially as a feed ingredient. Co-processed products manufactured by means other than extrusion are not currently eligible for commercial sale.

State: Because jurisdiction for the feeding of animal wastes is under individual state control, cooperation with each State Veterinarian's office is essential if a spent hen co-processing facility is to be licensed and permitted. Even if the product is to be classified as rendered, licensing and permitting for these types of facilities also generally lies with the State Veterinarian. Requirements from the State Veterinarian's office for rendering plant permitting may well exceed the associated national requirements for rendered products. In North Carolina, for example, a rendering facility is required to heat process materials "at a sufficient temperature for a sufficient time to destroy all disease producing organisms" (2 NCAC 52I.0004(a)). Since a number of viruses have been demonstrated to survive processing conditions of 230°F, this State's Veterinarian requires more stringent conditions than are required nationally. So, despite recent easing of federal restrictions, the nature and requirements for spent hen processing will vary among the states.

Proposed Standard for Spent Hen/Mortality Co-Processing Technologies: Currently, the only co-processing method for spent fowl that results in a marketable product (HWP) is extrusion co-processing. The AAFCO definition for this product includes the term "or their equivalent" following the description of accepted methods of heat processing. Unfortunately, no standard or guidance is available to clarify exactly what would constitute "equivalent" processing conditions. Because a letter of no objection from the FDA would be required by AAFCO in order to include any other processing conditions in the description of HWP, jurisdiction for this determination resides with this body.

The heating standard for both garbage and HWP is "boiling at 212°F or 100°C at sea level for 30 minutes." Therefore, in theory, if a novel processing method could be demonstrated to result in the same level of destruction of pathogenic organisms as boiling for 30 minutes, it would seem to be worthy of consideration by the FDA as an equivalent processing method. While the survival of targeted microorganisms in processed feeds, manufactured either from traditional or waste materials, can be determined by subjecting the material in question to microbiological challenge studies under simulated processing conditions in the laboratory; full-scale production conditions often result in variables that cannot be reproduced or anticipated in the laboratory. Therefore, it would be desirable to monitor the fate of the targeted challenge organism under actual process conditions. Unfortunately, it is generally unwise and unrealistic to risk working with high concentrations of known pathogens in production situations; both due to the threat of long term contamination of the equipment as well as the health and safety of the workers involved. Biological indicators, organisms similar to or more resistant than the pathogen in question, are often used in challenge studies to verify the adequacy of a processing technology (Pflug, 1990).

Foegeding and Stanley (1991) identified *Listeria innocua* ATCC 33091 (isolated from healthy pregnant women, serotype 6b) as an appropriate biological indicator to evaluate milk processing conditions for *L. monocytogenes*. This organism was demonstrated to be 1.5 to 3.0 times more heat-resistant than *L. monocytogenes* between 56 and 66 °C. Antibiotic resistance to rifampin and streptomycin were naturally conferred to this **non-pathogenic** species of *Listeria* (*L. innocua* ATCC 33091 M1) to facilitate selection and quantitative recovery among a large and complex background microflora such as might be found in foods and feed ingredients (Fairchild and Foegeding, 1993). Therefore, this organism is an excellent choice for conducting microbiological challenge studies of novel waste processing technologies.

In late 1999, Dr. Brian Sheldon, Dr. Peter Ferket (Department of Poultry Science, North Carolina State University) and Dr. Teena Middleton (AgProVision) proposed to the FDA the use of the non-pathogenic *L. innocua* ATCC 33091 M1 as an indicator of pathogen reduction in any novel process for converting animal waste by-products into feed ingredient meals. The use of this protocol would help to standardize results among the different processes evaluated and hence facilitate the determination of "equivalence" among processes. Moreover, this protocol would also be useful as a quality control measure of process biological safety once permitted. This proposal is currently under review by this organization.

PROMISING NEW TECHNOLOGIES

AgProVision (Kenansville, NC 28349) has worked in cooperation with North Carolina State University's Animal and Poultry Waste Management Center to develop a system for the co-processing of swine mortalities using both extrusion and flash dehydration. By combining these two technologies in a unique way, they have been able to decrease the amount of grain product diluent required and therefore increase the protein and energy content of the resulting feed ingredients. As a result, the increased nutritional and economic value of the product helps cost justify the capital investment required for construction and operation of such a facility.

The application of this technique appears to also show promise for the processing of spent hens and poultry mortality carcasses. As the material is partially dehydrated prior to extrusion, it appears feasible that mechanical separation can be employed to separated the meal fraction from the feather fraction of the product, allowing each to be further processed in a manner best suited to their unique character. A number of equipment manufacturers have pledged their support to this effort and grant proposals have recently been submitted to fund this investigation. Hopefully, this investigation will yield even more options for spent hen co-processing.

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EGG WASTE UTILIZATION

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INTRODUCTION

It is good to be back at the National Poultry Waste Symposium. I spoke at this conference two years ago on the subject of what to do with all of this inedible egg. The efforts of many organizations have only bought us more time. Inedible egg is a crisis waiting to happen.

It is readily apparent that neither my address nor position suggests that I am an expert on this subject. I serve the interests of the U.S. egg industry through United Egg Producers and United Egg Association by representing them before Congress and those agencies with regulatory oversight. But this offers a unique and privileged perspective on the issue of egg waste. Knowing what Congress can and will do, coupled with what the agencies are intending to do on environmental issues tells us that we, as an industry, ought to be finding solutions to our own problems.... And finding them fast.

There is a mistaken belief outside the Capitol beltway that a change in Administrations will put our problems behind us. Yes, we are looking for regulatory relief from what we have experienced the past 8 years, and most especially in the dwindling light of the sunset on Clinton's day. To think that total relief is coming is mistaken because the regulatory machinery is moving forward.

REGULATIONS COMING

For example, a new regulation will go into effect in December of this year. It is the National Pollutant Discharge Elimination System (NPDES) permits for Concentrated Animal Feeding Operations (CAFOs), including egg production facilities. This regulation will add to EPA's authority to control agriculture. The new regulations will require each operation to develop a Comprehensive Nutrient Management Plan that will include:

1) Maintaining records showing the amount of waste (manure) leaving the operation,
2) Name and address of the people taking the waste,
3) Proof that you provided the nutrient content of the waste, and
4) That the person(s) taking the waste have been properly informed how to properly manage the land application to prevent discharging into waterways.

REGULATORY HORIZON

What's next environmentally? Air quality standards. EPA is looking long and hard at the emissions of hazardous compounds such as ammonia and hydrogen sulfide. Farms classified as CAFOs (that includes practically every commercial egg farm today) must report when they exceed the allowable limits. Under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), EPA has the authority for enforcement actions against any farm that fails to report when their emissions exceed the limits.

What is the point? Enforcement actions are increasing relative to our changing environment. The egg industry must seek solutions. It is no longer "*business as usual*" in dealing with waste byproducts. And letters to Congress won't do the trick either. At best, they only delay the inevitable.

HOW MUCH INEDIBLE EGG IS THERE?

The egg industry is facing a crisis waiting to happen as it relates to egg waste. This is the inedible egg that cannot be processed into human food. It is estimated that between 1-3% of the eggs produced will be pulled out due to meat and blood spots, leakers, checks, and deformities of the shell and labeled as "inedible". Therefore, of the 8.4 billion pounds of eggs produced, upwards of 250 million lbs. is inedible egg.

What do you do with this product? A classic method of utilizing these eggs is to denature them with a food grade caramel color, spray dry them into a powder and sell into pet feed.

Those 250 million lbs. of inedible egg will yield about 30 million pounds of powder (Ave solids 22%). For years, the pet food market was a growing market. The demand for inedible egg grew. The manufacturers of inedible egg needed more product.

The egg breakers had a source when they spun their broken eggshells. Before disposing their eggshells in landfills, they had to remove the liquid. They were separating out the inner shell membrane and the albumin that is trapped in the shell. With nearly 30% of all shell eggs products going to the breakers, this liquid generates more than 183 million pounds of egg albumin. It is low in solids (about 15%) so when spray dried, it yields about 27 million pounds of solids. Still the pet food companies were demanding more.

More egg was needed. The hatcheries around the country had a disposal problem with their unhatched eggs. On average 10% of the eggs do not hatch, so that liquid remains in those eggs. My old company set up a system of collection of hatchery waste, spun out the egg, and took the remainder to the landfills. With the volume of broiler companies in the nation, this generated a substantial amount of inedible egg...156 million pounds liquid (25% solids) or 39 million pounds of powder.

These 3 sources produced about 96 million pounds of inedible powder. The domestic pet food market for inedible egg has reached a plateau in recent years.

EXPORT OPPORTUNITIES

There had been some exports of this product for the pet food market overseas until the EU decided to restrict poultry and egg products in 1997-98. Prior to this regulatory enforcement, the pet food companies in Europe feared they would incur significant costs by reformulating and altering their labels. Instead, they put the pressure on the suppliers to fill their pipelines. They couldn't get enough.

They started buying whole egg at 5-6 times the price of inedible. The following year, when they analyzed their costs of production.... Egg was too expensive. They re-formulated their diets. Now, the shortage turned into a surplus situation. Further market forces were coming into play.

EU PROTECTS ITS SUPPLIERS

The EU is an important market for inedible egg sales. It started to enforce a regulation that stipulated different denaturants. (EC Reg. No. 3665/93 Dec 31, 1993) (essence of lavender, oil of rosemary, birch oil, fishmeal, spirit of turpentine)

Some pet food companies did not want egg with other denaturants, so they bought their needs locally. All the while, the surplus situation in the U.S. continued getting worse.

The egg industry met in Washington to address this issue. It was decided to approach this issue from 2 different perspectives.

1) Try to promote the usage of feed grade eggs into other animals besides pets (baby pigs for example).
2) Try to get the EU to change their regulations.

The American Egg Board (AEB) has focused on the first objective. They set up research at Clemson University on the nutrient components of this product. They also funded market development in Latin America through the Poultry & Egg Export Council, headquartered in Stone Mountain, Georgia.

LEGISLATIVE SOLUTION

UEA and UEP addressed the situation in the way lobbyists do...legislatively. What the EU had done was change the agreement from the Kennedy Round of GATT negotiations (1963-67) whereby duty-free bindings were negotiated on a number of products included inedible egg.

The regulation change was demonstrated to be a violation of this agreement coupled with the violations of National Treatment basis allowing their own producers to use caramel color while restricting its trading partner.

Meetings with members of Congress initiated a "dear colleague" letter with congressional signatures to the USTR office. Pressure was brought to bear on the EU through the Foreign Agriculture Service office in Brussels to change this regulation.

I met with the Director Generals in Brussels of the EU Agriculture and Customs Committees. We also met with the Permanent Danish Representative. One of the major importers was in Denmark and was forced to pay $2 million in past duties on inedible egg. Numerous meetings were held in Washington and in Brussels.

Finally, the Danish government relented on the past duties and submitted a request that the EU regulation be changed.

Pressure should ease somewhat allowing us a little time to see how the research and promotional efforts at AEB allow the creation of additional markets for inedible egg. But protein markets are not the only solution. Other opportunities must be explored.

NEW TECHNOLOGY

One novel approach to dealing with poultry waste such as inedible egg is the thermo-depolymerization process (TDP). Using water, temperature and pressure in a completely enclosed environment, the TDP yields usable energy sources from residual waste streams. One year ago in December, a corporation called Changing World Technologies (CWT) held a ribbon-cutting ceremony on an R & D pilot facility at the Philadelphia Naval Business Center.

The Philadelphia Inquirer reported on the event by saying the process mimics natural geological and geothermal processes. That is how the earth's natural forces convert biomass into carbon fuel sources. The former Director of the Central Intelligence Agency, R. James Woolsey, commented on this new technology saying that it "offers all of us an opportunity someday to have a more peaceful and freer world." He meant that we could be less dependent on foreign oil. My concern is being less dependent on the typical way of disposing of poultry waste.... Burying it or spreading it. Whatever the outcome, it is technology such as CWT that will bring the poultry industry out of the waste dump it now finds itself.

It has been a real pleasure to be here and I am prepared for any questions you may wish to ask.

SOLUTIONS TO DAF ISSUES

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DAF is commonly referred to in the industry as biosolids or secondary protein nutrients (SPNs) and is defined as the material skimmed off following pH adjustments and the use of flocculants such as iron salts or aluminum sulfate designed to reduce the biological oxygen demand (BOD), nitrogen, and phosphorus.

WHY IS THERE A DAF PROBLEM?

Rendering

The production of DAF sludge (dissolved air flotation float/gravity sludge) is a major concern for the livestock and poultry industry. The utilization and disposal of this material is quite controversial. The product has a high content of protein and fat, but can also contain polymers, fat with a high content of free fatty acids, a high moisture content, and can be difficult to handle and process properly in many rendering systems.
As a result of their daily operations, almost all poultry processing slaughtering facilities create a tremendous amount of by-product materials that can not be sold for human consumption. These materials (offal, feathers, sludge from the wastewater treatment operation, etc.) are typically sent to either an on-site or an off-site rendering operation.

The rendering operation typically processes the feathers by first hydrolyzing, which is a heating process, and then drying them into what is known as feather meal. The offal and sludge are usually mixed in some proportion (80% offal, 20% sludge) and then processed through a cooking operation, which results in a poultry meal. Both the poultry meal and feather meal are then sold as an animal foodstuff

Both the poultry processors and the rendering facility have genuine concerns surrounding the recovery and the blending of the wastewater sludge with the offal material. These sludge products are typically high in nutritional value (fat and protein), but in many cases, have been processed with chemicals that can have a negative effect on the blended final product.

The poultry processors are looking for a process that meets their needs from a water quality treatment standpoint. On the other hand, the renderer is most concerned with the physical and chemical conditions of the recovered solids that he receives from the processing plant.

In most cases, the processors would prefer to use a basic metal salt chemistry (ferric sulphate or ferric chloride + a polyacrylamide) because of its effectiveness and low cost. But, from the renderer's standpoint, this process offers the least benefit, due to the fact that it produces a less stable product.

As a result of these issues, both the poultry processors and the rendering facility are evaluating various processes. The goal is to find the most efficient and most cost effective solution to these concerns.

Land and Landfill Applications

Environmental concerns have restricted land application in many parts of the United States. Also the cost of handling high moisture products ($0.05/gallon to $0.35/gallon) make this application less desirable.

Composting

The composting of high moisture DAF is labor intensive because more bulking material is needed to absorb the moisture and the product must be rotated frequently to keep the moisture contained. An open-air compost site is the least expensive, but can offer some environmental concerns because of problems containing the moisture, especially during rainy weather. Another approach to solving this problem is an In-vessel system, which will contain all the moisture, but can be cost prohibitive because of the low value of the end product.

WHAT IS THE CURRENT STATE OF THE ART?

The Fats and Proteins Research Foundation (FPRF), Inc., is initiating research to evaluate the biosolids issue. In an attempt to define the most common treatment processes to obtain DAF and identify priority areas of exploration, an industry survey was prepared and submitted to FPRF renderer members (render Magazine, 2000). The confidential survey was sent to 67 companies (including those with multiple plants) with 39 facilities responding. Of the respondents, 30 facilities generate DAF, nine do not and 24 of those 30 process generated biosolids. Of the six facilities that do not process DAF, three handle disposal in several ways: land application, process at another facility, belt press/sludge dryer. Eleven facilities acquire offsite DAF, but with specifications such as no aluminum, no ferric chloride (15 parts per million (ppm) ferric max), and no food/feed grade polymers. In all, 31 facilities process DAF material.

Once processed, renderers handle the DAF product in several ways. Four facilities prohibit the use in feed altogether while 24 prohibit the use of DAF float which contains specific chemicals. Out of 29 facilities, 19 limit the fraction of DAF float in finished product and 20 of the facilities develop specific products from DAF. Respondents recommended that research be conducted on DAF to find an inexpensive method to process separately or explore lower cost disposal alternatives as rendering may not be the most viable option, and refine procedures for processing a marketable product.

Continuing to use the terminology DAF, skimmings, float, or sludge to describe the material had respondents split down the middle. Other alternative names were recommended including inedible low grade tallow or grease, secondary poultry nutrients, recovered food process waste, reclaimed animal oil and protein, raw water by- products, and effluent reclamation material. Concerns by finished product users were also a 50-50 split and 20 of the 31 facilities do segregate products containing DAF.

Respondents shared many of their concerns about DAF material such as finished product color and quality, palatability in pet and dairy feeds, higher free fatty acids (FFA) in fat and finished tallow, and the increase of fat initial peroxide values. Survey participants also stated they cannot include DAF material in pet food or poultry meal ingredients, as requested by finished product users.

Problems often arise when handling DAF float, as evident by the remarks from half of the respondents. One comment stated that material from the cooker does not allow free fat to drain from solids in drainer systems. Another renderer said polymer DAF sticks to raw material trailers, center gates, walls, and machinery and is very difficult to remove and clean. Other processing problems included lower throughput due to high moisture, coating of cooker shafts, black grease being generated when dehydrating, odor problem enhancement, foaming problems, slow production, and higher processing costs due to lower yields.

When using specific chemicals in DAF, problems ranged from metal deterioration of equipment to polymer residues in finished product that create higher fat content in meals and even fires caused by irons. Respondents process DAF using a number of different chemicals from a wide selection of manufacturers. Survey participants were asked which type of wastewater treatment process they used, screening or gravity skimmer. While nine facilities use both, 10 utilized screening which included a filter basket, rotary wedge, rotary drum screen, rotoscreen, rotary screen, and even a few self-constructed screens. Eight facilities utilize gravity skimmers including drag chain paddle, top drag, and a number of self-constructed catch basins.

NEW TECHNOLOGIES RESEARCHED TO IMPROVE THE QUALITY OF DAR

<u>Closed Systems Inc. Process</u>

The bentonite clay/polymer process typically runs in the pH range of 4.5 - 5, as a result, like other low pH chemistries it renders a stable recovered material, Also, there are no oxidizing chemicals involved, the treatment dewaters well, and the water quality is good. The coagulant demand for this process typically runs in the range of 200 to 500 ppm. The additional chemical required for this process, such as sulfuric acid, anionic or cationic polymers, is related to the type of waste stream that is being treated (kill facility, further processing, etc.). Test results have shown that this process can reduce phosphorous levels by up to 30%. If a plant is concerned with its phosphorous levels, metal salts can be used in conjunction with the bentonite/clay to remove the remaining levels of phosphorous, By using this dual coagulant program, a processing plant could reduce the amounts of metal salts used on a daily basis. The metal salt (ferric chloride or ferric sulphate) required dosage would then be in direct proportion to the required phosphorous removal. The bentonite/clay system is one of the most cost- effective processes available.[2]

Dupont® Process

Particlear® silica microgel is produced by the acidification of sodium silicate. When acidified under the proper conditions, sodium silicate begins a polymerization process that initially forms one to two nanometer spheres followed by the linking of the spheres into three-dimensional chains. This polymerization process is stopped, when the microgel has reached an effective size, by diluting with water to a silica concentration of one weight percent or less. The solution is further stabilized by adjusting the pH to below 2.5 or above 9. The three dimensional gel has a high surface area, about 1200 meters squared per gram of silicon dioxide (SiO_2). In wastewater treatment, this high surface area provides a strong flocculation action by hydrogen bonding with many soluble species (e.g. blood) and by charge neutralization, also a surface phenomena, depending on the pH of the wastewater. The silica surface also appears to provide a suitable strata for bonding with oils. When treating wastewater from poultry processing, Particlear® can generally provide similar or improved levels of Total Suspended Solids (TSS) and Total Biological Oxygen Demand (TBOD) as ferric or aluminum salts without contaminating the solids with the metal salts.

Particlear® is produced in a fully automated device, referred to as a generator, located at the customer's site. The generator and a product skid are each about 5 feet by 5 feet with a height of 7.5 feet and provide 1000 gallons of Particlear® storage. The generator will start and stop automatically to keep the Particlear® level between specified maximum and minimum levels, either in the small tank included with the generator or in a customer's Particlear® storage tank. The generator's program logic controller (PLC) can also provide polymer dosing and pH control for the wastewater system with both local and remote touch panel interfaces for the operators. The ingredients used to produce Particlear® are sodium silicate, carbon dioxide, and sulfuric acid (to adjust the storage pH of the Particlear®). Particlear® has a storage life of two to four weeks, but is typically used within 24 hours of being produced.

Particlear® can be used at pH's ranging from 3.5 to 7. At the lower, acidic pH's, the typical application is pH adjustment (usually with sulfuric acid), followed by Particlear® addition, followed by the addition of cationic polyacrylamide (CPAM). If a stronger flocculant is required, one to two parts per million (ppm) of anionic polyacrylamide (APAM) can be added. If the wastewater is treated at higher pH's, for example 7, a polyamine is used in place of the sulfuric acid, followed by the addition of Particlear®, followed by the addition of CPAM.

Particlear® offers several benefits related to wastewater effluent quality. Particlear® removes 90% to 95% of the suspended solids and 40% to 60% of the soluble BOD components. This generally provides water quality similar to that achieved with metal salt systems (ferric chloride, ferric sulfate or aluminum compounds). Some of the advantages of Particlear® over metal salt systems are related to pH and temperature. Unlike the metal salts, the addition of Particlear® is independent of the target pH of the Dissolved Air Floatation (DAF). If a high level of soluble components are present, for example in the case of a blood spill, increasing the Particlear® addition will capture the additional soluble components without risking an excessive decline in pH which can cause the loss of flocculant formation. Also, unlike metal salts, changes in water temperature, such as when chillers or scalders are dumped, has little effect on flocculant formation or soluble component removal when using Particliear®. This increased stability reduces the amount of operator attention required to maintain good water quality.

Two benefits of using Particlear® related to the solids from the DAF are the reduced rate of rancidity increase and the improved ability to remove water from the solids. Unlike metal salts, Particlear® does not accelerate the formation of free fatty acids (FFA) in the DAF solids. Whereas metal salts may cause a 40 to 80 fold increase in FFA (from 1 or 2 to 80 or 150) of the DAF solids, the FFA of the DAF solids when using Particlear® is generally under 5, even after 24 hours. If allowed to decant, water quickly drains from Particlear®-based DAF solids resulting in a solids content of 30% to 50% by weight. The Particlear®-based DAF solids also belt press easily. In situations where high levels of oil are present, for example when the cookers are dumped during the sanitation shift in a further-processing operation, Particlear® results in most of the oil being contained in the DAF solids. When belt-pressed, the high oil -solids release the oil providing a low moisture, low oil solid.

Additional benefits due to DAF sludge quality occur in the rendering operation. The lower polymer content, compared to acidulation or multi-polymer systems, reduces the tendency to form hard lumps of carbonized polymer or to coat cookers with overcooked polymer. Because Particlear®-based DAF sludge drains and decants well, the sludge is often drier, reducing the energy required to reduce the sludge to dry meal. Separation of the oil content of the sludge is reported to be relatively easy and complete, and can be accomplished in a typical centrifuge that produces a water stream, an oil stream and a solids stream (Personal Communication, Larry N. Teasely).

Novis International, Inc. Process

The Claradigm™ system is a four step process to stabilize the sludge, remove some of the fat, and produce a higher quality product for the renderer or for drying. The first step is the addition of an antioxidant to stabilize the fat. The next step utilizes a direct steam injection and pipe cooker to process the biosolids. This process inhibits bacterial activity as well as enhances liquid and fat separation. The process continues to the Novapor™ technology. At this stage a polymer is added which enhances liquid /solid separation and fat/solid separation. The final stage is the oil/water separator. The Claradigm™ process produces both separated fat as well as an improved biosolids to be rendered or dried (Novis International, Inc.).

Drying Technology

Research is underway to develop new technologies to dry DAF. The high fat content makes the sludge stick to the dryers, as well as producing a dry product that can not be handled in conventional feed mill systems.

One new technology being researched is the Polifka Windhexe® Dehydrater. The Technology utilizes air pressure and vacuum to both grind and dry products suspended in an air vortex. The "tornado in a can" technology shows promise in drying the high fat DAF. Since products are dried suspended in the air vortex, the windhexe technology can reduce or eliminate the fat coating and cleaning problems experienced in other drying technologies. This technology has successfully dried DAF with moisture levels as high as 90%, however the dried product is too high in fat to be free flowing. Since the technology grinds as well as dries products, mixing DAF with other products (corn, etc.) can produce a sludge meal that will be free flowing and ready to be used as a feed ingredient.

THE VALUE OF DRIED DAF SLUDGE MEAL

Because of the high cost of hauling high moisture DAF, drying may the most cost-effective solution. Once a solution is reached to solve the quality issues, the dry product can have good nutritional value. The following tables illustrate some typical analysis of dried sludge meal produced by different processes:

	By product meal	Claradigm™
Protein	>65%	36-42%
Fat	10-15%	42-49%
FFA	15% max	15% max
PV	<20	<20
Moisture	<5%	508%
Ash	<20%	8-11%
Fiber	2.0%	1.8-2.5%

Novus International, Inc., July 12, 2000, Marietta, GA

Sludge Meal (% as given) from miscellaneous commercial drying equipment

Moisture Range	4-8	Protein Range	25-35
Fat Range	30-45	Ash Range	10-15
Fiber Range	2-4	Lysine Range	2.00-2.10
Methionine + Cystine Range	1.05-1.25	Arginine Range	1.45-1.70
Threonine	1.25-1.40	Tryptophan Range	0.35-0.55

Dr. Keith Rinehart, Perdue Farms, May 15, 2000 Report

ALTAPRO™ (typical analysis)

Moisture	10.75	Threonine	1.36
Protein	27.50	Alanine	2.03
Fat	35.0	Cystine	0.47
MetEn	1950.00*	Methionine	0.50
Ash	15.00	Cyst + Meth	0.97
Fiber	1.50	Phenylalanine	1.29
Calcium	2.15	Lysine	1.61
Total Phosphorus	1.10	Arginine	1.53
Avall Phosphorus	1.10	Tryptophan	0.28
Choline	1050.00*		

Closed Systems, January 26, 2000 Field Report

Computer evaluations of the feed grade sludge-meal range from 65% to 75% of the nutritional value of poultry meal, when fed at low levels in the formula (< 5%). The value is less when the inclusion level in the feed increases.

SUMMARY

Our industry must pursue a risk-taking atmosphere when considering new emerging technology and processes.

Our efforts must be directed toward a pro-active, not a re-active clean-up mode.

We now have the technology to use our waste by-products (sludge) beneficially as a feed ingredient. Drying sludge is an economically viable step in the waste treatment process that can not only create a marketable product, but will help in preserving our limited landfill space, thus, allowing us to maintain a healthy environment.

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INDUSTRY SOLUTIONS TO ON-FARM ENVIRONMENTAL ISSUES

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In day of olde
When knights were bold,
And regulations weren't invented
Agriculture was the way of life and life was fairly simple.

In this new millennium, we are going to see agriculture change in ways it has never changed. During this era, when no activity can be conducted without some sort of regulation, American agriculture is about to experience the "oversight" and that oversight will be conducted by individuals who think food is produced in the back rooms of our nation's supermarkets. One only has to observe the European model of animal agriculture to foresee what is coming to the American farming community. There will be those who will fight this oncoming regulatory juggernaut and some who just give up traditional farming and start growing houses. But someone will have to grow food for the American citizen and for the world community! What solutions will agriculture have to come up with to meet this new challenge?

Some people believe on-farm environmental issues are as simple as mandating the agricultural operations have a nutrient management plan, issuing a permit, shifting the liability and requiring poultry operations to have adequate manure/litter storage and dead-bird management. If it were that simple, I think the on-farm environmental issues would be easily solved. If we had the solutions to the on-farm environmental issues, we would not be having this discussion.

Certainly, no one has all of the solutions to the on-farm environmental issues. However, there are several options that should be explored by the poultry industry. I am not advocating one or any of these options, but just advancing them for thought and consideration. Throughout the entire discussion of on-farm environmental issues, companies must take care not to cross over that independent contractor line that is established by the contractual relationship between the producer and the integrator. On the other hand, companies may need to consider other business models and organizational structures.

Companies need to approach on-farm environmental issues the same way that they deal with facility environmental issues. Some of the steps are: identifying the issues, understanding the issues, understanding the regulatory parameters surrounding the issues, incorporating environmental solutions with other segments of the business, calculating economic impact and presenting the issues to senior management and the individual producers. In today's business climate, environmental issues do not exist in a vacuum. Environmental issues are intertwined with many of the other issues the industry is facing today. We cannot ignore food safety, bio-security, animal welfare and producer relations when making environmental decisions.

Our industry is entering a new arena in which neither the companies nor the producers have ever been. It is full of uncertainty, suspicion, and questions. An extensive educational effort must be mounted so that all players have the information they need to understand the issues they have been asked to address. Furthermore, the players in this new arena go beyond the companies and their producers. In today's environmentally conscience society, regulators, legislators, special interest groups and the general public are interested in our business and how we intend to protect the environment. Education programs must be developed that are tailored to meet individual stakeholder needs.

How is our industry responding to these challenges? Some are building cogeneration plants that use litter, some are building stand-alone power plants that use litter, and others, litter pelletizing plants. These so called solutions are all extremely capital intensive, but only shift the potential environmental impact to another receiving media and deal with the end result of an operation. Also, the industry is supporting the expanded use of manure/litter sheds and more effective dead-bird management. These efforts are simple and are a logical progression of the industry. But, do they really provide a solution or just a short-term fix? This certainly calls for the Plan, Do, Check and Improve approach to problem solving.

The concept of Pollution Prevention must be instituted as the industry addresses on-farm environmental issues. If what some people consider a waste stream is not produced, then we do not have to deal with that waste stream. If you are making cars, then pollution prevention is a relatively simple task. However, our industry is dealing with a living, biological entity, thus making pollution prevention somewhat more difficult. Traditional methods of grow out use organic material for bedding, i.e. pine shavings, rice hulls, etc. Use of renewable bedding material and new bedding materials must be investigated, refined and utilized. Do we need to continue to raise birds in the "wide-open spaces" of houses or do we investigate use of other methods? While such practices would not eliminate nutrient issues, the volume of manure/litter would certainly be reduced.

As mentioned earlier, environmental issues are intertwined with many other issues. The industry cannot forget the bird itself. What new feed formulations are needed to meet both the nutritional needs of the bird and assist in reducing environmental

impacts? What breed of bird is best at converting the new feed formulations? Do new breeds of birds need to be developed? Do different grow out techniques contribute to improved performance, as well as, reducing the environmental impact?

The role that the bird plays in environmental enhancement has more questions than answers.

As the industry evaluates potential new producers, we need to adjust our evaluation procedures to include environmental issues. Does the site meet the minimum requirements for environmental protection? Will the site present any environmental challenges to the daily management of the operation? How will the producer manage the manure/litter issue? Does the producer understand his role and his responsibility as it relates to environmental protection? Will the producer understand and accept the role that the integrator must play to ensure it meets requirements imposed by environmental regulations? Clearly, there will be some evolution in the producer-integrator relationship.

On-farm environmental Issues are and will continue to be a challenge for the poultry industry. All stakeholders have not been heard, the goals have not been clearly presented and the rules of the game have not been finalized. Another hurdle has been placed in front of agriculture in their continuing efforts to feed the American people and the world. I am sure that the industry is up to the challenge and will continue to do its part in the protection of the environment. However, should all else fail, get out of the country.

TECHNOLOGIES FOR AMMONIA CONTROL IN POULTRY FACILITIES

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Nitrogen (N) is excreted in animal waste as urea, which is an excellent N fertilizer. However, after excretion, the urea in manure is quickly converted to ammonia via urease enzymes, produced by microorganisms. Once converted to ammonia, this valuable N source is lost into the environment in gaseous form, decreasing the nutrient value of the litter. Ammonia, once released into the atmosphere of poultry facilities, adversely effects both the birds and personnel working on the farms.

Previous research has indicated that high levels of ammonia in poultry facilities can cause increased susceptibility of birds to diseases, such as airsaculitis (Kling and Quarles, 1974), Newcastles disease (Anderson *et al.*, 1964), and keratoconjunctivitis (Bullis *et al.*, 1950). High ammonia levels have also been found to decrease growth rates (Reece *et al.*, 1980), reduce feed conversion (Caveny and Quarles, 1978), and decrease egg production (Deaton *et al.*, 1984). Due to the problems caused by ammonia, it is recommended that ammonia levels in poultry facilities not exceed 25 ppm (Carlile, 1984). Therefore, it is important to control ammonia volatilization from poultry litter.

The effect of many different chemicals on ammonia volatilization from poultry litter has been studied in the past. These litter amendments fall into three separate categories, those that inhibit microbial growth and urease production (which slows conversion of urea to ammonia), clays which absorbs ammonia odors and reduces ammonia volatilization by absorbing moisture, and acidifying agents that convert ammonia (NH_3) to ammonium (NH_4), which is not volatile.

There are several litter treatments available to poultry producers. Therefore, it is important to research these products to determine which is most effective at reducing ammonia volatilization. This paper will review several of these chemical amendments and report the results found in the research.

MICROBIAL/UREASE INHIBITORS

Ammonia volatilization can be controlled using microbial/urease inhibitors. When urea is deposited in the litter, microorganisms produce an enzyme (urease) which converts urea to ammonia. Therefore if the growth of these microorganisms can be prevented or slowed down, the conversion of urea to ammonia would also be reduced.

Microbial inhibitors were among the first ammonia control products studied. Paraformaldehyde flakes (Seltzer *et al.* 1969) and volatile fatty acids (Parkhurst *et al.* 1974) seem to work as both an antimicrobial agent and a litter acidifier. In studies using paraformaldehyde flakes, microbial populations and ammonia concentrations were greatly reduced in laboratory and field studies (Seltzer *et al.* 1969). Control pens had high levels of ammonia (100+ ppm) while the treated chambers had low ammonia levels (5 ppm) (Seltzer *et al.* 1969). This study also showed that the treatment had a short duration; 14 d after application the treatment had evaporated and no longer controlled ammonia (Seltzer *et al.* 1969).

Antibiotics have also been found to reduce ammonia volatilization from poultry litter (Kitai and Arakawa, 1979). Thiopeptin added to fresh poultry litter showed a significant reduction in ammonia emissions. Additions of thiopeptin or zinc bacitracin also had significant reduction in ammonia emissions (Kitai and Arakawa, 1979).

More recent studies have been done using specific urease inhibitors. Laboratory studies were conducted by Varel (1997) using cyclohexylphosphoric triamide (CHPT) and phenyl phosphorodiamidate (PPDA) which are urease inhibitors. Theses treatments when added to manure weekly prevented 92% of the urea from degrading to ammonia (Varel 1997). Field studies using (CHPT) and N-(n-butyl) thiophosoric triamide (NBPT), also a urease inhibitor, show significant accumulation of urea in the manure (17g/kg manure) which indicates ammonia volatilization was restricted (Varel 1999). The ability of urease inhibitors to control ammonia loss into the environment is temporary (4-11d) but can be extended by retreating weekly (Varel 1999).

CLAYS

Certain clays have the ability to absorb both moisture and odors. By lowering moisture content of poultry litter and absorbing ammonia odors, ammonia levles can be reduced. Clinoptiloite (zeolite) can reduce moisture content of poultry litter by 15% and when added at 5km/m^2 (Nakaue *et al.*, 1981). At the same application rate, ammonia levels were reduced by 15% (Nakaue *et al.*, 1981). Additions of 10% clinoptiloite to the bird diet also significantly reduced ammonia levels (Nakaue *et al.*, 1981). When clinoptiloite was used as a bedding source for the birds dust levels were significantly increased as well as bird mortality (Nakaue *et al.*, 1981).

ACIDIFYING AGENTS

Ammonia has no ionic charge and is not easily bound. Therefore, it can readily be released into the atmosphere as a gas. Ammonia can be protonated and converted to NH_4, which is not volatile, in acidic environments. Therefore, ammonia volatilization from poultry litter is extremely dependent on litter pH. The pH of normal poultry litter is basic (8.0-8.5),and by adding acids to the litter ammonia volatilization can be reduced. Many different acidifying agents have been studied to determine there effectiveness in reducing ammonia volatilization. These chemicals are superphosphate (Cotterill and Winter, 1953; Reece *et al.*, 1979), phosphoric acid (Reece *et al.*, 1979), ferrous sulfate (Huff *et al.*, 1984, Moore *et al.*, 1996), ferric chloride (Moore *et al.*, 1996), aluminum sulfate (Moore *et al.*, 1995; 1996;1999), and sodium bisulfate (Moore *et al.*, 1996; Terzich, 1998).

Early research evaluated acidifying agents such as superphosphate (Cotterill and Winter, 1953; Reece *et al.*, 1979), and phosphoric acids (Reece *et al.*, 1979). Superphosphate (0.4 kg/m2) was shown to be able to reduce litter pH form 7.5 to 6.6 and phosphoric acid (0.4 kg/m2) reduced litter pH from 7.6 to 5.4 (Reece *et al.*, 1979). The pH of the litter slowly increased over the study period and treated litter pH and control litter pH became equal at 17 weeks (Reece *et al.*, 1979). Ammonia data from this study showed a decrease from 180 ppm for the control to 125 ppm for superphosphate and 26 ppm for phosphoric acid (Reece *et al.*, 1979). As shown with the increase in pH over time the ammonia levels also increased over time (Reece *et al.*, 1979). Of the two litter amendments the phosphoric acid had greater acidifying capabilities and was able to reduce litter pH and ammonia volatilization better than superphosphate. Although these amendments reduce ammonia volatilization, treating with these compounds adds phosphorus (P) to the litter which can lead to environmental problems.

Moore *et al.* (1996) conducted a study in which several different acidifying agents were added to poultry litter and ammonia volatilization analyzed. The chemicals compared in this study were (1) sodium bisulfate, (2) ferric chloride, (3) ferrous sulfate, (4) aluminum sulfate (alum), (5)phosphoric acid, and (6) Ca-Fe silicate with phosphoric acid coating. The results of this study indicated that of all the acidifying chemicals used, alum and phosphoric acid had the lowest amount of ammonia volatilization and lowest pH values. Ferrous sulfate also had significant ammonia reduction and low pH, however mortality with ferrous sulfate treatment is often high, probably due to iron toxicity (Moore *et al.*, 1996).

There have been several studies conducted showing that alum can greatly reduce volatilization from poultry litter (Moore *et al.*, 1995; 1996; 1999). Ammonia emissions were reduced to zero for the first four weeks when alum was used in commercial broiler houses (Figure 1). Other studies have shown alum use increases broiler growth rates, results in improved feed conversion, and lowers energy use in broiler houses (Moore *et al.*, 1999). Alum applications to broiler litter have also been shown to offer environmental advantages, such as reduced phosphorus runoff (Shreve *et al.*, 1995; Moore *et al.*, 1999), reduced heavy metal runoff (Moore *et al.*, 1998a), and reduced estrogen runoff (Nichols *et al.*, 1997), without increasing aluminum runoff (Moore *et al.*, 1998a) or aluminum availability in soils (Moore *et al.*, 1998b).

NEW TECHNOLOGY FOR AMMONIA CONTROL IN HIGH-RISE LAYING HEN HOUSES

Dry acids, such as alum, have worked very well as litter treatments in the broiler industry. However, due to the large amount of manure accumulation in high-rise laying hen houses, it is not feasible to use dry products. One alternative for this type of facility would be to

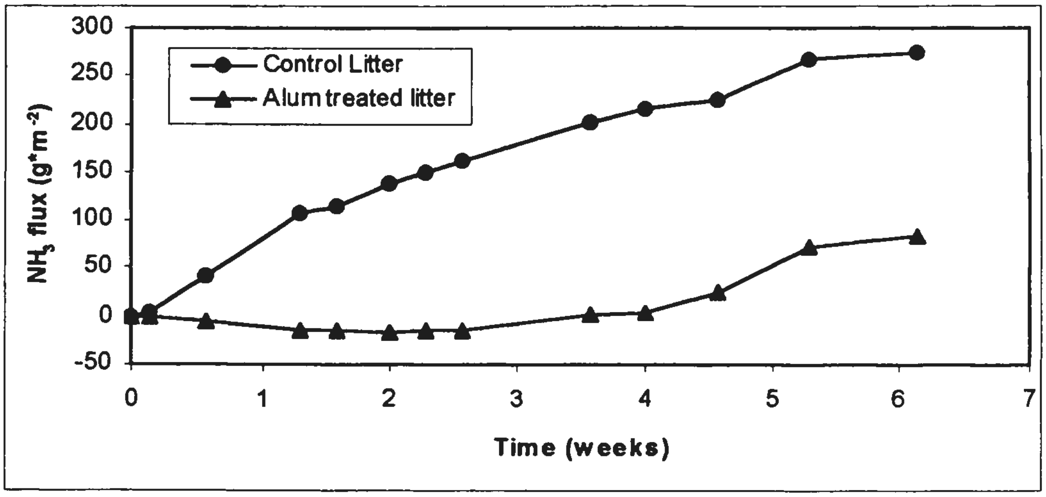

Figure 1. Ammonia flux from litter as a function of time using alum (Moore *et al.*, 2000).

spray liquid acids, such as liquid alum, and scrub the ammonia from the air. The objectives of this research were to design and build a liquid alum delivery system for a high rise laying hen house and to determine the effectiveness of liquid alum applications on reducing ammonia levels in these facilities (Wilson *et al.*2000).

Preliminary ammonia studies were conducted to determine the effectiveness of liquid alum at reducing ammonia levels. Ammonia flux chambers (35 gallon plastic trash cans equipped with battery operated fans inside) were used (Wilson *et al.*, 2000). Alum treatments were applied after the chambers were inverted over the litter. Three studies were conducted using the flux chambers. Each of the studies utilized a randomized block design with four replications per treatment. The first study compared different rates (40 g and 80 g) of liquid alum (48.5% alum dry weight basis). The second study evaluated the effect of different aluminum containing compounds (liquid alum, high acid alum, and aluminum chloride). The third study compared different concentrations of liquid alum (12.5, 25 and 50%). Once the data from these studies were analyzed, it was concluded that the 25% liquid alum solution was effective in reducing ammonia levels, while not adding excessive moisture.
After the preliminary data was collected the delivery system was designed and installed in a high-rise hen house. The system was constructed of 1" PVC pipes suspended over each of the five rows of manure. The 1" PVC was connected to a 6" PVC pipe at the center of the house. Liquid alum was pumped into the central 6" PVC into the 1"pipes. The alum is then sprayed through RainBird® irrigation nozzles using air pressure. The system is operated using a controller which can be ran manually or run automatically using timers or ammonia sensors. Once the system was installed in the house, data was collected to determine the rate and frequency of alum treatments needed to control ammonia. The first treatment was 10 seconds sprayed every hour. Ammonia levels at bird height were very high initially (around 70 ppm) when data collection started (Figure 2) (Wilson *et al.*, 2000). Once the alum was sprayed and stir fans began mixing the treated air, the ammonia levels dropped from 70 to 40 ppm in less than 20 minutes. Then ammonia levels came to a plateau. After each alum treatment, ammonia levels would decrease to a lower level than the previous treatment making a stair-

step pattern (Figure 2). The reason for this stair-step pattern is fairly simple; when alum is applied, it only scrubs the air downstairs (Wilson *et al.*, 2000). After the fans are turned back on, the air upstairs and downstairs mixes, causing a dramatic reduction in ammonia upstairs. An equilibrium is then reached and the ammonia concentrations level out. Then alum is applied again and the process is repeated. It should be noted that the mechanism of action for liquid alum being sprayed is much different than in a broiler house, where reductions in pH cause lower ammonia emissions. In this case, the liquid alum is actually scrubbing the ammonia from the air, rather than preventing emissions.

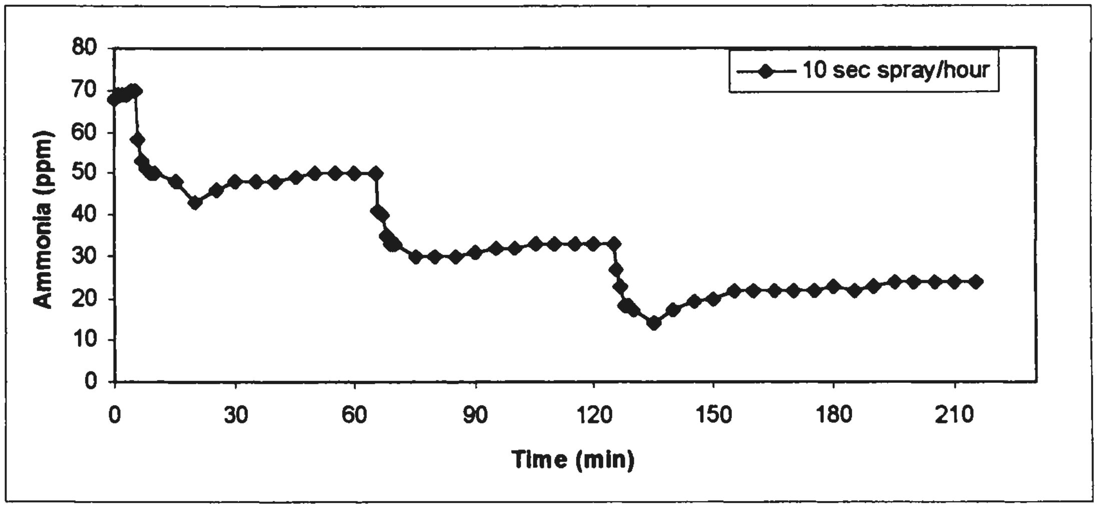

Figure 2. Ammonia data collected when liquid alum was applied in 10 sec sprays in a commercial high-rise laying hen house (application occurred at 5, 65 and 125 minutes).

In the second trial, the objective was to determine if a lower rate of alum sprayed more frequently would work as well or better than the longer spray times. Alum was sprayed for 2 seconds every 30 minutes. Again, ammonia levels were extremely high in the beginning (~90 ppm). The results showed a quick decrease in ammonia levels after the initial alum spray, then the ammonia levels would slowly increase (Wilson *et al.*, 2000). As in the previous trial, the ammonia was reduced following alum applications (Figure 3). The lower rate applied more frequently appeared to reduce the ammonia levels more efficiently than in the previous treatment.

As mentioned earlier, the mechanism of ammonia reduction using this technology is different from that used in the past. Laying hen manure is very wet and has a high base content. The amount of acid needed to lower the pH of this manure is much greater than that needed to scrub ammonia from the air. Hence, this technology is much more cost-effective than previous litter treatments which function by litter acidification.

The data collected in this study thus far have indicated that liquid alum is very effective at reducing ammonia levels in high-rise laying hen houses. The next step is to determine the most effective rates and frequencies of alum application (Wilson *et al.*, 2000). From an economic point of view, it will probably be most cost-effective in fully automatic systems, where alum is only sprayed when ammonia sensors detect ammonia levels above a certain threshold level (such as 25 ppm).

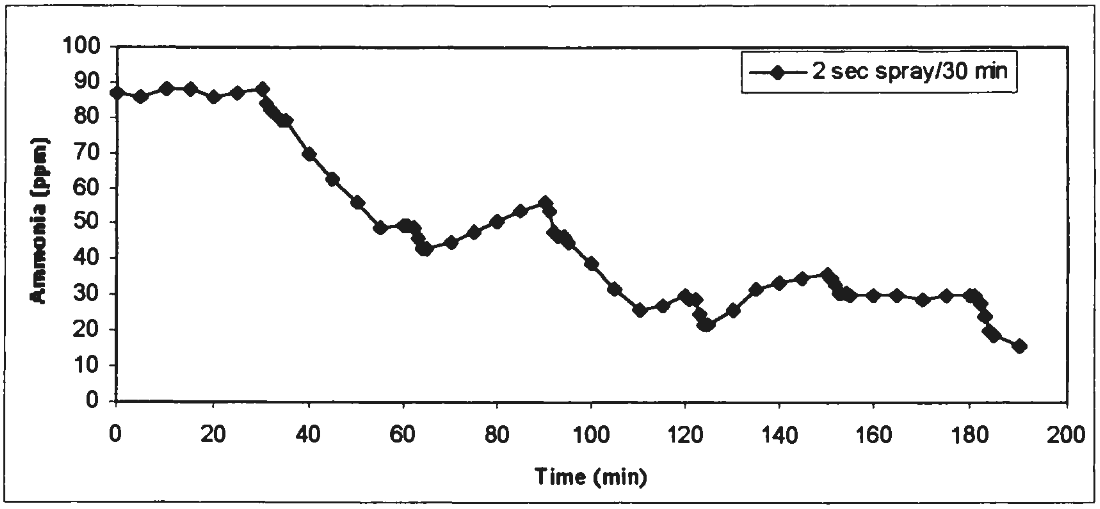

Figure 3. Ammonia data collected when 2 second alum sprays were applied every 30 min using the full scale alum delivery system in a high-rise laying hen house.

By decreasing the ammonia levels in laying hen facilities, hopfully there will be an increase in productivity of the hens. Reduced atmospheric ammonia levels in these facilities will also make them a safer place for farm workers.

SUMMARY

Ammonia volatilization from poultry litter is detrimental to agricultural workers in these facilities, poultry and the environment. There are several options available to poultry producers to reduce ammonia release from poultry litter. Microbial/urease enzyme inhibitors work well at reducing ammonia volatilization short term. In order to obtain long term ammonia control, these products must be reapplied weekly. Acidifying agents are another alternative to the ammonia problem. Acidifying agents can control ammonia up to four weeks, although the amount of control decreases with time. Of the acids researched with poultry litter, alum and phosphoric acid seem to obtain the greatest ammonia control. Although phosphoric acid controls ammonia, the P content of the litter is increased which can accelerate P runoff into the environment. Alum not only has great ammonia control, but also binds P in the litter which reduces P runoff into the environment. By using ammonia control products, there can be an economic benefit to the producer, better poultry production, and better environment for both the birds and the workers.

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EVALUATION OF MORTALITY PROCESSING ALTERNATIVES

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Current U.S. broiler production approaches eight billion birds annually and the industry suffers a death loss of an estimated 400 million birds/400,000 tons each year (based on an approximated 5% mortality rate and 2.0 lb. average carcass weight as used by Blake *et al.*, 1990). These carcasses create disposal challenges in all production regions and can pose microbial risks to watersheds and contribute to air quality concerns. Commercial methods of mortality management can include burial, digestion, incineration, rendering, or composting. Use of these mortality management strategies varies by production region.

Since all of these strategies can be problematic due either to cost, extensive carcass handling, labor and management requirements, microbial contamination risks to the watershed, or a combination of these factors, widespread research and development activities are continuing to identify new, more efficient and more economical mortality management alternatives. Newer technologies under investigation and development often support stabilization of carcasses destined for nutrient recovery (i.e. rendering) or other value-added uses.

Several states now allow the use of mass burial procedures only for catastrophic loss events. Implementation of new, low management, environmentally friendly, on-farm management alternatives are needed to meet some of the challenges facing industry while protecting environmental quality.

SUMMARY OF TRADITIONAL MORTALITY MANAGEMENT OPTIONS

Mass Burial Pits

Mass burial pits have historically served as a basic means of carcass disposal. However, this method is quickly loosing favor in areas of concentrated production, more populated regions, or in environmentally at-risk watersheds due to potential problems associated with microbial contamination of groundwater. Alabama, Arkansas, Georgia, Texas and some other states have banned the use of mass burial pits except under conditions of a catastrophic loss.

Incineration

Incineration is an expensive but biologically safe method of carcass disposal. Incinerators consume fossil fuels and discharge emissions that contribute to atmospheric pollution. However, due to the ease of operation and relatively low management required, they will likely be part of many management plans for years to come. Generation of an end product with little or no value combined with the expense of operation puts incinerators in a position to be replaced by more economy-minded strategies that allow for lower operating costs and/or value-added end products.

Composting

Composting is an environmentally friendly, natural process that yields a useful end product with value-added potential. When managed correctly, composting will produce a quality product that can be used for improving soil tilth and soil nutritional levels and can be marketed to landscape, horticultural or agronomic enterprises. The success of the composting process depends on several basic conditions including moisture content of the raw material, ability to aerate the compost mass, degradability of the organic material, and the presence of appropriate microflora.

Although several composting technologies are available including windrow, static bin and other in-vessel techniques, static bin composting has been the most widely adopted composting technology in the poultry industry for management of mortality.

Rendering

Transport of mortality to a rendering facility for nutrient recovery is perhaps one of the most logical methods of mortality management currently available and results in value-added end products. Rendering produces a number of products, including protein, bone meal and fats, which can be used in a number of products including livestock feeds.

Challenges that appear to limit the use of rendering techniques as part of a farm mortality management strategy include the need to be in close proximity to a rendering facility, biosecurity issues associated with transport of potentially diseased carcasses, value of the rendered products, and the need for temporary on-farm mortality storage facilities. At present, refrigeration is the most common on-farm storage technique for mortality that are awaiting delivery to a rendering facility.

CURRENT STATUS OF MORTALITY MANAGEMENT BY STATE

Following are updates on mortality management activities by state obtained via personal communication:

Alabama

As of July 1, 2000, burial is no longer permitted as a method of disposal for poultry carcasses in Alabama except in the case of a catastrophic loss event (J.P. Blake, personal communication, July 24, 2000). As a result, incineration, composting and rendering are the only commercial options currently used in Alabama. Approximately 20% of the state's mortality is managed using incineration techniques, 70% by composting and 10% by rendering.

Composters have become widespread in the state and seem to be working well when managed properly. Only one integrator and one private company that services growers under contract to various integrators are utilizing rendering. Refrigeration is the means being used commercially to store carcasses on-farm while awaiting pickup and delivery to a rendering facility. No new technologies are being implemented on a commercial scale at this time, however field-testing of a fermentation system is underway.

Arkansas

Growers for one integrator utilize freezers for on-farm mortality storage prior to delivery to a rendering facility (S.E. Watkins, personal communication, July 31, 2000). Approximately 25% of the state's mortality is managed through rendering techniques, 30% are composted and about 45% are incinerated. Other mortality management strategies such as acidification are not being implemented commercially at this time.

Use of incinerators in Arkansas will probably remain popular in the future due to convenience, but fuel prices will have an obvious influence. Use of composting will likely increase if incineration looses favor due to cost. Some composting operations have experienced problems with wildlife attraction. This attraction could facilitate encroachment of diseases from the wild as well as promote spreading of diseases between producers. The use of burial pits became illegal in Arkansas in 1992.

Georgia

Poultry producers in Georgia can choose between several state-approved methods including pits (roughly 3 X 8 X 6 ft deep, unlined chambers), composting, incineration, rendering and digestion (D.P. Smith, personal communication, July 26, 2000). Approximately 90% of the producers utilize pits, especially as a backup to other options such as incinerators or composters. Five to 10% of growers use composting techniques (primarily static bin) while 10-15% use incinerators. Less than 5% utilize rendering options or on-farm digestion techniques. Digesters (basically sealed tank operations) are now being discontinued as an approved method by the Georgia Department of Agriculture due to operational problems.

Mass burial is used only for emergencies and alligator farms are being used on a trial/test permit basis at this time. The use of composting and incineration may increase slightly in the future, while rendering and digestion techniques will probably decrease.

North Carolina

North Carolina poultry producers can dispose of mortality through burial, although dead pits are not allowed in the coastal area where the water table is high (T.A. Carter, personal communication, August 1, 2000). Approximately 35% of the carcasses in North Carolina are managed using burial techniques, 20% by composting, 25% by incineration and 20% by rendering.

The future in North Carolina will probably see a reduction in use of burial pits and increased usage of incinerators. Construction of new composters in the state has nearly ceased. Rendering continues to show some potential when using freezers or other preservation methods for on-farm carcass storage. However, carcass transportation cost from the farm to the rendering facility as well as quality of the rendered product continues to hold back acceptance of this management technique.

Texas

The approved methods of mortality management primarily used in Texas include incineration, composting and rendering (J.B. Carey, personal communication, July 28, 2000). At present, estimates indicate that each of these three methods is used equally by industry. Increase in the use of rendering may occur in the future, especially if transportation logistics are improved. Centralized composting procedures may provide additional options for some growers.

Work is ongoing in the area of fermentation as an alternative to freezing for on-farm storage of carcasses prior to rendering.

EMERGING MORTALITY MANAGEMENT TECHNOLOGIES

Following are summaries of emerging mortality management strategies that are not yet widely used in the poultry industry:

Fermentation For On-Farm Storage Prior to Rendering

As an alternative to freezing for on-farm storage of carcasses prior to delivery to a rendering facility, lactic acid fermentation techniques will preserve carcass tissues for several months (Blake and Donald, 1995). The fermentation process typically utilizes microflora present in the digestive tract to convert added carbohydrates into lactic acid for pH reduction to below 4.5.

This process requires grinding of carcasses to release lactic acid forming bacteria and subsequent mixing with a fermentable carbohydrate in sealed fermentation tanks. Due to pH reduction, the fermented product can be stored until it is economical to transport mortality to the rendering facility. Pathogenic microorganisms associated with the carcasses are inhibited during the fermentation process.

Acidification For On-Farm Storage Prior to Rendering

This procedure is similar to the fermentation process except that sulfuric or phosphoric acid is added to carcasses (Blake, 1998). Nutrients are preserved, pathogens are inhibited and rendering yields acceptable quality feed ingredients.

Alkaline Storage Prior to Rendering

Poultry carcasses can be preserved for several months using alkaline hydroxides to increase the pH to 13.0 (Burgess and Carey, 1999b). Using a 10% solution of KOH, mortality from up to three flocks of broilers could be preserved by adjusting the pH to 13 between each flock. Feeding of the rendered product in broiler starter diets appeared feasible from preliminary trials (Burgess and Carey, 1999a). Also based upon preliminary studies, use of the remaining alkaline effluent as a soil amendment appears feasible (Burgess *et al.*, 1999).

Extrusion

Extrusion uses friction to generate the heat required to sterilize and dehydrate mortality and this process can be used as an option to rendering (Blake, 1998). Carcasses can be ground with other feed ingredients if desired prior to extruding.

Extrusion is currently considered an expensive alternative to rendering and is not suitable for on-farm use due to the cost of equipment.

Rotating Tank, In-Vessel Composting

Composting of poultry carcasses mixed with poultry litter using a rotating-tank in-vessel composter can decompose carcasses in three days and complete thermophilic stabilization of the compost mass in four to six days (Cawthon and Freeman, 1999). A compost containing 25% carcasses by weight was found to be free of coliform and salmonella bacteria as well as botulism spores and toxin. When analyzed as a feed, the compost contained 24.9% crude protein, 4.0% fat, 15.3% fiber, and 82% total digestible nutrients and could have value-added application as a ruminant livestock feed ingredient.

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COMPOSTING OF MANURE IN HIGH-RISE LAYER HOUSES

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Manure from curtain sided high-rise layer houses can be characterized as a black putrid material that is difficult to spread, causes odors and can attract and generate flies. To reduce these negative aspects of manure handling and to enhance the market potential of layer manure the following in-house composting system was devised and tested.

THE SYSTEM

Beds of 5 inches, 10 inches or 15 inches of a sawdust/woodchip mixture were placed under the cage lines of a curtain sided high-rise commercial laying house. Each bed was 130 feet long. Manure excreted by the birds was depositied on the surface of these woodchip lines. At two week intervals, the manure/woodchips mixture was turned with a mechanical compost turner to promote composting. To compare the effect of composting to that of the conventional method of allowing the manure to simply accumulate, one line received neither woodchips nor turning.

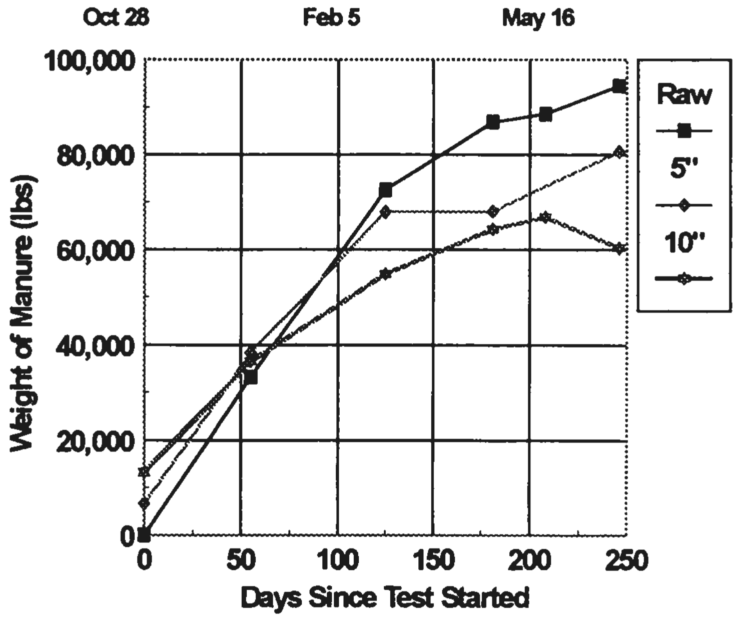

Figure 1. Weight of manure remaining during in-house composting test per 130 foot line.

RESULTS

During the 246 day test period the birds deposited approximately 280,000 pounds of manure onto 4 each 130 foot long test sections of the manure line. The manure lines contained: 0 pounds (control), 6,600 pounds (5 inches), 13,225 pounds (10 inches) or 19,825 pounds (15 inches) of a sawdust/woodchips substrate, respectively.

During the test period the weight of manure excreted by the birds (280,000 pounds) was reduced by 67.2% by simply allowing it to accumulate and air dry. However, addition of 5 inches, 10 inches or 15 inches of wood chips and turning at two week intervals reduced weights by 72%, 80% and 82.2%, respectively. In Figure 1 is shown the weight of the manure/compost which accumulated under the cage lines during the 246 day test period. The manure weight was sampled periodically over the 246 day period as indicated in the graph. The manure weight was determined by sampling a 16 inch long cross-section of each treatment at selected points and weighing the manure removed from that cross-section. Weight reduction in the 10 inch and 15 inch lines were similar

The volume of manure which accumulated under the cage lines was measured by profiling a cross-section of the top surface of the lines at selected points. In Figure 2 is shown the volume of the manure which accumulated under the cage line using 10 inches of sawdust/woodchips mixture. After March 2, the manure appeared to be breaking down at

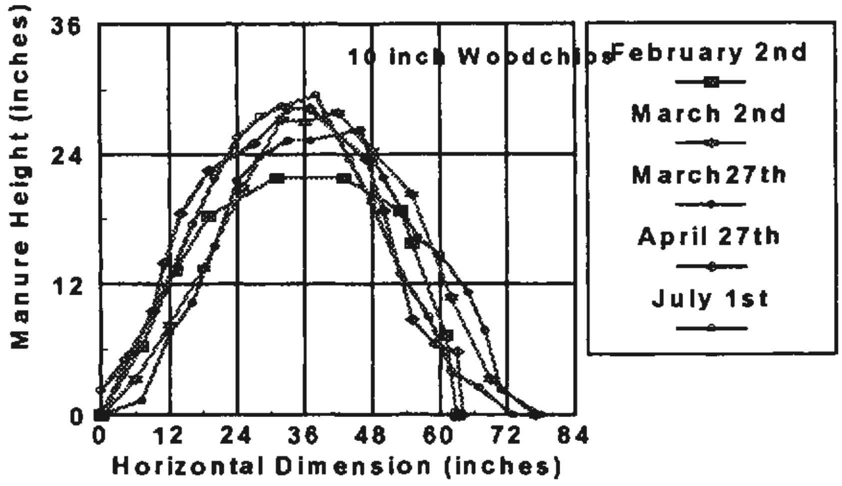

Figure 2. Volume increase of the layer manure/compost with 10 inches of woodchips.

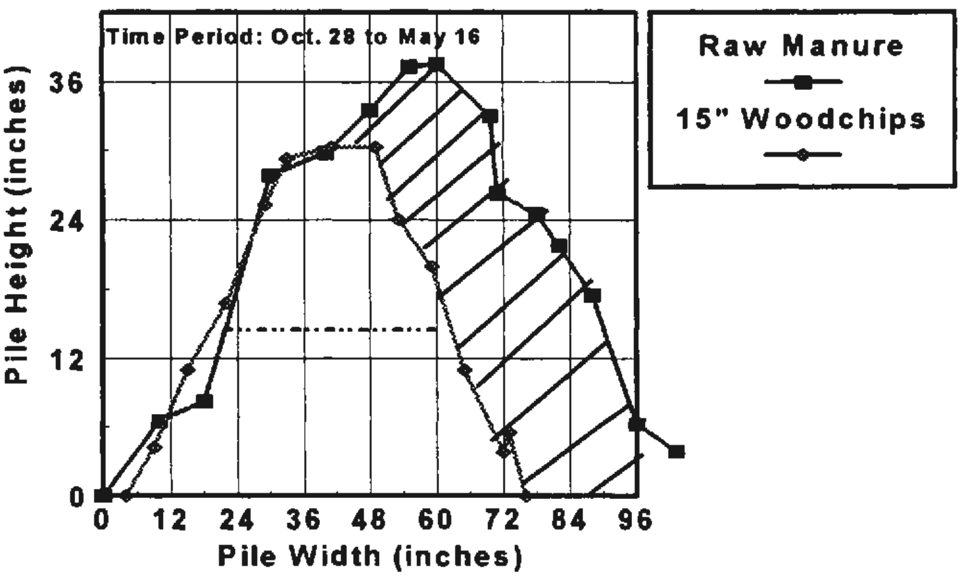

Figure 3. A comparison of the cross-section volume of the composted and non-composted layer manure. The area under the dotted line indicates the original volume of the 15 inch sawdust/woodchip mixture.

approximately the same rate it was being deposited and thus the volume remained approximately the same. Figure 3 compares the cross-section volume of manure composted with 15 inches of woodchips with that of untreated manure. The cross-hatched area shows the increased volume of the untreated manure to that of the composted manure. The volume reduction in the 10 inch and 15 inch woodchips treatments were approximately the same.

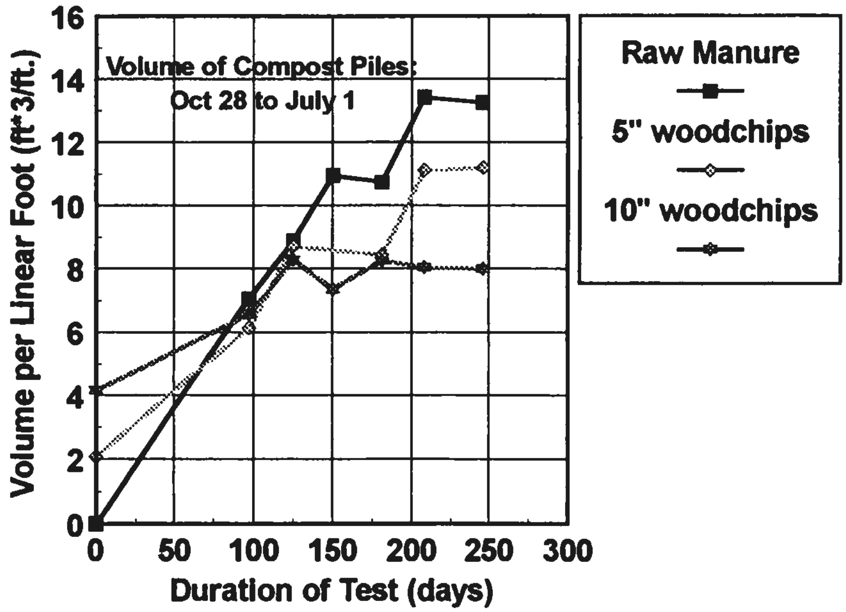

Figure 4. Volume of the Manure and the Composted Materials Over the 246 Day Test Period.

Evaluation of the reduction of volume of manure composted in a high-rise laying house after 246 days revealed that the manure line receiving no treatment contained 13.5 ft^3 of manure per linear foot of line whereas the composted lines containing 5, 10 or 15 inches of woodchips contained 11.2, 8.0, and 8.0 ft^3 per linear foot of line, respectively.
Figure 4. Volume of the manure and the composted materials over the 246 day test period.

The composted material had an earthen like odor and would not attract flies or support their growth. Analysis of the dry weight 15 inch compost revealed a N, P_2O_5, K_2O and $CaCO_3$ (lime) content of approximately 2, 8.5, 4.5 and 40 percent, respectively. The composted material had a more acceptable market potential.

SUMMARY

Interpolation of data from the 130 foot section of lines to a whole house condition (100,000 birds on 5-each 540 foot lines) determined that 363 tons and/or 550 cubic yards less material would need to be removed and handled using 10 or 15 inches of woodchips for composting as compared to a conventional manure system.

The compost has an improved market potential due to its improved physical and aesthetic properties.

ON-FARM ASSESSMENT AND ENVIRONMENTAL REVIEW PROGRAM

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ABSTRACT

The importance of proper environment management at livestock operations in the U.S. has drawn increased attention in recent years. Environmental management at livestock operations generally focuses on preventing contamination of surface or ground water sources, and reducing odor and pest impacts. America's Clean Water Foundation (ACWF) has implemented a program designed to improve the overall environmental stewardship of livestock producers while improving efficiency if possible.

ACWF's On-farm Assessment and Environmental Review (OFAER) project provides livestock producers a confidential, comprehensive and objective assessment of water quality, odor and pest risk factors at their operations. Participation in the project is purely voluntary on the part of and at no charge to the livestock producer. Producer participation and farm specific information is kept strictly confidential. A producer is provided a written assessment report following completion of an assessment. The assessment report provides recommendations to reduce an operation's actual or potential impact on surface or ground water quality, and ways to minimize the generation of odor and pests from an operation.

Assessments are conducted by teams of professionals who have been trained, tested and certified to identify water quality, odor and pest risks through the use of specific assessment techniques and protocols. Initially developed for use in the pork production industry, the assessment techniques and protocols have been developed and refined by a team of agricultural engineers and manure management specialists from private industry, the Cooperative Extension Service, the Natural Resources Conservation Service, and producers. These assessment techniques have proven effective on a wide variety of production facilities from small, open-lot operations to large, total confinement facilities. The assessment techniques and protocols have been further refined for use in other livestock sectors including poultry, egg-laying, dairy, and open-lot cattle operations. Assessment have begun in those livestock operations as well.

Data gathered from over one thousand assessments conducted to date indicate most risk factors can be addressed through implementation of relatively low-cost and easy to

implement better management practices that not only improve environmental performance but, in many instances, the economic efficiency of operations as well.

ADVANCES IN INSECT CONTROL

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The management of arthropod pests on poultry production facilities has been a challenge that has best been met by the use of Integrated Pest Management programs. The use of cultural, biological and chemical methods has provided an avenue by which producers could implement pest management programs to attempt to maintain pest populations below pest and nuisance thresholds. Each of the three components of IPM has been utilized in currently used IPM programs, but the predominate component has been the reliance on chemical control to keep pest populations below thresholds levels. The use of chemical control is generally viewed as short term control while the use of cultural and biological control components provide a longer and more stable control program.

New advances in insecticides for use in animal production facilities has slowed due to the time and cost associated with the development of new materials and gaining EPA registration for them. In addition, under the current EPA program to review registered materials, a number of existing compounds will be removed from the market place.

Advances in cultural/management techniques have had an impact but are restricted to working within the current building or housing design. Since many production facilities have been in production for 20 years or more, changes in how manure is handled or changes in ventilation are limited to those which can be implemented within the constraints of the structure. Using fly control as an example, there are many aspects of management that have enormous impact on fly production. Time of year that clean outs are done, once or twice as dictated by the market for manure for use in cropping systems, impact how long manure deposited on the floor will be attractive to flies for breeding in layer systems. The amount of salt in water and feed has an impact on the water consumption of the birds and the moisture level of the manure. The ability of the house and fan system to remove moisture from the manure pack is very important. In general, the older the house the less insulation, and during cold weather ventilation, very little air is moved over the manure allowing for moisture build up making the manure attractive for winter fly breeding. Changes in the ventilation system that allows for an increased air flow over manure greatly increasing drying and getting the manure to below 60% moisture where it is less attractive to fly breeding.

Advances in bio-control have been slow due to the difficulty of working with living organisms as the control agent and the use of these organisms in the production setting. New strains of parasites show great promise as well as new techniques for the rearing and trapping of some predators of flies in poultry facilities. The use of the fungus *Beauveria bassiana*, an entomopathogenic fungus for the management of adult flies and beetles in poultry facilities is a new application for this bio-pesticide.

Beauveria bassiana is a fungus pathogen of arthropods that tends to be site/host specific. The specific isolates used in poultry houses for both beetles and flies were isolated from naturally infected darkling beetles and house flies from poultry facilities. These strains of fungus are more active against the specific insect species/group they were isolated from and tend to have higher efficacy when used in the same or similar environments that they were originally isolated from. The beetle isolate has shown excellent efficacy in litter and manure against hide and darkling beetles but has had low efficacy against house fly. The reverse is true with the strains isolated from flies, where efficacy against flies has been excellent and low efficacy against beetles. Both strains have shown little efficacy against the beneficial arthropods found in poultry manure which makes the use of *Beauveria bassiana* fully compatible with maximizing the use of predators and parasites for fly control.

The mode of action of *Beauveria bassiana* is simple. The conidia (spore) comes into contact with the insect cuticle, the conidia germinates and pushes a germ tube through the exoskeleton of the insect and allows the fungus to grow inside the insect. When the insect is consumed, the fungal mycelia emerges, and sporulates on the outside of the insect. For spore production of *Beauveria bassiana* to take place in the field, the environmental factors must meet the specific needs of the fungus. In the field, except under the most special conditions, there is little reproduction of the fungus.

The use pattern for *Beauveria bassiana* in poultry facilities is one of an inundative release. A specific number of conidia are applied to the pests environment that insures that the target pest will come into contact with the conidia and allow the fungus to attack the pest and kill it. The specific concentration of conidia needed varies based upon the target species, application method and substrate. Because *Beauveria bassiana* is a living organism that attacks another living organism, we have a basic predator/prey relationship where if one would wait for the natural reproduction of the fungus, the pest population would be out of control before the fungus would be present in sufficient numbers to lower the insect population to below pest thresholds. Additionally, *Beauveria bassiana* does not kill the insect instantly, but requires 3 to 7 days to kill the target insect after it is picked up by the insect. Due to this delayed period to kill, it is important that *Beauveria bassiana* be applied in the environment before pest levels are out of control.

In poultry facilities, the insects that we deal with as pests are fairly predictable. Darkling beetles, if not treated in broiler and turkey houses will increase rapidly through the flock cycle. There is only one window of time that treatment can be applied, just prior to the flock placement. Any material used for control of the beetles must have a residual activity period that is long enough to break the life cycle of the beetle, slowing down the population increase so that at the end of the flock the beetle numbers are low. The only practical time for application of *Beauveria bassiana* is just prior to the placement of the birds. In layer facilities, fly populations are problems after any clean out or when the manure increases in moisture to above 60%. The use of *Beauveria bassiana* in layer facilities for fly control would begin at the first sign of flies, and continue on the specific recommended application schedule until the manure ceases to be suitable for fly breeding. A second use of *Beauveria bassiana* for fly control is the incorporation of *Beauveria bassiana* in a fly bait, which can be used at any time and re-applied on an as needed basis.

EFFICACY EVALUATIONS OF *Beauveria bassiana*

The efficacy of *Beauveria bassiana* against Darkling beetles, hide beetles and house flies has been evaluated under both laboratory and field conditions. Turkey brooder houses (cleaned out after each flock), turkey grow-out housing (deep litter), broiler houses (deep litter) and layer houses (high rise) have been used for the field evaluations. The efficacy of *Beauveria bassiana* was compared against an untreated control house as well as against the standard chemicals used for these pests today. Houses were treated with a 10 foot boom sprayer. Beetle populations were monitored using 9 tube traps per house.

Turkey Production

Brooder and grow-out houses were treated with either Jabb 25 (Bb) at a rate of 1e10 spores per square foot or Tempo® at label rate prior to the placement of birds. Jabb25 was applied at a rate of 12 gallons of finished spray per 16,000 sq. ft. Brooder houses were cleaned out after each flock and treatments were made to new shavings. Grow-out houses were all built-up/reused litter. Treatments were made to the grow-out litter after it had been tilled and prepared for the next flock. Each house was treated for 2 flock cycles.

Both treatments kept all of the treated brooder houses free of beetles for each flock. Control in the grow-out houses was similar for both treatments. Initial populations were slightly higher in the Bb treated houses and at the completion of the first flock the total number of beetles per trap was higher in the Bb treated house. After the 2nd treatment was applied, both materials decreased the beetle numbers as indicated in Figure 1. By the end of the 2nd flock the Bb treatments were lower than the standard. The pattern seen in this study, where control is significantly better after the 2nd treatment with Bb is typical. We feel that this is due to the 3 to 7 days required to kill an insect with the Bb. By the second treatment, the number of adults is decreased and the number of eggs in the environment is decreased allowing for the fungus to "catch up" with the population.

Broiler Production

Trials in broiler facilities were conducted using an untreated control, Jabb 25 (Bb), micro-encapsulated dursban and micro-encapsulated permethrin. Three, 2 house pairs served as one of 3 replications completed for each treatment with the houses being treated for 7 consecutive flocks. Figure 2 contains the summarized data for these trials. All 3 of the materials used gave acceptable control of darkling beetles with the exception of 2 permethrin treated flocks, 1 and 4. Control with Bb or dursban was virtually the same through the 7 flocks (Figure 1).

Turkey Trials - Total Beetles

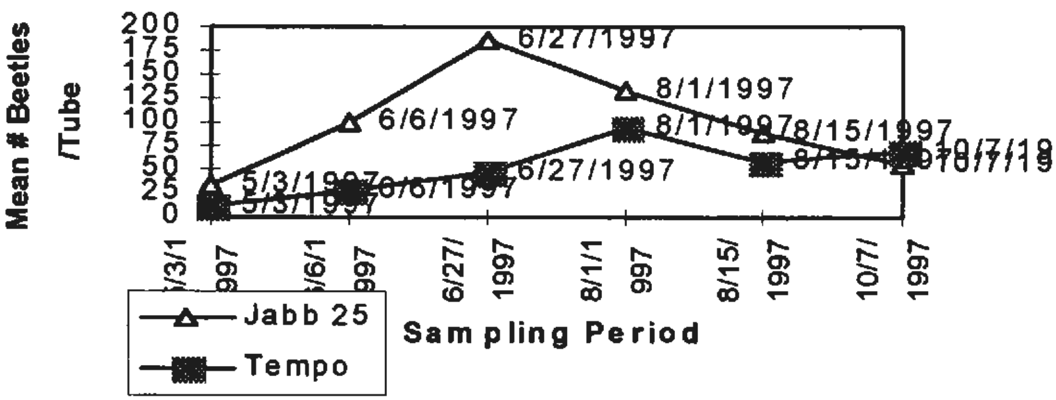

FIGURE 1

All of the houses treated were on a similar production schedule and litter removal schedule. Litter was removed from each flock following the completion of the 4th flock. By the end of the 2nd flock, beetles were found only under the feeder pans in the treated house with low numbers found along the wall. Each of these houses used 1/3 or ½ house brooding and it was interesting to note that after the 2nd flock, the portion of the house that was not used for brooding was virtually beetle free, with the beetles remaining in the part of the house that received heat and birds at bird placement. With the population of beetles concentrating under the feeders and to a lesser extent along the side walls, speculation as to where control materials should be placed and how much of the house should be treated is warranted. These results suggest that once the beetle population is under control, the application of a control material should be directed at the areas of the house that the beetles prefer, under feeder lines and along walls. If this method of targeting these areas is successful, the amount of any control material can be reduced without the loss of efficacious beetle control.

Layer Production

Two trials were conducted in high rise layer production facilities. A seven house complex with each house housing 175,000 birds was used in these trials. The initial trial was conducted from December of 1997 to April of 1998. 3 applications of Jabb 25 (Bb) were made to the litter spaced evenly in this time period. Darkling beetles decreased from an average of 10 per trap to less than 1 per trap. Hide beetles decreased from 8 per trap to 1.5 per trap and the beneficial insects, earwigs increased from 2 to 5 and carcinops. Two trials were conducted in high rise layer production facilities. A seven house complex with each house housing 175,000 birds was used in these trials. The initial trial was conducted from December of 1997 to April of 1998. Three applications of Jabb 25 (Bb) were made to the litter spaced evenly in this time period. Darkling beetles decreased from an average of 10 per trap to less than 1 per trap. Hide beetles decreased from 8 per trap to 1.5 per trap and the beneficial insects, earwigs increased from 2 to 5 and carcinops increased from 8 to 11 per

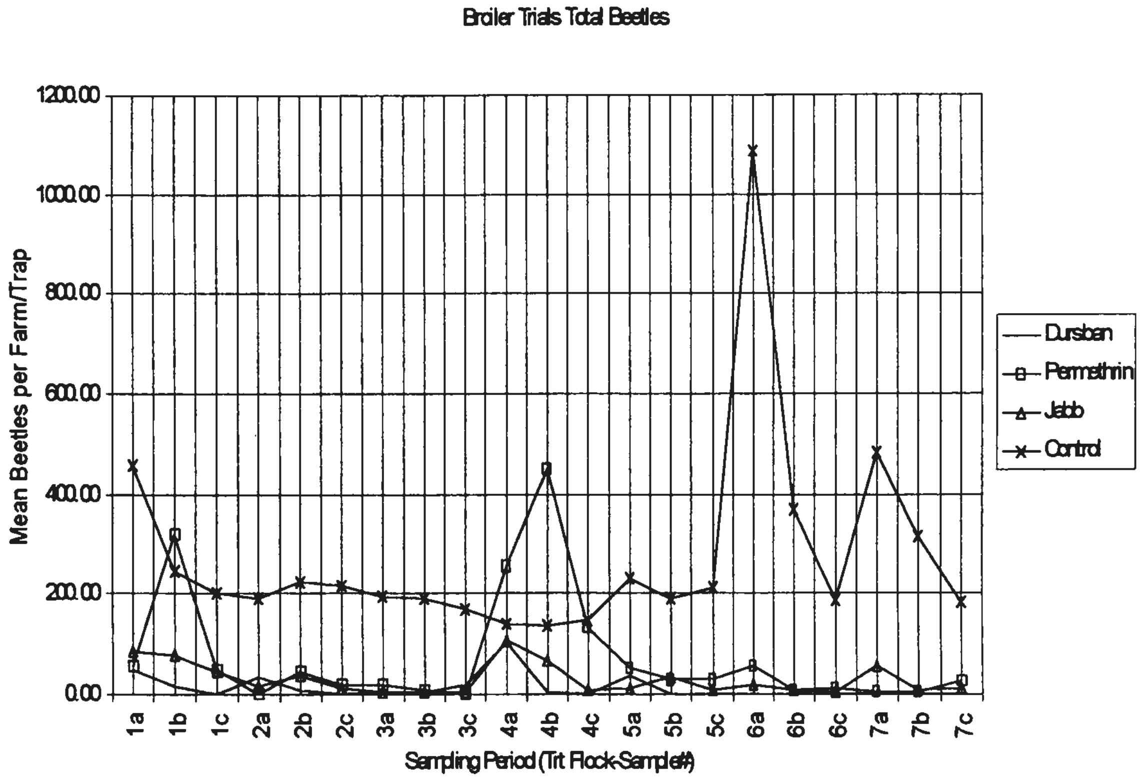

FIGURE 2

beneficial insects, earwigs increased from 2 to 5 and carcinops increased from 8 to 11 per trap. Based upon these results, a year long trial was begun in October of 1998 when the when the manure was removed from the house. Applications of Jabb 25 were applied ca. monthly (11 applications in 12.5 months) using 7, rotating foggers spaced down the center of the house in the manure pit. Spores were applied at a rate of 19 per square foot by turning off the fans, fogging the material out in 1.5 to 2 minutes and then returning the fans to normal operation. Only a single house of the complex was treated, #4 in the row of 7 houses. By treating only a single house, we allowed for maximum migration of both darkling beetles and hide beetles to the treated house for a maximum challenge of the bio-pesticide.

Samples from the house were evaluated throughout the trial. No darkling or hide beetles were found in the litter until 5/17/99. These were few in number and were felt to be migrating from the adjacent un-treated houses. Evaluations concluded in October of 1999 with no larval darkling beetles or hide beetles found and a small number of adult beetles. Our conclusion was that even though we had migration of adult beetles of both species, neither was able to establish a breeding population because of the presence of the Beauveria, and at the completion of the flock there were an insignificant number of adults in the litter that would cause no problems when the litter was applied to fields.

A second concern was the condition of the litter at the end of the cycle. It has been proposed that the darkling beetle is an important part of the beneficial population of organisms in a high rise layer house. It has been felt that their activity of tunneling in the manure aids in the drying of the manure, making the manure less attractive for fly breeding and that the beetles may actually feed on fly eggs and larvae as the carcinops beetles do. It would be our observations that the beetles do not enter the manure until it has begun to dry. This takes place after the first 6 to 12 weeks post-flock placement as the manure reaches 10 to 14 inches in depth and it begins to naturally compost creating it's own heat. As the manure begins to release moisture and dry, it shrinks creating that honey comb appearance and the beetles move into this environment because it is ideal in temperature, harborage and food. While we observe them in this manure moving in and out they give the appearance of tunneling, when in fact they are just using the manure as a place to live. When the manure reaches a state of dryness that it is attractive to beetles, it is too dry to be attractive for fly breeding. In this trial, the absence of beetles for the entire flock had no impact on manure condition as the manure removed from this house was as dry or dryer than that from the 6 untreated houses. These houses utilized parasitic wasps as well as naturally occurring beneficial insects, earwigs and carcinops to aid in fly control. The populations of earwigs was excellent in the manure and the fungus did not show any impact on the release and efficacy of the parasitic wasps.

A strain of *Beauveria bassiana* isolated from house flies was evaluated under laboratory conditions and under simulated field conditions. This strain has shown good efficacy against house fly when formulated as a bait and when used as a fog. A 600 square foot mini-layer house containing 100 layers housed 3 per cage was used in the simulated field trial. Manure as allowed to accumulate and flies breed. Flies were added in 20,000 fly allotments from an established colony to increase the adult numbers and breeding in the manure. If needed, water was added to the manure to maintain it in top fly producing condition. Speck cards were used to evaluate the fly population. The Jabb fly strain of *Beauveria bassiana* was applied using a standard fogger and formulated to provide 1e7 spores per square foot of floor area. Application was accomplished by turning off the ventilation fans, fogging the material and then returning the fans to normal.

Results from this trial were encouraging (Figure 3). Initial fly populations reached levels equal to those found in poultry houses where fly breeding is unchecked. Speck cards were evaluated on a 3 day basis instead of weekly due to the large number of specks per card. Treatments were applied on day 0, 3, 10 and 27. Release of 20,000 adult flies was completed on days 6 and 10.

Speck card counts began at 200+ specks in a 3 day period at day 0 and were reduced to below 40 by day 6, following 2 applications. The added flies to the room increased the counts to near 100 by day 10 when the 3rd treatment was applied. No further treatments were applied until day 27 when the counts approached 50 per card. Control of the adult flies was excellent and presence of large numbers of larvae in the manure indicated that flies were continuing to be produced. Following these results, full field testing of the fly material is planned for the fall of 2000.

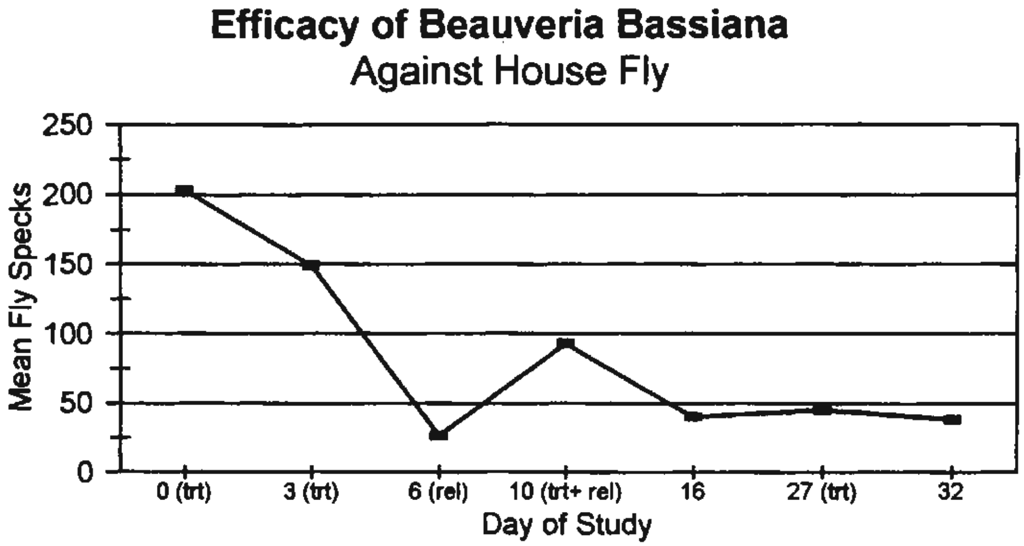
Efficacy of Beauveria Bassiana
Against House Fly
Mean Fly Specks
250
200
150
100
50
0
0 (trt)
3 (trt)
6 (rel)
10 (trt+ rel)
16
27 (trt)
32
Day of Study

FIGURE 3

POTENTIAL OPPORTUNITIES WITH A SAND-BASED LITTER

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In most integrated poultry operations, logistical, operational and economical constraints necessitate the concentration of live broiler production farms within close proximity of the centralized hatchery, feed mill, and processing facilities. This efficiency driven structure often results in geographically dense poultry production regions with excessive demand on critical management inputs (labor, utilities, and bedding materials), as well as outputs (farm mortalities and manure).

Commercially, virtually all broiler chickens in the United States are raised on the floor using some type of a bedding material (litter) to segregate and insulate birds from the ground or flooring, and to absorb excess moisture from the droppings and the drinkers. The nature, quantity and quality of the bedding material used varies greatly from region to region, based primarily on local availability and cost of agricultural by-products.

Pine shavings and sawdust are currently the most predominant and preferred bedding materials for broiler production in the US. At times, a number of other materials are substituted regionally in place of pine products, including hardwood shavings (Carter *et al.*, 1979), peanut hulls (Lien *et al.*, 1998), bark (Dang *et al.*, 1978), rice hulls (Veltmann *et al.*, 1984), kenaf core (Malone *et al.*, 1990), and straw (Hermes, 1996). Periodically, the by-products of other industries have received interest as bedding materials, primarily driven by local recycling efforts and entrepreneurship. Products such as recycled or shredded paper (Blake and McDaniel, 1998; Lien *et al.*, 1992; Malone and Chaloupka, 1983), ground drywall waste (Reed and Mitchell, 1997) and particle-board residue (Hester *et al.*, 1997) have been field tested successfully (Hess *et al.*, 2000). Basically, two broad factors triggered our interest in sand as a bedding material for broilers: 1) the lack of availability and/or high cost of wood-based products, primarily due to competition from alternative value-added uses, and 2) increasing restrictions on land application or disposal of used litter arising from emerging environmental issues and regulatory oversight.

Growing chickens on sand is not a new or novel concept. Sand has been used as a bedding material for poultry in early days of the broiler industry in the US, and is currently being used in many countries around the world with limited forestry resources. Sand has also been used successfully by the dairy industry as a non-carbon based bedding material.

Research conducted at the Department of Poultry Science at Auburn University for the past four years has examined the feasibility of using sand as a bedding material for broilers. The project has been carried out in two phases. The first phase involved comparison of sand with pine shavings in controlled replicated pen studies. In the second phase, sand is continued to be evaluated as a bedding material under commercial conditions.

Floor-Pen Research on Sand as a Bedding Source for Broilers

Floor-pen studies were conducted successively over a two year period, in which sand (washed, mortar or building grade sand) was compared with pine shavings in terms of live production and processing performance, health, and in-house environmental factors (Alley *et al.*, 1998; Bilgili *et al.*, 1999a, b). Live performance (growth rate, feed conversion, and livability) of broilers grown on sand was comparable to those reared on pine shavings over a two year period. Similar results were obtained for the processing parameters (carcass and deboning yields, and grade). Foot pad quality of birds raised on sand was consistently better than those raised on pine shavings.

Litter moisture, temperature, and ammonia production measurements did not show significant differences between the two litter types. However, bacteria levels (coliforms and aerobic plate counts) were significantly reduced on sand litter.

Commercial Application of Sand as a Bedding Source for Broilers

Currently, there are six commercial broiler houses (40 x 400 ft) bedded with sand in Alabama, with anywhere from 2 to 16 grow-outs completed. In addition, plans are underway to include seven more houses by this fall to broaden the geographical and company-wide participation in this study. With few exceptions, most of the houses are bedded with washed mortar sand at a depth of 4 inches (about 300 tons per house). Field experience with sand as litter over the last two years has given us a unique perspective. Following are a list of our critical observations :

1. Once the sand is placed, ample time and ventilation is necessary to assure dryness. This is very critical prior to initiation of brooding, as sand usually carries excessive moisture from outside storage at commercial sources.

2. Bird activity in the house quickly levels and packs the sand during the first grow-out. It may be necessary to inform and educate the catching crews, especially the hoist driver, to anticipate the fluffiness and shifting characteristic of sand during maneuvering in the house, as compared to wood shavings.

3. We have had problems with cup drinkers, as sand accumulation eventually caused water leaks and wet litter in the house. However, it was much easier to dry sand in the house after a major water leak.

4. Brooding can be a problem, especially if pancake brooders are not available. We have had complaints about cold bedding, excessive gas use to keep the house warm and high early chick mortality due to sand consumption. However, in all of these cases, other management factors (wet sand, inadequate pre-warming, starve-outs etc.) were involved.

5. In general, we have seen 2 F temperature differential with sand, warmer in winter and cooler in summer, as compared to pine shavings litter. This is an interesting observation and may actually be beneficial in reducing heat stress mortality.

6. In terms of weight gain, livability, and whole bird condemnations in the plant, birds reared on sand have performed equal to or better than sister flocks reared at the same farm on pine shavings. This is remarkable considering the fact that caked litter is removed and fresh litter is added between the successive grow-outs in pine shavings houses. Usually, very little caked sand is removed and no top dressing is employed with sand litter houses.

7. Compared to pine shavings, there is visually very low incidence and activity of darkling beetles in sand litter. This, of course, basically eliminates the need and expense of chemical control measures in the long term.

8. House ammonia has not been a major problem, even after 15 successive flocks on sand. In one particular farm, where sand was used for 26 months, we only detected 60 ppm ammonia in the sand house, as compared to 20-30 ppm on houses bedded with pine shavings after one flock.

9. After two years of use, the height of the litter in the broiler house has increased about 2 inches. This necessitated the removal of some litter, mostly light organic material. Since sand is heavier, it continuously sifts the lighter, dried-organic material to the surface. New technologies may be available soon to specifically separate this material from the sand in the house .

10. Feathering initially appears rough on birds, possibly due to increased "dust bathing" behavior in the house. This does not affect the carcass quality in the plant. As a matter of fact, because of lower infectious viability in the bedding environment, whole-bird condemnations has been lower as compared to pine shavings houses.

Certainly the most important characteristic of sand bedding is its durability or long life. We now anticipate that with periodic cleaning (screening, heat sterilization, and even washing) sand may be used for up to 5 years in broiler houses. This is a tremendous economic advantage for the producer compared to pine shavings litter. Depending on the cost of alternative bedding materials available, pay-back on the initial cost may be as early as 1.5 years.

Research is currently underway to explore new markets for used sand after clean-out. Increased use of sand commercially should reduce the yearly litter disposal, alleviating environmental concerns while providing novel and lucrative markets for the producers. It is our hope that used sand will actually create a demand for specific uses (i.e., turf grass, athletic fields, golf courses) such that its replacement at the farm level may even be subsidized.

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ON-FARM ENERGY GENERATION FROM BROILER LITTER

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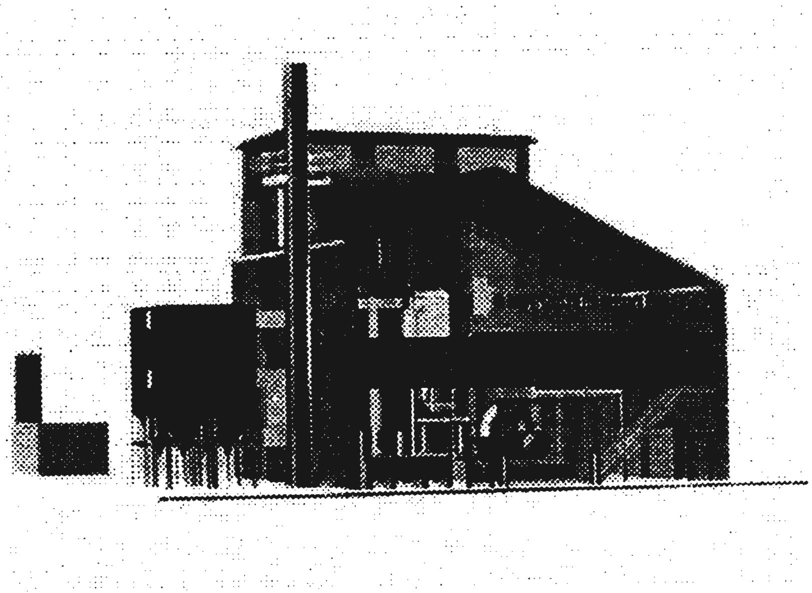

There exists a considerable problem with poultry producers in that they have been in the habit of storing and disposing of animal waste on the ground, often spread as a fertilizer, from which the waste has seeped into the local watershed. In Maryland, where a lot of poultry producers operate, the problem has become so pervasive that the waste has contaminated some areas of the Chesapeake Bay and has actually killed fish because the nitrogen in the waste promotes growth of algae, robbing the water of oxygen. This is an intolerable situation, apart from the unpleasant odors that such animal wastes cause, with the inevitable offense to the local population.

This program of development has centered on the use of an Internally Circulating Fluid Bed (ICFB) boiler which will burn waste fuels, including poultry litter. This boiler can be made in the range of 3,000-50,000 lbs/hr, but the company has designed complete modular small co-generating power plants in the range of 50 – 200 KWs electrical generation with equivalent steam outputs of 3,000 – 12,500 lbs/hr of steam. These plants would fit on a particular processors or grower's premises and supply electricity and steam for heating the chicken houses by burning the poultry litter.

The company has an ICFB already installed at a nursing home near Pottsville, PA, which has been tested on poor grade anthracite and bituminous coals. Tests on poultry litter have been carried out by the Energy Institute of Penn State University under identical combustion conditions to the full size boilers and full emission testing was carried out. The results of these tests are reported in this paper.

The complete design of the modular plants of the sizes 50, 100, 150 and 200 KWs has been completed. The capital and running costs of these plants have been computed and talks with the processor for the siting of the first one is under way. The detail costs involved in building the plant are reported in the paper.

INTRODUCTION

Small bubbling fluid bed boilers have been manufactured since the early 1980's, this investigator being responsible for some 36 boilers at that time, but they have never been operated satisfactorily when burning animal wastes. There have been many and various reasons for this, most of which have to do with the preparation and feeding of the fuel, the variability of the fuel with low BTU content and the fuels propensity to cause slagging and corrosion inside the boiler.

The ICFB boiler is ideal for the burning of these types of fuel, such as poultry litter, because of its unique internal bed circulation coupled with the ability to vary the heat extraction from the fluid bed, thus accommodating the lowest BTU fuel without putting the fire out. Also, because the micro-turbine proposed only requires saturated steam the high temperature super heater is eliminated, thus eliminating the high temperature corrosion, caused by sulfur and chlorides in the poultry litter.

The micro-turbine being considered has only recently been developed as a package for use on small industrial sites or on farms where the emphasis is on low cost rather than high pressure and sophistication. The packaged single-stage back-pressure turbine will accept saturated steam up to 275 psig, and uses advanced, high-efficiency nozzles to insure high output per pound of steam, so co-generation with flows as low as 3,180 lbs/hr (50 KW electrical) are possible. The micro-turbines are supplied pre-packaged with the steam turbine, induction generator, over speed protection, and generator controls all mounted on a heavy steel base plate. Units may be supplied in 50, 100, 150, and 200 KW sizes. The turbine may exhaust steam in the range of 2-50 psig and the pressure used usually depends on the process requirements of the user.

We had originally intended to use the ICFB boiler at Resthaven Nursing Home to do the burn tests on poultry litter, but the County Commissioners were reluctant to allow us to bring poultry litter into the facility. In view of their reservations, we had talks with the Energy Institute at Penn State University who had a fluid bed rig which could be run at the same conditions as the full size ICFB boiler. We established that we could simulate the full size conditions and establish (1), that we could burn the poultry litter and (2), measure the emissions. We therefore shipped over three tons of poultry litter from a Hegins, PA grower to the University and carried out a series of parametric tests on their FBC rig adapted for bubbling bed operation over the same fluidizing velocities as used in the full size boilers. These tests are described below and in more detail in the Energy Institute report (Moulton *et al.*, 2000) but confirmed that you can burn the material at relatively reasonable emissions. We designed a series of modular plants to have an electrical output from 50 to 200 KWs and a steam output from 3,180 to 12,500 lbs/hr of steam. These plants all have a truck tipping bay with a bucket elevator for seven days of poultry litter storage, conveyors to the boiler, a baghouse after the boiler, and an ID fan exhausting the flue gas to a stack. The ICFB boiler provides saturated steam at 150 psig to the small steam turbine and generator set which produces the electricity and exhausts the steam at 12 psig to the growers heating system. The whole plant is controlled by a Distributed Control System mounted in a small control room that will control the plant automatically, so that it can be monitored by one man on a day shift basis.

The costs of these plants are in the range of $1.5 to $2 million installed and have a reasonable payback depending on the alternative costs of poultry litter disposal in the district.

THE INTERNALLY CIRCULATING FLUID BED BOILER

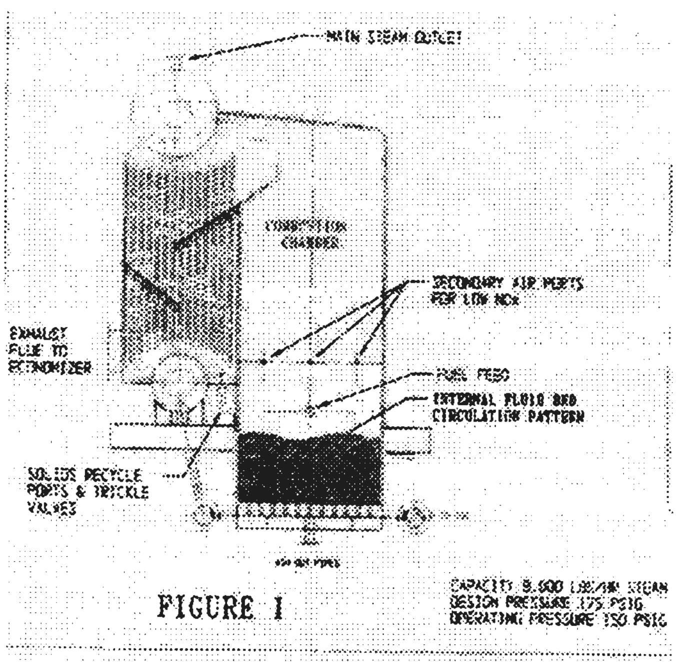

FIGURE 1

The ICFB boiler is shown in figure 1 and is essentially a typical "D" shaped package boiler with a unique bubbling fluid bed grafted onto the bottom of the combustion chamber. By using the well established "D" type design and making a modular unit for complete manufacture in the boiler manufacturing plant, the cost of the boiler can be kept down to acceptable levels compared to a field erected unit.

The fluid bed containment is arranged in the bottom of the combustion chamber and is fluidized through non-sifting nozzles of a proprietary design by primary air supplied from a three compartment windbox which, in turn, comes from a primary air fan (not shown). The fuel is screw fed (or with some fuels, chute fed) in the middle of the combustion chamber immediately above the top of the dense bed. Internal circulation is induced in the dense bed by supplying relatively little air to the center bed and relatively more air to the outer bed nozzles, thus causing the dense bed to move down in the middle, engulfing the incoming fuel and up at the sides where the fuel is mostly burnt out.

The evaporator tubes are arranged so that they bend out of the wall into the fluidized side panels, which are controlled by the two side windboxes. If the fuel that is fed to the bed has a lower BTU than usual (because it is wet, for example) the temperature of the bed will be depressed. This is sensed by the control system which will immediately reduce the air to the side panels, thus reducing the heat transfer to the "nose" tubes, this in turn restores the heat to the main bed, thereby restoring temperature and maintaining good combustion despite the poor fuel. The boiler output will tend to temporarily drop, but the main boiler control loop will sense this and increase fuel rate to the center bed thus restoring boiler output to the required rate. This control is sensed and responded to with instruments and automated controls.

The fluid bed may be fed with limestone to absorb sulfur or other sorbents and the unit installed at Pottsville is equipped with the facility to do this, if required. It actually is not required with anthracite waste fuel with less than one quarter per cent sulfur but the provision exists. The poultry litter units are equipped with a separate sand (for start-up) and clay hopper (for slagging prevention) and feed screw to the buffer hopper so separate amounts of these materials may be metered into the fluid bed.

The fluid bed is heated up by the over-bed gas fired burner to a temperature at which the solid fuel will continue to burn. In this boiler the gas burner may also be used to obtain at least two-thirds of full load in the case of the solid fuel being unavailable.
The fuel will burn within the dense circulating fluid bed and volatiles will tend to burn in the freeboard above the fluid bed. The freeboard is of generous dimensions in this boiler and NOx control is achieved by adding secondary air immediately above the dense bed. Thus the dense bed may be run at or slightly below stoichiometric air/fuel ratios to inhibit NOx pre-cursors.

At the top of the combustion chamber the gases turn the corner and enter the main evaporator bank. At the bottom of the first pass, the gasses go through a 300° turn where solids will tend to drop out of the gas stream. The boiler is equipped with three trickle valves at the bottom of this pass, between the mud drum and the combustion chamber back wall, that allows any separated solids to flow back to the fluid bed. In this way any un-burnt carbon is recycled through the combustion chamber thereby increasing combustion or carbon burnout efficiency. The back of the boiler is equipped with two sootblowers to remove deposits above each baffle, but they are not shown in Figure 1.
The reduced temperature boiler flue gas is then ducted to a small economizer and baghouse before being drawn to the stack by the induced draft fan, which is shown in the general boiler room layout on Figure 2.

In the final modular plant, the boiler supplies saturated steam to the packaged micro-turbine. Essentially the boiler, micro-turbine generator set, and the baghouse would be shipped to the site as separate modules (the boiler may come as a kit for some sites). Fuel preparation and handling equipment often depend on individual site requirements but these studies have gone as far as possible towards standardization.

MODULAR POWER PLANT DESCRIPTION

The modular power plant is based on using the ICFB boiler described above when coupled to a small reactive turbine/generator set in the range of 50 – 200 KWs. The steam is fed to the boiler at 150 psig (or 220 psig for 200 KWs) and exhausts from the turbine at 12 psig (or 30 psig for 200 KWs). The turbine is automatically controlled, shutting down when the steam flow is too low and restarting as needed, see Table below for terminal conditions to the micro-turbine.

We conceived these power plants so that the main components can be delivered to the site for erection in one piece. The main components being, the ICFB boiler, the micro-turbine generator, the baghouse, the deaerator, the FD and ID fans, the fuel feed hopper, the DCS system, the motor control center, the control room with air conditioner, and ash dump hoppers. Those components having to be delivered in sections are the fuel bunkers, the stack, the bucket elevator, the main building, and the lean-to fuel delivery bay. The general arrangement of a typical plant is shown on the attached drawing.

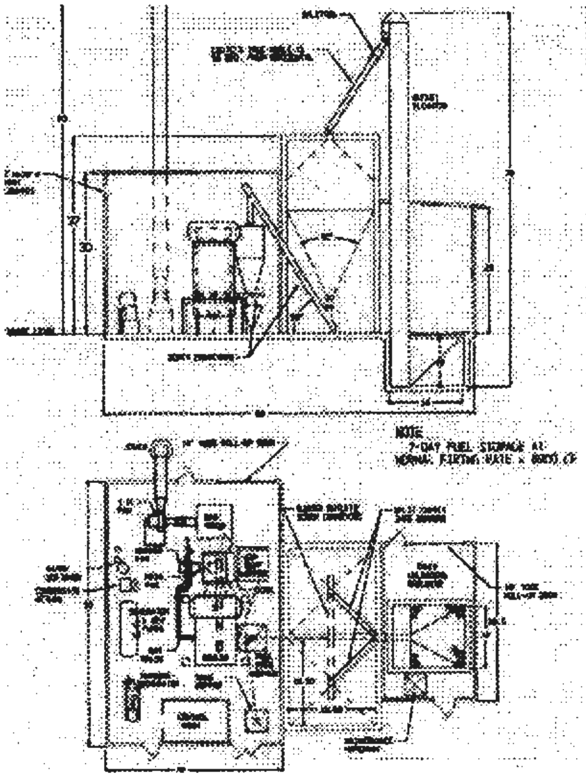

Figure 2

Table 1. The Plants Were Designed to Have the Following Specifications

Generator	Steam Rate	Pressure	Fuel Rate	Boiler Efficiency
50 KW	3,180 pph	150/12 psig	964 pph	60.5 %
100 KW	6,360 pph	150/12 psig	1,714 pph	68 %
150 KW	9,500 pph	150/12 psig	2,484 pph	71 %
200 KW	12,500 pph	220/12 psig	3,303 pph	73 %

The above figures are based on the Hegins Valley poultry litter sample of 5,547 btu/lb with 26.97% carbon and 20.95% moisture and other analysis recorded (Table 1). The plants take up relatively little space including the poultry litter storage which is based on seven days supply. The total area for the 50 KW plant is 43' x 56.5' and for the larger plant of 200 KWs is 56' x 75'.

The total costs for the plants erected in PA are in the range of $1.5 million to $2 million.

MARKET AND RESOURCE ASSESMENT

Michael Hulet, Professor of Poultry Science at Penn State University, supplied information on the numbers of poultry producers in Pennsylvania and Delaware. The total value of production in Pennsylvania is about $266 million in 1998. The value in Delaware was about $529 million in 1997. The producers or growers in Schuylkill County produce about 15,810 lbs/year of poultry at a value of $6 million. On the Delaware Peninsula the poultry industry produces about 800,000 tons of litter a year. The use of this poultry litter as a fertilizer in the Chesapeake Bay watershed area, of which Schuylkill County is a part, has caused considerable problems in the Delaware River and the top part of the Chesapeake Bay itself.

What happens is that the high nitrogen (typically 3.5-4%) poultry litter is spread over farm land as fertilizer. Although it is a good fertilizer the rains wash the material down into the streams and rivers raising the nitrogen content of the water. This in turn causes excessive growth of algae which in itself uses up a lot of oxygen in the water. In the extreme concentrations now being experienced in the Chesapeake Bay area this is depleting the oxygen in the water and causing the fish in the bay to die.

While the individual amounts do not seem excessive now, there are hundreds of growers on the Delaware Peninsula and the concentrations of nitrogen in the watershed of the bay has achieved epic proportions and caused the problem outlined above.
A potential solution is to burn the poultry litter in small cogeneration plants that produce heat and power on each growers facility. These plants were designed in the range of 50 – 200 KWs electrical capacity and are described in 7. Modular Plant Design.

Professor Hulet and the author visited three chicken growers in the Hegins Valley area of Pennsylvania. The growers are all similar in that they rear (grow) the chickens from day-old chicks to five week old chickens, weighing 5-6 lbs in large sheds (about 50' x 200') which contain 31-32,000 chickens. The grown chickens are then sent to a processing company such as Pennfield or Perdue. The floor of these sheds is originally covered with wood shavings (usually pine) which the chickens eventually cover with litter. When the first batch or "flock" of birds is reared, the mixture of chicken litter and wood shavings is turned over and spread ready for the next "flock". After some six flocks have been reared like this, the chicken shed is cleared out and produces about 175 tons of poultry litter.

Most of the growers have at least three of these chicken rearing sheds and some many more. As the growers are essentially farmers, most of them then use the poultry litter as fertilizer on the land on which they are growing crops. When this form of "fertilizer" is used in high concentrations, as in the Chesapeake Bay watershed, the problems outlined above occur.

We took samples from two representative growers which had typical litter. The material would appear to be suitable as a fuel as the caloric value was 5,547 – 5,788 btu/lb while having a moisture content of only 20 – 30%. The nitrogen values were quite high as expected at 3.5 – 4 % but the ammonia was lower than expected at 0.64 – 0.96 %. The potassium was very high at 10.5 – 13% and phosphorous also at 4- 6.5 %. This can cause a problem in fluid bed burning as these are low temperature eutectics, which can tend to form clinkers in the fluid bed. It was the purpose of the burn tests to solve these problems. One way of curing the formation of low temperature eutectics is to dose the fluid bed with clay, which forms high temperature silicates with these metals and thus avoids the formation of clinkers.

POULTRY LITTER BURN TESTS.

The burn tests were carried out at the Energy Institute of The Pennsylvania State University. The fluidized bed combustion rig used to carry out this work was originally designed for operation as a Circulating Fluid Bed (CFB) but was modified for these tests by building a wall in bricks between the sluice return and the main bed chamber. The unit could then be run as a bubbling fluid bed (BFB) by running at the same fluidizing velocities as the ICFB boiler at Resthaven. The general arrangement of the rig is shown on Figure 3. The rig is instrumented with a full battery of data logging and emission equipment including O2, CO2, CO, SO2, NOx and NH3 analyzers with CH4 being detected by taking bag samples, which were subsequently analyzed by gas chromatograph. The fuel could be added through two weigh hoppers with independent screws feeding the same chute to just over the fluid bed surface. The following is a summary of the tests reported of Moulton *et al.*, 2000.

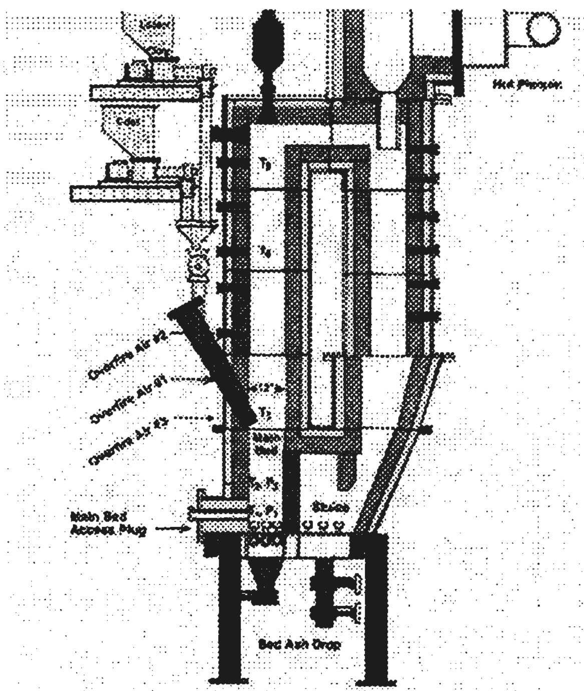

Figure . GENERALIZED DIAGRAM OF THE FLUIDIZED BED COMBUSTOR

Figure 3

Preliminary tests were first carried out to get a feel for the correct parameters while establishing good combustion aiming for 4% oxygen, which represents the same excess air used in the full size boiler (25%). The air was adjusted to give 6ft/sec fluidizing velocity in the BFB, which is the same as the ICFB. In order to establish stable combustion the unit was started up on gas and then switched to coal fuel, after which the chicken litter was added. At first it was found necessary to keep about one third of the fuel on coal, by heat input, to keep the unit up to temperature, 1,600°F being the goal. As expected, after a while operating on poultry litter, the bed clinkered up probably due to the high concentrations of potassium and phosphorous in the bed. After that, we added 25% by weight of clay to the poultry litter and in subsequent tests clinkering in the bed was avoided.

After we had completed the preliminary tests we designed a series of three parametric tests where we would progressively increase the overfire air to estimate how much was needed for satisfactory combustion in the freeboard and emissions.

During the first test it was evident that much of the poultry litter was burning in the freeboard because the temperatures in the top of the rig increased to over 2,000°F. This raised the NOx level to about 500 ppm, while not demonstrating particularly good combustion with CO in the range of 1,000 – 6,000 ppm. Although it must be said that the occasional CO levels of 6,000 ppm were felt to have been induced by the pulse air flow on the feed chute used to keep it from blocking. None-the-less, 1,000 ppm is unacceptable.

However the biggest result was that fuel ash was seriously slagging the upper part of the furnace. This could be seen by looking down from the eyeglass on top of the furnace where slag build-up was evident on the furnace sidewall and on the thermocouple (T6). This build-up of slag shut the furnace down after 3 ½ hours operation.

It was obvious that with the high freeboard temperatures, slagging was occurring and that to maintain operations a lower freeboard temperature must be maintained by introducing more secondary air. This was affected by adding overfire air ports.

In Test #2 initially the freeboard temperature tried again to climb above 1,800°F, but the introduction of overfire air #2 reduced that to 1,650-1,700°F. The CO emission was better but still in the range 2,000-3,000. It was noticed that the introduction of poultry litter actually reduced the NOx from about 200 ppm to 100-150 ppm. We believe that is because the poultry litter contains amounts of ammonia (.6-1%) and that at temperatures of 1,500-1,900°F reacts with NO to form elemental nitrogen. That is despite the fact that poultry litter contains over twice the amount of fuel bound nitrogen than the coal. Eventually the high T3 and T6 temperatures caused slagging that blocked the transition duct and the unit was shut down.

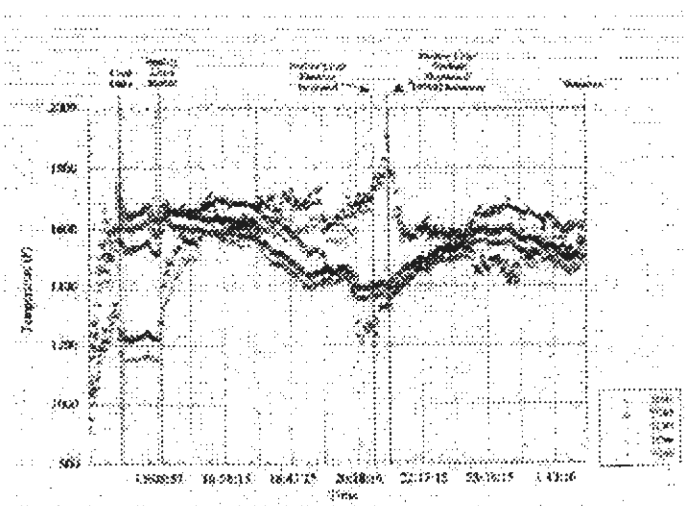

Figure 12: FLUIDIZED BED COMBUSTOR TEMPERATURE PROFILE FOR [illegible] POULTRY LITTER TESTING ON MARCH 8, 2000

Figure 4

For Test #3 we added a further secondary air immediately opposite the feed chute in order to control T3. In this test it was possible to control the temperatures quite closely to within fairly close limits. As shown in Figure 4. The CO was mostly under 1000 ppm and NOx was about 100 ppm for the whole test. SO2 was 500 ppm. Negligible amounts of ammonia and CH4 were traced during the tests. The unit was shut down failure but the test was concluded satisfactory after 11 hours of successful running on poultry litter.

These tests were carried out to evaluate the combustion performance of poultry litter when simulating the conditions in a ICFB boiler.

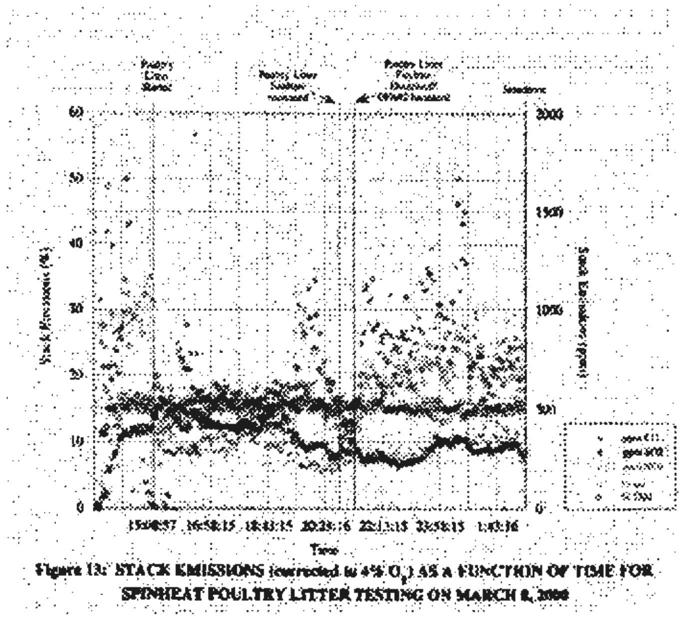

Figure 5

Three areas of concern were addressed during the testing. Plugging of the feed tube by poultry litter was encountered. This problem was overcome by adding a sparge air line down the center of the feed tube to assist the feed into the unit. Bed clinkering of the poultry litter was eliminated by the addition of clay. Finally, the slagging in the freeboard section was eliminated by the addition of overfire air. The last test demonstrated the successful burning of the poultry litter with 20% thermal input of coal (Figure 5).

The design of the ICFB boiler overcomes most of these problems by the use of an in-bed feed screw for the poultry litter so more of it will be burnt in the bed. This will almost certainly remove the need for use of coal as an auxiliary fuel. It also ensures less freeboard burning and therefore lowers temperatures in that region. The freeboard is also water cooled thereby lowering the temperature. The secondary air of the ICFB is immediately above the bed and higher up spread around the furnace further lowering the temperature.

The use of clay to avoid in-bed clinker formation was particularly successful and smaller quantities would almost certainly suffice in the larger boiler because of the in-bed feed.

MODULAR PLANT DESIGN

A modular plant has been designed for a range of sizes; 50 KW, 100 KW, 150 KW & 200 KW and are shown on the typical drawing. Each plant has poultry litter storage for seven days to ensure an uninterrupted normal delivery schedule. In the event of unavoidable delivery delays, each plant can be operated at two thirds capacity by the boiler's start-up burner operating on natural gas, or oil.

Poultry litter is to be delivered by dump trucks unloading into a below-grade hopper feeding a bucket elevator. Two chutes from the outlet of the bucket elevator fill the two bunkers. Two cross screw conveyors from each of the bunker outlets discharge into another conveyor that lifts the fuel into the boiler's day-bin.

From the day-bin, poultry litter is metered under computer control into the boiler by the fuel feed screw conveyor. Fly ash is filtered and collected by a baghouse operating at a particulate emission rate well below EPA requirements. Bottom ash, expected to be minor, is discharged by a water-cooled screw conveyor. Both fly ash and bottom ash are conveyed by screw conveyors into a pugmill that dampens the ash before it is discharged into the dump hopper for transport to land fill.

On initial start-up, the boiler's fluid bed is to be sand that will be heated by the start-up burner to the combustion temperature required by the poultry litter. To maintain a bed sufficient for fluidization with poultry litter as the sole fuel, a continuous, small flow of sand is required. The sand is to be metered into the day-bin by the sand screw conveyor, under computer control, from the small sand hopper. The sand hopper will be filled from 60 lb bags of sand or clay.

The boiler train consists of the boiler, burner, economizer, forced draft fan, burner fan (doubling as the secondary air fan) and induced draft fan. Included in the plant is a pulse-jet baghouse with 10ft-long Ryton bags, self-supported stack, boiler make-up water treatment, condensate return tank and pumps, deaerator and boiler feed water (BFW) pumps. The condensate and BFW pumps will each have an installed spare.

Motor Control Center and the turbine-generator are located in the boiler room. The boiler room and truck unloading building are all of the pre-engineered modular type with steel columns and roof trusses and insulated sheet steel cladding. A mechanized roll door is included and ventilators along the one side wall for air inlet to the boiler.

The entire plant is fully automated and controlled with a state-of-the-art Distributed Control System (DCS). The plant is designed primarily to function with only one operator from a small, enclosed control room inside the main building. A computer, screen graphics and control panel are all that are needed to set operating parameters and check on all functions and readings of the operating system. A printer is available to record historical operating conditions and trends. All real-time and historical operating data will be available by modem to any authorized remote site.

PLANT COSTS.

Based on the designs outlined, the specifications of the major plant components were prepared and costs established. The man-hours required for the installation were based on those experienced at the Resthaven Nursing Home installation and those for the building based on the supplier's estimates. Those estimates presented here are based on non-union labor.

The costs of each plant are as follows:

- 50 KW plant $1.5million
- 100 KW plant $1.6 million
- 150 KW plant $1.75 million
- 200 KW plant $2.0 million

These estimates assume a green field site with a covered fuel reception area with a lean-to, custom made hoppers with a fugitive emission system consisting of a fan and ducting pulling air from the truck unloading and bunker areas, and feeding that air to the primary air fan.

The fuel is screw fed to the boiler and may be drawn from either or both bunkers. The capacity of the bunkers is based on storing a seven day supply. The fuel is metered through the fuel feed day bin. If coal is required it can be supplied via the other bunker or the sand hopper with the clay feed. The disadvantage of the former arrangement is that the poultry litter storage would be reduced by half, i. e. to 2 ½ days.

The ICFB boiler has been described earlier and is very similar to the Resthaven unit. The boiler flue gas goes through an economizer and then the baghouse. The ash is removed from the baghouse hopper by an automatic screw by means of level controls. Bottom ash is removed from the furnace bottom by means of a water-cooled ash screw. The ash is then conveyed to the ash dump truck through a pug-mill where the ash is conditioned to avoid fines spillage. The flue gas is exhausted through the ID fan to the stack.

Auxiliary equipment includes the deaerator, boiler water feed pumps, condensate return tank and pumps, water softener and appropriate piping, valves and controls. The turbine generator is a self contained unit which, once started, will load and unload itself automatically via a built in PLC controller. As the generator is a non-synchronous unit it must be in a system of about twice its total capacity for correct synchronous operation.

The whole system is controlled from an air conditioned control room within the overall steel clad insulated building that is easily erected by the general contractor.

CONCLUSION

The plan is to build a 150 KW capacity modular power plant, which includes a 9,500 lb/hr boiler and 150 KW steam turbine generator set to the layout shown on drawing no: SBIR-1002/R0. The ownership of the power plant operating company will be divided between Power Consultants Inc. and Spinheat Ltd.

The company will site the first plant at a processing plant. This is important, because there is legislation pending in Delaware in which cogeneration plants that require the exporting of poultry litter across property lines are likely to be banned under new "NIMBY" laws. The plant proposed here is small enough to avoid this law if it is passed. The progress that the plant has made will be stated in the paper presentation at the time of the Conference.

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CONTROL OF PATHOGENS IN POULTRY FACILITIES

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NO PAPER SUBMITTED

USE OF GIS TO ESTIMATE WASTE LOAD VERSUS AVAILABLE LAND FOR UTILIZATION

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Large-scale poultry production, like other industrial activities, generates both useful products and byproducts which may or may not be useful. In the present context, the major byproduct of poultry production (animal waste) is considered a biological resource which, like other similar resources, may be used beneficially, if it is part of a properly designed and engineered bioproduction system, or wasted. Wasting the resource is however problematic from at least two perspectives: a) it may pose significant stress on the environment receiving the waste, and b) the potential monetary value of the resource is lost. Beneficial uses of poultry wastes, on the other hand, include plant nutrition, cattle nutrition and energy production (Collins *et al.*, 1999). Their use in these systems must be carefully designed, in accordance with the receiving system's input requirements, to avoid producing secondary wastes.

This paper is focused on the use of poultry manure for plant nutrition and on factors that affect the quantity of this biological resource that can be used beneficially for that purpose. The analysis is motivated in part by recent legislation mandating the adoption of (first) nitrogen-based and (later) phosphorus-based nutrient management plans by crop producers in Maryland and other states, before the end of the decade. This legislation is aimed partially at controlling the recurrence of fish kills believed to be caused by excessive nutrient concentrations in surface waters which trigger blooms of toxic microorganisms and cause low dissolved oxygen levels (Novotny and Olem, 1994). Wastes from animal agriculture are believed to be significant contributors to this nutrient load (Smith and Alexander, 2000). The lost resource (wasted) apparently becomes a stressor that adversely impacts other resources (here: aquatic). The loss of potential income from beneficial use of the resource might then be further compounded by income loss from exploitation of the now less productive aquatic resource.

The chemical characteristics of poultry manure are such that its ratio of nitrogen (N) to phosphorus (P) is less than that required for plant nutrition (Mullins, 2000). The mandated shift from N-based nutrient management to P-based management may hence decrease the total amount of poultry manure that can be applied to cropland as fertilizer and understandably generates anxiety amongst poultry producers. Sims (2000) further indicates that as poultry production has significantly increased over the past 50 years, the cropland area has simultaneously decreased, which may compound potential problems. It may however be noted that crop yields have significantly increased and their nutrient uptake per unit area is higher than 50 years ago. Overall, the above considerations raise the question of how much of the poultry manure resource can be beneficially used as crop nutrients and how much should be diverted to other uses.

The perspective adopted here is not one of limiting poultry production since the industry is a staple of the Maryland economy. Rather, it is believed that once the amount required for plant nutrition is quantified, it becomes easier to ascertain the need for developing additional beneficial uses of the resource. Clearly, the beneficial use of poultry manure as a fertilizer is not only a question of quantity but also of management. Hence, after presenting some basic mass balance issues, the paper discusses issues of export control and buffering. The combination of these techniques has the potential to maximize the amount of the poultry manure resource used beneficially for crop nutrition.

COUNTY SCALE NUTRIENT BALANCE

Lander et al. (1998) recently presented nationwide, county-based estimates of nutrients available from livestock manure in relation to crop growth requirements. Their results (which are re-analyzed later in this section) indicate that nutrient availability from manure exceeds harvested cropland, hayland and pasture N requirements in 50 counties while P requirements are exceeded in 134 counties, nationwide. Nutrients from livestock manure thus exceeds crop requirements locally, but the resource might be spatially redistributed for beneficial use in adjacent counties. Their results for Maryland indicate no nitrogen surplus but significant phosphorus surplus in 4 eastern shore counties (Table 1). The total surplus in these counties is estimated at 5 million lb and nearly matches the total P deficit in the other 5 Maryland eastern shore counties which amounts to 4.5 million lb (Table 2). This suggests again, that localized cross-county redistribution of livestock manure (principally poultry) can lead to full beneficial use of the resource, as fertilizer. The remaining 14 Maryland counties have a total P deficit estimated at 12 million lb (Table 3).

Table 1. Manure Phosphorus Surpluses in Maryland Counties[a]

County	Crop, Hay and Pasture P need (1000 lb)	P from Livestock Manure (1000 lb)	P Excess (1000 lb)
Wicomico	825	3119	2294
Somerset	520	1842	1322
Worcester	1241	2254	1013
Caroline	1138	1496	358
Total:	3724	8711	4987

[a] Data from Lander *et al.* (1998).

Table 2. Manure Phosphorus Deficits in Eastern Maryland[a]

County	Crop, Hay and Pasture P need (1000 lb)	P from Livestock Manure (1000 lb)	P Deficit (1000 lb)
Dorchester	1318	841	477
Talbot	1172	326	846
Queen Anne's	1942	431	1511
Kent	1630	414	1216
Cecil	969	469	500
Total:	7031	2481	4550

[a] Data from Lander et al. (1998).

Table 3. Manure Phosphorus Deficits in "Western" MD[a]

County	P Deficit (1000 lb)	County	P Deficit (1000 lb)
Allegany	377	Garrett	1082
Anne Arundel	376	Harford	1144
Baltimore	971	Howard	564
Calvert	210	Montgomery	987
Carroll	1544	Prince George's	354
Charles	361	St. Mary's	446
Frederick	2329	Washington	1190
Total (2 cols):	11,935		

[a] Data from Lander et al. (1998).

The above results appear encouraging in that only a limited amount of redistribution is required. They however need independent verification. To this effect the phosphorus requirements of crops, hay and pastures have been re-calculated, for Dorchester county, using data from the 1992 and 1997 censuses obtained from the Maryland Department of Natural Resources (DNR) as a watershed-based digital data file. Yields and acreages were back-calculated from these data to obtain an estimate for the county. The P requirements were calculated from crop and hay production as well as from acreages of pastures and woodland. The conversion factors were obtained from Lander et al. (1998, Table A-1.) and found to be similar to values reported by Novotny and Olem (1994, p. 333) and Lowrance et al. (1997, p. 696). Results presented in Table 4 indicate nearly equal phosphorus requirements in 1992 and 1997 despite differences in production of individual crops. The results also compare well to the 1.3 million lb P requirement calculated by Lander et al. (1998) (cf. Table 2). The inclusion of woodland increases the annual phosphorus requirement of the county to 1.7 million lb. Some of these woods are presumably located inland where deliberate phosphorus application is required to achieve the stated uptake (in timber production for example) while others are part of riparian buffers and essentially pick-up some of the excess phosphorus applied to the land (if they are properly located and sized).

Table 4. Phosphorus Requirements for Dorchester County Vegetation

	Year:	1992		1997	
Crop	**P Required / Yield Unit (lb P / Bu)**	**Production (1000 Bu)**	**P Required (1000 lb)**	**Production (1000 Bu)**	**P Required (1000 lb)**
Grain Corn	0.154	2352	362	2373	365
Soybean	0.358	1826	654	1775	636
Wheat	0.232	1003	233	1097	255
Barley	0.179	559	100	377	67
	(lb P / ton)	**(ton)**		**(ton)**	
Hay	4.72	1668	8	1365	6
	(lb P / Acre)	**(Acre)**		**(Acre)**	
Pasture	30	1740	52	1740	52
		Sub-Total:	1409	Sub-Total:	1381
Woodland	20	15340	307	15340	307
		Total:	1716	Total:	1688

The annual P produced by livestock were similarly re-calculated. The 1997 census inventory of layers, calves and hogs were used to calculate animal units (1000 lb of live weight) assuming 4 lb per layer, 250 lb per calf and 110 lb per hog. The number of meat chickens sold was used to obtain animal units assuming 50% broilers, 50% roasters for a mean bird weight of 3.125 lb (Collins et al., 1999) and 7 cycles per year. The number of pounds of P per animal units were obtained from Tables 1.1 to 1.6 of Collins et al. (1999; P_2O_5 multiplied by 0.44 to convert to P), Launder et al. (1998, Appendix III) and Loehr (1984, Table 4.4) converted to annual bases if necessary. Results presented in Table 5 indicate that values calculated using data from these sources are in general agreement and agree with the value given in Table 2. One notable difference however is in the nutritive value of litter from broilers/roasters which contains more P than raw manure and may hence affect nutrient balances. In the present case, the extra phosphorus contained in the litter base does not cause the total animal P production to exceed crop, pasture and hay requirements of Dorchester county.

Table 5. Livestock Phosphorus Production in Dorchester County

		Collins et al. (1999) Manure		**Collins et al. (1999) Litter**		**Lander et al. (1998)**		**Loehr (1984)**	
Animal	**Animal Units**	**lb P / A.U. / year**	**P produced (10^3 lb)**	**lb P / A.U. / year**	**P produced (10^3 lb)**	**lb P / A.U. / year**	**P produced (10^3 lb)**	**lb P / A.U. / year**	**P produced (10^3 lb)**
Broiler	8212	101.1	830	132.8	1091	99.0	799	94.9	780
Layer	819	109.6	90	99.6	82	97.3	80	102.2	84
Hog	258		14[a]		14[a]	41.1	11	54.8	14
Calf	152		6[a]		6[a]	30.3	5	40.2	6
		Total:	940	Total:	1193	Total:	895	Total:	884

[a] Obtained using values from Loehr (1984).

The independent re-calculations presented above increase confidence in the results of Lander et al. (1998) but also indicate that litter composition may differ from that of raw manure. Additionally, before concluding that redistribution can solve localized manure resource excess problems, one must consider that the total cropland, hayland and pastureland of a county may belong to several different individuals, not all of which are involved in poultry production, and some may require incentives and technical assistance to accept poultry litter or manure onto their fields. Additionally, whereas manure is produced year round, crop requirements are to be met only during the growing season and hence some form of leak-proof manure storage is strongly recommended to prevent wasting the resource during other parts of the year.

EXPORT CONTROL

Full beneficial use of the manure nutrient resource, as outlined above, also requires the minimization of off-site exports. The fraction of manure-based nutrients, applied to a field, that eventually runs off this field or leaches to groundwater is a lost resource and requires adequate replacement which may be costly. Controlling such unintended exports using Best Management Practices (BMPs) can therefore help the farm from both economical and environmental standpoints. Recent reports indicate that the adoption of some BMPs (eg. conservation tillage and poultry waste management systems) is proceeding well in at least some parts of eastern Maryland (MD DNR, 1999). Potential problematic side-effects may however arise when BMPs selected for one chemical (eg. P or N or a pesticide) might favor off-site exports of another chemical. Kleinman (2000), for example, reports that no-till significantly increased off-site delivery of nitrate in a paired watershed monitoring scenario. Hence, one part of the nutrient resource may be preserved by the BMP (here: phosphorus) while another is lost.

Appropriate selection of BMPs is critical to optimal resource use. The most appropriate BMP(s) for a given site depends on local conditions which govern the most likely mode of export (surface or subsurface) as well as the component of the resource most likely to be lost. Where local conditions include steep slopes and erodible soils, surface solids export is most likely, and may lead to loss of bound phosphorus. On flat well drained soils, export via subsurface flow is dominant and may lead to loss of nitrogen (as nitrate) and of dissolved phosphorus. No-till preserves the nutrient resource in the first case but may promote losses in the second, especially where fields have subsurface drains.

The site-specific nature of BMP applicability coupled with the heterogeneity of agricultural environments can make it difficult to manually develop effective BMP allocation plans. Decision Support Systems (DSS) that combine Geographic Information Systems (GIS), potential export indices, distributed parameter hydrologic models and Artificial Intelligence (AI) based decision aids are being developed to ease the process and make it more objective, precise and accurate (Montas et al., 1999a,b, 2000a). The major steps in the application of such systems are: data acquisition, identification of zones with a high potential for resource loss and prescription of appropriate BMPs. Typical data sources include digital soil maps (eg. NRCS SSURGO), topographic maps (eg. USGS DEM), watershed boundary data files (eg. DNR/USGS 14-digit watersheds) and land cover maps developed, for example, from DNR Digital Orthophoto Quarter Quads (DOQQs). These data are input in the GIS (eg. ERDAS IMAGINE or ESRI ArcView/ArcInfo) and used to drive physically-based surface hydrologic models (Montas et al., 1999a), subsurface hydrologic models (Montas et al., 2000a) or site indices (Leytem et al., 2000) to quantify potential resource loss, in detail, on a spatial basis. Results are typically aggregated on a field by field basis and used to identify the most likely cause and mode of unintended resource export (diagnosis) and then prescribe one or more BMP(s) to control this export. The diagnosis and prescription can be performed manually, by an expert, but the use of expert systems and neural networks are being researched to perform these data intensive and time-consuming tasks automatically.

Figures 1 and 2 present the decision-tree representation of three rules in an expert system for BMP prescription for nitrogen export control and the architecture of a neural network for phosphorus loss control, respectively. The expert system was implemented within the ERDAS (Inc.) IMAGINE GIS using the Knowledge Engineer tool (Montas et al., 1999b) and the neural network was implemented using the MATLAB Neural Network Toolbox (MathWorks, Inc.) and used with the ESRI (Inc.) ArcView GIS (Montas et al., 2000b). A major difference between the two systems is that knowledge is represented explicitly in the expert system which makes it easy to modify and update whereas it is represented implicitly in the neural network (through training) which makes it faster. An example of the results of the expert system is presented in Figure 3, where crops and application rates were assigned randomly among fields since this example is for illustration purposes only. The most important aspect of these results is the variety of appropriate BMPs. A single solution to resource conservation does not apply everywhere, even in this relatively small area. Results indicate that intercropping was selected for fields with high residual nitrogen to promote full use of this nutrient resource, terracing (or contouring) was recommended on fields with steeper slopes to prevent surface losses and irrigation management was suggested in irrigated fields (again, randomly assigned) with a high potential for subsurface leaching (see decision tree in Figure 1). The analysis further indicates that BMPs may not be required on all fields in the area since soil and topographic conditions are highly variable and hence the potential for resource loss also varies from field to field.

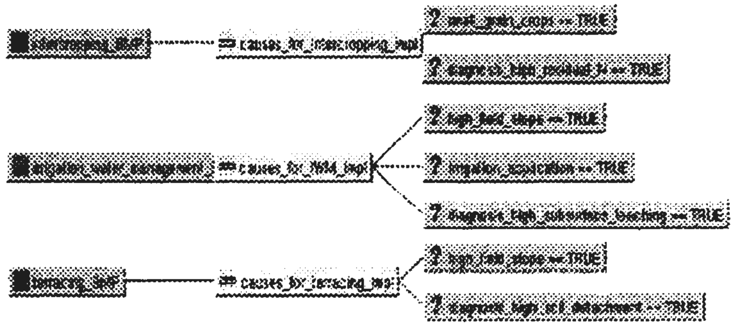

Figure 1. Decision Tree Representation of Three Rules for Prescribing Appropriate BMPs to Control Losses of the Manure N Resource from Cropland

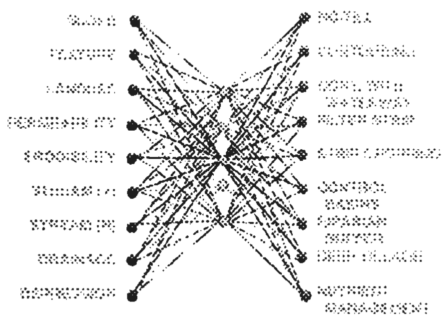

Figure 2. Architecture of a Neural Network for Identifying Appropriate BMPs to Prevent Losses of the Manure P Resource from Cropland. Conditions are on the left, prescriptions on the right. There are 5 hidden nodes (synapses).

BUFFERS ZONES

While appropriate application rates (based on plant requirements) and precisely selected export controls can theoretically eliminate resource loss, it is almost guaranteed, in practice that some unintended losses will still occur. This lost resource may not be economically recoverable but it may still stress downstream natural resources and have significant off-site effects. Consider for example, that a phosphorus concentration as low as 20 μg/l may be sufficient for a lake to become eutrophic (Novotny and Olem, 1994) while 100 μg/l can trigger algal blooms (USEPA, 1997). Using Dorchester county for an illustration, with a land area of 371,200 acres (150,283 ha), annual precipitation of 111 cm (Rasmussen and Slaughter, 1957) and assuming 70% evapotranspiration (Saxton, 1982) yields a net annual rainfall input of 502 million m^3 to dilute possible P losses. The eutrophic and bloom concentrations may be reached if the county's P loss exceeds 22,000 lb and 110,000 lb, respectively, which, for 102,300 acres of cropland translates into 0.22 lb P loss / acre and 1.10 lb P loss / acre, respectively. In terms of poultry litter, these bounds are equivalent to 14 lb and 70 lb of lost litter per acre per year, respectively. Losses of this magnitude can occur because of lower than expected yields, unusual climate or mis-calibrated application equipment and are hard to avoid. Clearly, some sort of buffering mechanism or device must be either in place or implemented to prevent such small losses from becoming environmental disasters and to improve the margin of operation for producers.

Permanently vegetated areas which do not receive manure application can serve this important buffering function if they are properly sized and located. Inasmuch as lost nutrient resources are transported with surface and subsurface flows towards open water bodies, the vegetated areas that lie at the interface between the land and these water bodies (riparian areas) are expected to play the most significant role in mitigating the potential negative effects of the lost resources (Lowrance et al., 1997). Permanent inland vegetation (Vegetated Filter Zones (VFZ) and inland woods) may also help when they are located in the path of motion of lost nutrients. Results presented earlier in Table 4 indicate that if all woodland in Dorchester county was effective at buffering unavoidable

P losses then up to approximately 300 lb of lost litter per acre of cropland per year may be successfully mitigated. The margin of error for manure application would be multiplied by 4 to a magnitude that is more manageable with current application technology. Unfortunately, it is highly unrealistic to expect all woodland in the county to act in this way.

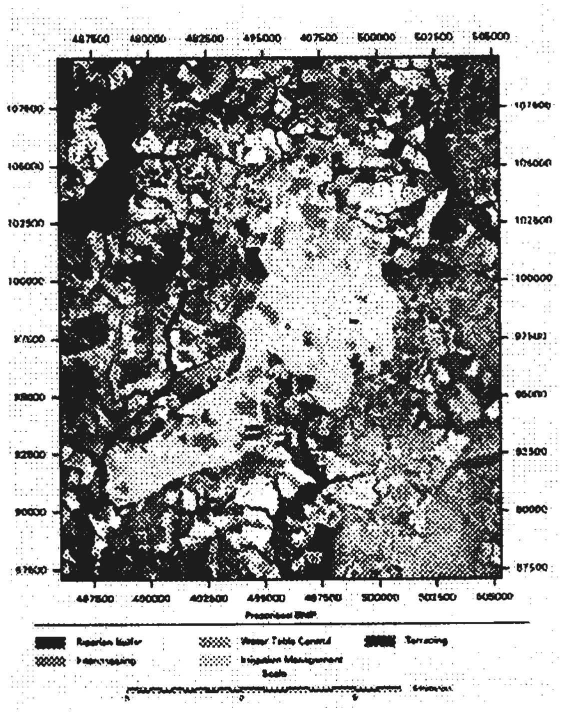

Figure 3. Example of BMPs Prescribed by an Expert System for N Loss Control with Random Crop/Management Allocation (for illustration purposes only)

The effectiveness of permanent vegetation in buffering lost nutrients depends, among others, on local hydrologic conditions, the size of the vegetated zone and the nutrient loading. Similarly to the potential for resource loss, these variables show significant spatial variability which makes manual assessment of buffer effectiveness very time-consuming and costly. GIS coupled with detailed hydrologic models can however provide rapid and accurate pictures of this effectiveness. Figure 4 presents the results of this type of analysis performed on a Maryland watershed and aimed at evaluating the effects of riparian buffers on nitrate delivery to streams (Montas et al., 2000b). As in the previous section, spatial data were acquired from SSURGO, USGS DEMs and DOQQs. These data were input into the ERDAS (Inc.) IMAGINE GIS in which the subsurface flow and transport model Hydrosub was implemented. Hydrologic simulations were then performed to identify the quantity of nitrate delivered from the land, to streams, through riparian buffers. Results indicate clearly that nutrient delivery is highly heterogeneous. Very little nitrate enters the main stream directly because of its wide, vegetated, riparian area. Significant amounts however enter the south-westernmost tributary and the three northernmost tributaries suggesting insufficient buffering in these zones. Equipped with these results it is possible to efficiently target riparian buffer implantation and restoration efforts to those areas of the watershed where they are most needed. The reader must note however that results presented in Figure 4 are based on random land cover allocation as they are meant only to illustrate the capabilities of the technology.

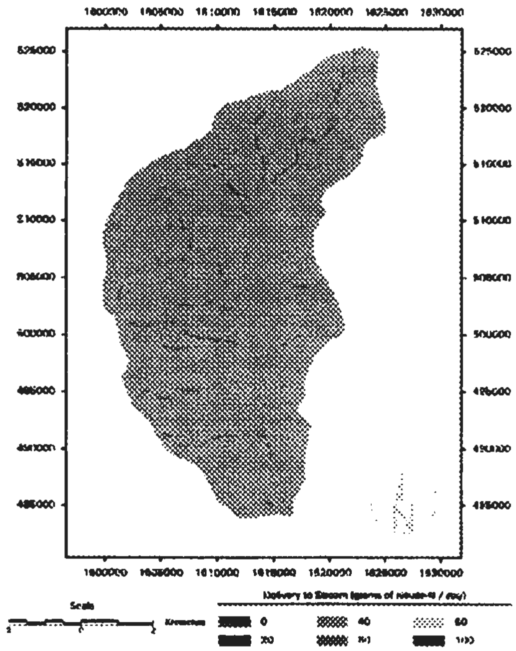

Figure 4. Spatial Distribution of Nitrate-N Delivery to Streams in a Watershed with Riparian Buffers of Various Sizes (for illustration purposes only)

SUMMARY

Poultry and other livestock manure is a valuable resource for plant nutrition. Manure phosphorus excesses from Maryland's 4 lower eastern shore counties may compensate for deficits in other eastern counties. Export control and adequate buffering are however required to ensure full beneficial use of the resource with minimal side-effects. The combination of GIS, hydrologic models, site indices and AI into DSSs can be used to efficiently and objectively identify appropriate site-specific BMPs that prevent resource loss and to identify areas where additional buffering is required to maintain the integrity of downstream resources. Research is both planned and underway to extend the flexibility and accessibility of these technologies and to couple them with GPS to support precision farming activities and in-field decision-making processes.

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FSIS PERSPECTIVES ON SANITATION AND SAFETY ASPECTS OF PROCESSING

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On October 20, 1999, the Food Safety Inspection Service (FSIS) published a final rulemaking *Sanitation Requirements for Official Meat and Poultry Establishments* in the Federal Register that became effective on January 25, 2000. The rule establishes regulatory sanitation performance standards applicable to all official meat and poultry establishments (FSIS Docket 96-037F, 64 FR 56400). Federal requirements for the source, use, and reuse of water in poultry processing plants, however, have remained essentially unchanged. Keep in mind that the new performance standards are stated broadly to allow flexibility in meeting the requirements. This is in sharp contrast to the prescriptive regulatory requirements under which FSIS formerly operated. Establishments are required to document and monitor water reuse activities either in their Sanitation SOP's or HACCP plans.

It is the responsibility of the establishment to ensure that plumbing and sewage systems provide an adequate supply of potable water for processing and other purposes and move waste and sewage from the establishment without adulterating product or creating insanitary conditions. Although prior approval of facilities is no longer required, FSIS will continue verifying, through inspection, that plumbing and sewage systems neither adulterate product nor create insanitary conditions.

FSIS does not require compliance with any of the private organizations' standards or codes and does not specifically endorse their use. However, these standards and codes usually provide useful information concerning construction, plumbing, and sewage disposal and, in many cases, compliance with them by meat and poultry establishments could meet the sanitation performance standard regulations. Establishments may use other codes or information provided they comply with all applicable Federal, State, and local laws governing construction, plumbing, and sewage disposal. FSIS plans to reference additional codes and standards, as appropriate, in future versions of its compliance guide.

REGULATORY STANDARDS

FSIS adopted as the performance standard the current requirement that potable water comply with EPA's National Primary Drinking Water regulations. These regulations are promulgated under section 1412 of the Public Health Service Act, as amended by the Safe Drinking Water Act, and are applicable to public water systems. The EPA standard of water potability is sufficient.

The EPA National Primary Drinking Water regulations, contained in 40 CFR part 141, require testing of drinking water for fecal coliforms and other contaminants at specified frequencies. Because FSIS is requiring that water used by meat and poultry establishments meet the EPA requirements, which include testing requirements, FSIS did not promulgate separate testing requirements for municipal water supply. Certifications of water potability provided by State or local governments or other responsible entities will show whether water meets the EPA requirements.

Some meat and poultry establishments use private wells for their water supply. EPA classifies private wells as "noncommunity" water sources and does not require testing for potability. If an establishment uses a private well, FSIS requires that the establishment make available to FSIS documentation, renewed at least semi-annually, certifying the potability of its private well water. Most establishments will obtain this documentation from private laboratories.

In many circumstances, establishments can reuse water in a manner that will neither adulterate product nor create insanitary conditions. FSIS already permits certain uses of nonpotable water. For example, water is recirculated in tanks to chill raw poultry; water treated by an advanced wastewater treatment system can be used to wash equipment or carcasses prior to any openings, if followed by a potable water rinse. Water treated by an advanced wastewater treatment facility cannot be used in formulating product. Minimally treated reuse water can be used to wash floors or equipment in areas where edible product is not handled. FSIS performance standards provide for the reuse of water in numerous processing contexts, provided that the establishment takes actions necessary to ensure that product is not adulterated by the water and that sanitation is not compromised.

Water reused to chill or cook ready-to-eat product must be free of pathogens. The presence of fecal coliforms and other pathogens, or other physical or chemical contaminants in reuse water, ice, or processing solutions indicates insanitation that may, in fact, lead to the adulteration of meat and poultry products. The control of pathogens in water used in processing, therefore, is essential for ensuring that meat and poultry products do not become adulterated. The performance standards establish the necessary conditions to ensure that water, ice, and solution reuse do not compromise sanitation or cause the adulteration of product.

FSIS has a single set of reuse performance standards applicable to water, ice, and solutions. However, because of the different physical characteristics and uses of water, ice, and solutions, it is expected that establishments will meet the performance standards for these substances in different ways. For example, an establishment recirculating water in a chill tank for raw poultry might add chlorine to the water to reduce the number of pathogens. An establishment reusing ice to chill raw poultry might bag the ice to prevent it from contacting product.

Meat and poultry establishments have the responsibility of ensuring that the nonfood compounds and proprietary substances that they use will not adulterate product or create insanitary conditions. FSIS will verify that these chemicals are being used appropriately through inspection, review of documentation substantiating the safety of the chemicals, and if necessary, sampling and testing. FSIS anticipates that research and competition will compel chemical manufacturers to demonstrate to meat and poultry establishments that their products are safe and satisfy the standards established in these regulations.

The following text is the FSIS regulatory language in 9 CFR 416.2 that pertains to water use and reuse:

Establishment Grounds and Facilities

Plumbing: Plumbing systems must be installed and maintained to

(1) Carry sufficient quantities of water to required locations throughout the establishment;
(2) Properly convey sewage and liquid disposable waste from the establishment;
(3) Prevent adulteration of product, water supplies, equipment, and utensils and prevent the creation of insanitary conditions throughout the establishment;
(4) Provide adequate floor drainage in all areas where floors are subject to flooding-type cleaning or where normal operations release or discharge water or other liquid waste on the floor;
(5) Prevent back-flow conditions in and cross-connection between piping systems that discharge waste water or sewage and piping systems that carry water for product manufacturing; and
(6) Prevent the backup of sewer gases.

Sewage disposal: Sewage must be disposed into a sewage system separate from all other drainage lines or disposed of through other means sufficient to prevent backup of sewage into areas where product is processed, handled, or stored. When the sewage disposal system is a private system requiring approval by a State or local health authority, the establishment must furnish FSIS with the letter of approval from that authority upon request.

Water supply and water, ice, and solution reuse: (1) A supply of running water that complies with the National Primary Drinking Water regulations (40 CFR part 141), at a suitable temperature and under pressure as needed, must be provided in all areas where required (for processing product, for cleaning rooms and equipment, utensils, and packaging materials, for employee sanitary facilities, etc.). If an establishment uses a municipal water supply, it must make available to FSIS, upon request, a water report, issued under the authority of the State or local health agency, certifying or attesting to the potability of the water supply. If an establishment uses a private well for its water supply, it must make available to FSIS, upon request, documentation certifying the potability of the water supply that has been renewed at least semi-annually.

(2) Water, ice, and solutions (such as brine, liquid smoke, or propylene glycol) used to chill or cook ready-to-eat product may be reused for the same purpose, provided that they are maintained free of pathogenic organisms and fecal coliform organisms and that other physical, chemical, and microbiological contamination have been reduced to prevent adulteration of product.

(3) Water, ice, and solutions used to chill or wash raw product may be reused for the same purpose provided that measures are taken to reduce physical, chemical, and microbiological contamination so as to prevent contamination or adulteration of product. Reuse that which has come into contact with raw product may not be used on ready-to-eat product.

(4) Reconditioned water that has never contained human waste and that has been treated by an onsite advanced wastewater treatment facility may be used on raw product, except in product formulation, and throughout the facility in edible and inedible production areas, provided that measures are taken to ensure that this water meets the criteria prescribed in paragraph (g)(1) of this section. Product, facilities, equipment, and utensils coming in contact with this water must undergo a separate final rinse with non-reconditioned water that meets the criteria prescribed in paragraph (g)(1) of this section.

(5) Any water that has never contained human waste and that is free of pathogenic organisms may be used in edible and inedible product areas, provided it does not contact edible product. For example, such reuse water may be used to move heavy solids, to flush the bottom of open evisceration troughs, or to wash antemortem areas, livestock pens, trucks, poultry cages, picker aprons, picking room floors, and similar areas within the establishment.

(6) Water that does not meet the use conditions of paragraphs (g)(1) through (g)(5) of this section may not be used in areas where edible product is handled or prepared or in any manner that would allow it to adulterate edible product or create insanitary conditions.

Cmpliance guidelines

Compliance guidelines that contain examples of reuse plans can be found on the FSIS website at `http://www/fsos/isda/gpv/OPPDE/rdad/FRPubs/96-037C.htm`. These guidelines are not regulatory. The October 1999 sanitation regulation can also be found at this site.

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WATER REUSE OPTIONS

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The concept of water reuse for both process water and waste water in the meat and poultry industries has been discussed and considered for many decades. In 1978a and 1982 Lillard; for example, advocated the reuse of poultry chiller water and developed methods for rendering poultry chiller water suitable for recycling. More recently, Ng et al (1994) developed a flocculation technique for conditioning and subsequently recirculating chiller water while Carawan and Sheldon (1996) compared several methods for chiller water reuse.

During the last 10 years, the concept of water reuse has gained significant attention both by industry and state and federal regulatory agencies due to increasing cost of water use, concern for depleting water supplies, and the lack of adequate supplies of water in many portions of the US. The cost of obtaining water by poultry processors presently ranges from ≈\$3.00 to \$6.00/1000 gallons. Given that the average poultry processing plant can utilize between 1 – 3 million gallons of water per day, the annual cost of water per plant can be in excess of 4 – 6 million dollars. In addition to increasing costs for water usage, the availability of water for poultry processing has become a priority issue. In many areas of the US, new plants and plant expansions are dependent upon the ability to purchase water permits from local municipal authorities. Droughts, which have been relatively severe during the past 3 years in the southeastern and mid-Atlantic states have resulted in some restrictions on plant operating schedules, restricted availability of water usage permits, or threats of impending water usage restrictions.

In response to increasing concern with water use in the meat and poultry industries, the USDA and FSIS have initiated a series of regulatory revisions to address guidelines and directives that allow water reuse. The first revision of USDA, FSIS "Sanitation Performance Standards" was in June, 1990 and was entitled "Guidelines for the safe reuse of treated effluent water for meat and poultry processing". The 1990 guideline document specifically stated that "the need to conserve potable water is becoming critical". The first action guideline was issued by USDA, FSIS in August, 1997, Section 416.2(g) and for the first time stated that "proposed performance standards are intended to account for every allowable water reuse situation and eliminate the need for prior

(USDA) approval". Several revisions of this guideline were issued through 1998 and 1999 with a directive issued in 12-99 and a final directive issued in the spring of 2000.

Of the several methods cited in the USDA, FSIS Directive No: 11,000.1, Section 416.2(g) as treatment options for water reuse, ultrafiltration is regarded as the most suitable method for producing acceptable, consistent water quality and relatively high flow rates for obtaining maximum cost effectiveness. Recent investigation, for example, examined ozonation, screening, sand filtration and filtration with diatomaceous earth (DE) as a filter medium (Carawan and Sheldon, 1996). Lillard (1978b) obtained chiller water that was free of pathogens and had excellent clarity using filtration and DE filter medium.

CSI-Industrial Applications Group, Inc. conducted pilot projects with several leading poultry producers to evaluate the capability of ultrafiltration to treat poultry process and waste water for reuse. Using an automated filtration system, chiller water, bird wash water, and waste water were all successfully treated and demonstrated to exceed USDA water quality guidelines for process and waste water reuse.

METHODS

Ultrafiltration of Chiller and Bird Wash Water

In order to deploy DE filter media and conduct ultrafiltration pilot projects, a flextube pressure filter manufactured and marketed by CSI-Industrial Applications Group, Inc. was used (Figure 1). The flextube filter used for all in-plant pilot projects was a 16" diameter unit having 226, 36" long flextubes. The effective filtration area of the filter was 84 sq. ft. The filtration system consisted of a 36" vibrascreen fitted with 80 mesh screening coupled to the flextube filter. The system was fully automated including pre-coat and self-cleaning cycles. The vibrascreen and all piping and fittings were stainless steel . The filter body was carbon steel coated with Sherman Williams 4.76 food grade epoxy. As configured, the ultrafiltration system was capable of processing chiller and bord wash water at 25 – 100 gpm, depending on the porosity of DE filter media used in a given trial.

Several grades of DE were evaluated during the course of the pilot studies, conducted at five different poultry processing facilities. Based on evaluation of these various grades of DE, a grade having an effective removal capacity of 0.5 u was selected for use in all experiments with filtration of chiller and bird wash water.

Samples were simultaneously collected from ulfiltered and filtered process water on an hourly basis throughout 8 hour process periods. Samples were collected by laboratory staff at each respective process plant. Samples were collected in appropriate vessels for each respective analysis and typically analyzed by both plant in-house laboratories and outside, state certified, contract laboratories. Analyses conducted for each sampling period in either chiller or bird wash water were total aerobic plate count (TPC), total coliform bacteria, total *E. coli*, and total suspended solids (TSS).

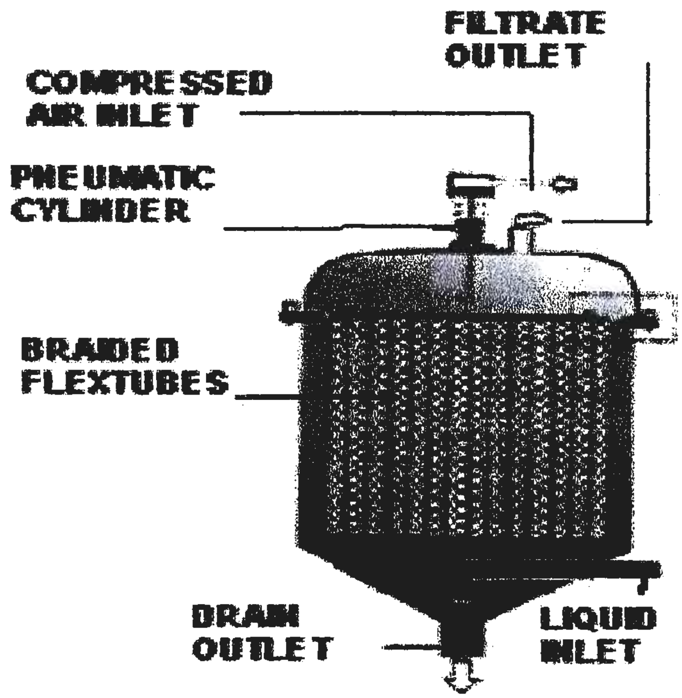

Figure 1. CSI Flextube Filter Used for Ultrafiltration of Poultry Process and Waste Water

Ultrafiltration of Waste Water From a Waste Water Treatment Plant

The underflow from a DAF (dissolved air floatation) unit at the waste water treatment plant of a poultry producer was subjected to ultrafiltration. As in the case of chiller and bird wash water evaluations, the flextube filter was a CSI 16" unit having an effective filtration area of 84 sq. ft. Flow rates were 25 – 100 gpm. DE filter media having a mean particle removal size capacity of 0.5 u was used for all pilot projects and trials. The filatration system consisted of only the flextube filer and associated plumbing and did use a vibrascreen pretreatment stage.

Samples were collected in approximately sample vessels by plant laboratory staff. All analyses were conducted by both local municipal analytical laboratories and state certified contract laboratories. Analyses conducted on each respective sample consisted of those analyses required by the USDA, FSIS Directive No: 11,000.1, Section 416.2(g). This Directive specifies monitoring criteria for total aerobic bacterial plate count (TPC), total coliform bacteria, *E. coli*, total organic carbon (TOC), and turbidity.

Ultrafiltration of Waste Water From Cooling Towers

Water was typically pumped from the sump area under the inclined plates of an industrial cooling tower into a CSI flextube filter. The 16: CSI flextube filter, as described above (Figure 1) was used for cooling tower experimental trials discussed in this report. No vibrascreen or other pretreatment methods were employed prior to filtration. DE media used for cooling tower experiments had a porosity of 0.5 u and an effective particle removal size of 0.1 u. All water analyses conducted for cooling tower trials were the same as described above for waste water. Typical flow rates during the experimental period were ≈ 100 gpm.

Ultrafiltration of Waste Water From Poultry Plant Air Scrubbing Units

As in the case of cooling tower effluents, water from air scrubber modules was pumped from the sump of a given unit and fed to a CSI flextube filter. No vibrascreen or other pretreatment stage was used between the air scrubber unit and the filter. Filters used for air scurbber experimental trials were totally automated, 16" units as described above. DE filter media used to treat air scrubber water had a porosity of 0.3 u and an effective particle removal size of 0.09 u. Typical flow rates during the experimental period were 80 – 100 gpm.

RESULTS AND DISCUSSION

Ultrafiltration of Chiller and Bird Wash Water

Ultrafiltration of chiller water, using a flextube filter and DE filter media, resulted in reductions in bacterial counts and turbidity that exceeded USDA, FSIS guidelines for chiller water reuse (Table 1).

USDA, FSIS regulations (as per FSIS "Sanitation Performance Standards Compliance Guide, Federal Register, 9CRF 416.2 (g) and USDA, FSIS Directive No: 11,000.1) specify that chiller water used for reuse in processing raw product can not have total bacterial plate counts (TPC) in excess of 500 cfu/ml. As summarized in Table 1, the average TPC for untreated chiller of 135 cfu/ml was reduced to an average TPC of 0 cfu/ml thr9ough treatment with ultrafiltration. Similarly, FSIS guidelines for total coliform bacteria and *E. coli* specify a threshold of 0 cfu/ml. For both total coliform and *E. coli* bacteria, chiller water processed with ultrafilatration methods had plate counts of 9, regardless of plate counts in the ambient chiller water. Turbidity of chiller water for reuse, as given in FSIS regulations can not exceed 5 NTU's. As indicated in Table 1, although turbidity in the chiller bath reached >40 NTU after 6 hours of processing, NTU values in ultrafiltered chiller water never exceeded 3 NTU's.

Table 1. Results – Chiller Water Reuse Trials Using Ultrafiltration

TPC (cfu/ml)			Total Coliforms (cfu/ml)			E. coli (cfu/ml)			Turbidity (NTU)		
Chiller	Filter	% Change	Chiller	Filter	% Change	Chiller	Filter	% Change	Chiller	Filter	% Change
10	0		0	0		0	0		21.0	0	
0	0		0	0		0	0		21.1	2	
80			2	0		1	0		21.4	2.5	
190	0		22	0		13	0		27.2	3	
280	0		16	0		5	0		32.5	2	
230	0		3	0		1	0		40.9	1	
160	0		6	0		0	0			3	
Ave:	Ave:		Ave:	Ave:		Ave:	Ave:		Ave:	Ave:	
135	0	100%	7	0	100%	3	0	100%	27.4	1.9	93%

As in the trials with chiller water, bird wash water treated via ultrafiltration using DE media also was found to exceed USDA water quality guidelines for water reuse (Table 2).

Table 2. Results – Bird Wash Water Reuse Trials Using Ultrafiltration

TPC (cfu/ml)		Total Coliform		TSS (ppm)		Turbidity (NTU)	
Water	Filtered	Water	Filtered	Water	Filtered	Water	Filtered
>10^6	<1	Pos.	Neg.	132	10	20	<.05
19	<1	Pos	Neg.	124	12	23	>0.5
1	<1	Pos	Neg.	154	52	39	<.05
1	<1	Pos	Neg.	168	30	50	<.05
>10^6	<1	Pos	Neg.	162	<5	39	<.05
>10^6	<1	Pos	Neg.	132	8	65	0.9
>10^6	<1	Pos	Neg.	136	12	61	3.3
>10^6	<1	Pos	Neg.	152	12	54	3.2
Ave:	Ave:	Ave.	Ave:	Ave:	Ave:	Ave:	Ave:
>10^6	<1	Pos.	Neg.	145	18	44	<1.2

While total bacterial plate counts (TPC) and total coliform plate counts of untreated bird wash water were often far in excess of FSIS guidelines, during the daily process cycle, all bacterial counts were less then detection in filtered bird wash water. Similarly, total suspended solids (TSS) were reduced from an average of 145 ppm in untreated bird wash water to an average of 18 ppm in ultrafiltered bird wash water. As in the case of chiller water (Table 1), turbidity in filtered bird wash water was significantly below the FSIS regulatory threshold of 5 NTU's. Turbidity was reduced from an average of 44 NTU's in untreated bird wash water to an average of <1.2 NTU's in ultrafiltered bird wash water.

Ultrafiltration of Waste Water – Treatment Plant

Results from continuous ultrafiltration of the DAF unit as a poultry waste water treatment plant indicated that the water could be successfully treated for plant reuse (Table 3). Total dissolved solids loading in the DAF underflow water was reduced from 50 to 13 ppm using ultrafiltration. COD loading was also reduced by 62.9%. Recycling of cooling tower effluent using ultrafiltration indicated that total solids could be reduced by ≈ a factor of 10, from 7.7 to 0.7 ppm. COD concentrations were also reduced from 115 to 111 ppm. In processing air scrubber effluents using ultrafiltration, concentrations of solids were again reduced approximately ten fold, from 495 to 52 ppm. COD concentrations were reduced by 82%.

Table 3. Results – Waste Water Reuse Trials Using Ultrafiltration

	TSS (ppm)		COD (ppm)	
Waste Stream	Water	Filtered	Water	Filtered
DAR-Underflow	50	13	956	354
Cooling Tower	7.7	0.7	115	111
Air Scrubber	495	52	1844	339

The results of treating the DAF, cooling tower, and air scrubber water waste streams at a large poultry processing plant (Table 3), indicated that waste water streams could be successfully treated via ultrafiltration for water reuse. In practical application, rather than filter individual waste streams, it is recommended that individual waste streams be plumbed to the central DAF unit for processing. A single ultrafiltration system could then be installed for processing DAF underflow water. The filtered DAF underflow water could then be plumbed in a manifold configuration for individual reuse applications such as plant process, cooling tower, air scrubber, truck wash, boiler water, etc.

Cost Savings in Plant Operations

The ability to reuse up to 80% of all poultry process water at any given process plant, within USDA, FSIS regulations, could potentially result in cost savings representing a major portion of a plant's current operations annual budgets. The average rate of potable water use for most poultry processing plants is >2 M gallons/day. The average cost of obtaining, using, and disposing of water is ≈ $4.50/1000 gallons. Using these assumptions, the annual cost of water use in the poultry industry is $3,285,000 (i.e., 2,000 x $4.50 x 365). If water usage per plant could be cut by ≈ 80%, the annual savings per plant could be as high as $2,628,000. In addition, cutting poultry processing plant water consumption by ≈ 80% would be a large contribution to US water conservation initiatives and would alleviate anxiety over operating plants in drought stricken areas of the US.

SUMMARY

1. In-plant experimentation with poultry chiller and bird wash effluents indicated that ultrafiltration using DE filter media was an effective method for recondition process water. Reconditioned water was found to meet and exceed all USDA, FSIS regulations for process water reuse.

2. In-plant experimentation with poultry waste water indicated that ultrafiltration with DE filter media was an effective method for reconditioning waste water; including plant process waste, as well as cooling tower and air scrubber effluents. Reconditioned waste water was demonstrated to meet and exceed USDA< FSIS regulations for waste water reuse.

3. Reuse of process and waste water could result in reuse of $\approx$ 80% of all poultry process plant potable water.

4. Reuse of $\approx$ 80% of poultry process plant potable water could result in annual operations budget savings >$3M.

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INCREASING PROCESSING OPTIONS BY WATER RE-USE

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Since 1988 American Water Purification, Inc. has been working with the USDA and poultry processing plants to allow the poultry processing industry to reuse wastewater in slaughter and further processing areas of their processing plants.

In the early days, the only guideline offered to the poultry industry by the USDA was CFR 381.66, which addressed only the reuse of chiller water. This regulation required a plant to increase water flow to the chillers up to 175% and had never been implemented in a processing plant. The members of the USDA Water Reuse Committee were uncomfortable with this reg, a fact that made it almost impossible for a processor to actually begin recycling.

During 1996, the USDA granted American Water Purification, Inc. approval to recycle water for food contact use in all federally inspected meat and poultry plants. By the end of 1997, plants were eliminating city water use in chillers by using recycled water instead of city water. During 1998, plants were using recycled water in the picking rooms, heaters and bird washes, as well as the chillers. The new food safety initiative brought pressure on plants to use greater amounts of water and pressure on the USDA to create rules to allow plants to reuse water without increasing the risk of higher pathogen levels on America's meat and poultry supply.

In January 2000, the USDA issued a paper entitled "Water Supply and Water, Ice and Brine Solution Reuse." This USDA clarification opened the way for plants to solve water acquisition and discharge difficulties, reduce operating costs, increase production and meet the new HACCP requirements, while at the same time reduce plant discharge and city or well water acquisition.

WHAT IS THE EFFECT OF ANTI-MICROBIOLS ON THE WASTE STREAM?

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NO PAPER SUBMITTED

AIR QUALITY INTERVENTION STRATEGIES IN THE PROCESSING PLANT: A SYSTEMS APPROACH

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Poultry slaughter and processing plants typically process 50,000 or more birds per day. The shackling, killing, scalding, and picking areas of these plants emit airborne microorganisms, moisture, and dust. These contaminants are unwanted because they can affect product safety and quality and are a potential hazard to worker health. Air currents within any plant can move pathogens and other contaminants from place to place within the plant and onto the product. A recent recall of RTE meats contaminated with Listeria was attributed to post-product contamination resulting when microorganisms were distributed from the raw area to the cooked area through the ventilation system onto unpackaged product.

The design and maintenance of ventilation systems in poultry slaughter and processing plants is often overlooked after the plant is built. During the design and building of poultry slaughter and processing plants a ventilation engineer is typically hired to design the air handling system for adequate control of moisture, dust, and microorganisms. However, after the plant has been operating for a while maintenance procedures may become lax and then when making additional modifications to the plant to improve efficiency, worker safety, etc., air quality considerations are often overlooked.

A typical poultry slaughter plant consists of shackling, scalding, evisceration, chilling, packaging, and storage. Further processing plants may contain areas designated for grading, sizing, slicing, packaging, storage, and shipping. Often, a single plant houses both slaughter and further processing. Historically, poultry slaughter and further processing plants were ventilated with negative pressure ventilation to allow for treatment of odorous exhaust air. Air was drawn into the plant from the outside through doors, windows, and air dampers. Recent trends suggest that positive pressure ventilation is the direction of the poultry and red meat industry. Using a positive pressure ventilation scheme for better control over air infiltration and better compensation for high winds or doors opening and closing. These situations are difficult, if not impossible to control for in a negative pressure ventilation facility.

In the ideal poultry processing plant, air should be moved from the cleanest to dirtiest parts of the plant. Figure 1 shows a schematic of such an ideal air flow pattern. Outside air enters in the shackling room, storage/shipping area, and packaging area through roof inlet and travels to the exhaust in the scalding room. In a slightly modified building, Figure 2, a heater was added for worker comfort in the packaging area, and a fan was added in the chilling area to reduce condensation. The air flow pattern has been altered considerably. Air travels in through the shackling area to the exhaust port in the scalding area. Also air enters the packaging area from the roof intake; however, when the heater is operating, it creates an opposing airflow that results in air being pulled from the storage/shipping area into packaging. In addition, the fan in the chilling area is blowing toward evisceration which in turn may cause air to move from evisceration into storage/shipping and back into packaging. This altered air flow pattern could cause odors and potentially introduce bacteria into the packaging area.

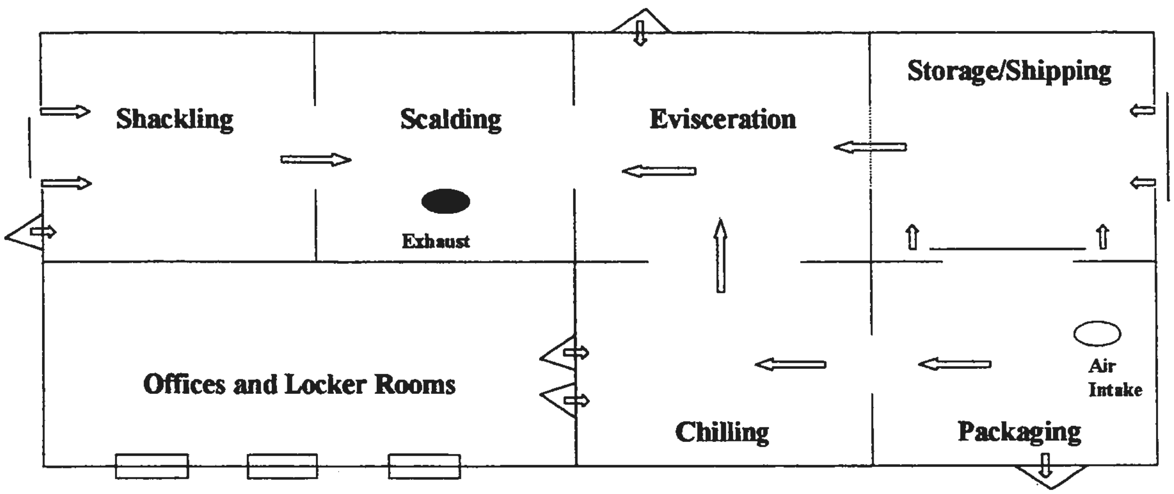

Figure 1. Idealized Air Movement in Poultry Processing Plant.

Large doorways between rooms allow air to move readily between them. It has been observed in a number of poultry slaughter and processing plants that wall openings are considered for convenience in product flow, worker and vehicle traffic. However, the size and location of these openings may have a significant impact on food safety.

In a negative pressure system, air leaks into rooms, around doorways, and other openings. Some areas in poultry processing plant are separated by double doors, large garage doors, plastic strips doors, and air curtains, such as entrance and exit doors, refrigeration, and shipping/receiving docks. Most areas however are not separated by any physical device. A large door with a crack around the bottom may allow 500 cfm air flow into an adjoining room, depending on the pressure difference between the two rooms (e.g., 0.02 in H_2O). A door opening into a pressurized room can produce a localized pressure difference allowing air to enter at a velocity of 50 ft/min or more **as long as the door remains open** (Paulson, 1995). This air may bring moisture, bacteria, and odors with it. A potential food safety hazard.

In an ideal poultry slaughter plant, air is drawn into the picking and scalding room. Approximately 30 to 90% of this exhaust air is drawn into the scalding area through the shackling area from outside (Heber *et al.*, 1995). The roof ventilators over the scalding rooms create negative static pressures (0.1 in. H_2O or more) and draw air from adjoining parts of the plant. The air flow balance is dependent on the size and location of openings within the room.

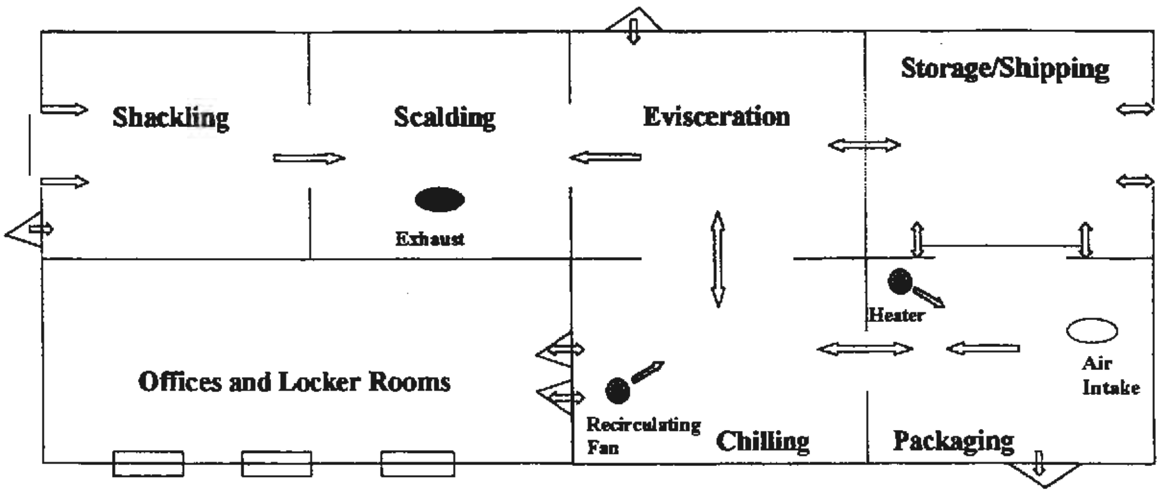

Figure 2. Air Movement in Modified Poultry Processing Plant.

Many poultry processing plants have made structural, equipment, or other process changes to increase processing capacity, eliminate condensation, or improve worker conditions without considering their effects on ventilation. This has resulted in many significant alterations to the original building ventilation design. In the original design of the plant, consideration was given to air handling, but as additions and renovations have occurred, little to no effort has been made to maintain acceptable air handling. This has resulted in processing plants with stagnant air zones, ice formation on floors outside of freezers or the ice room, water vapor from slaughter area moving into further processing area. Condensation build-up on structures above chillers, dripping onto equipment,personnel, and floors below. Condensation drips from large portions of the roof after summer thunderstorms, because of the rapid drop in outside temperature.

AIR HANDLING CONSIDERATIONS WHEN DESIGNING A NEW POULTRY PROCESSING PLANT

When designing a new poultry slaughter or further processing plant a systems approach is a typical approach to ensuring proper ventilation and air quality at all locations in the plant. The systems approach for ventilation considers the whole plant as the control volume and then subdivides this into separate control volumes for each area, room, and activity quantifying the additions and losses of moisture, heat, and carbon dioxide for personnel, equipment, and structure. Air intakes, exhaust, distribution, and conditioning (heating, cooling, dehumidification) systems are located appropriately taking these considerations into account. In addition, microbial concerns dictate that air is moved the cleanest to dirtiest part of the plant. A recommendation when designing a processing plant is to hire an air quality specialists with experience in processing plant design. These persons are usually members of the American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE) and/or the American Conference of Governmental Industrial Hygienists. They should also be a licensed engineer (P.E.) or certified industrial hygienist (C.I.H.).

A recent poultry slaughter plant designed by Vaughn, Coltrane, Pharr, & Associates Inc. (Tucker, GA) is a positive pressure ventilation system. The packaging area was the most positive area, the evisceration area was a little less positive, and the picking and scalding area were neutral. This allows for the directional air flow from clean to dirty, but also allows for the makeup air to be filtered and no dirty air from outside is drawn underneath doors or through other penetrations. Condensation problems were also reduced using this positive pressure system. The impact on condensation control on the walls is more related to good positioning of the supply diffusers than to positive/negative pressure ventilation design. A negative pressure air ventilation design could also control condensation if it had good diffuser locations with adequate air velocity on walls and ceilings. A negative air handling system with no powered makeup air has a limited effect on reducing condensation and is successful only near wall louvers.

AIR HANDLING CONSIDERATIONS WHEN RENOVATING AN EXISTING POULTRY PROCESSING PLANT

Poultry processing plants are currently under financial hardship and building a new plant to increase processing capability may not be a suitable option, but renovation may be. In these situations, one needs to consider how the proposed renovations will affect the existing air handling system. Removing a wall and adding 50,000 sq. ft. of additional processing space without consideration of additional air handling requirements is an all too common occurrence. Many unforeseen problems can result such as stagnant air regions, condensation, and uncomfortable working conditions. In one situation a wall was removed to 8 ft and a large addition was added, but the ceiling height was 15 feet at the peak. Addition holes as needed above 8 ft were created to allow conduit and other necessary wiring and equipment. The result after renovation was a newly expanded processing plant with twice the original capacity. However, upon starting processing, problems with stagnant air regions above the removed wall in the new addition created a condensation problem. A fan was installed at the ceiling to increase circulation, but it did not remedy the situation. Also there was limited insulation in the ceiling of the newly designed area and on cold mornings, clouds of water vapor would form in the ceiling area. After six months of frustration and continuous problems with condensation, a separate ventilation system was designed for the new processing area to control condensation.

Before any building renovations are started an assessment of the existing air handling system needs to be performed. The first step is to measure air temperature and relative humidity, air speeds, airflow patterns, and static pressures in each processing area. Second, assess how any renovations may affect air handling in the plant, alter air flow patterns and produce stagnant areas, produce negative static pressure areas in further processing area that may potentially draw "dirty" air into this area. This needs to be completed for all areas of the plant and not just the adjoining work areas where renovations are occurring. If one is not familiar or experienced in air handling, it would be beneficial to bring in a specialist for advice on alterations or changes to the air handling system to maintain proper ventilation after the renovations are completed. Experience has shown an ounce of prevention is worth two pounds of condensation, 5 NR's, two rolls of plastic sheeting and a very large headache!

POINTS OF CONSIDERATION

Process Areas

Air distribution needs should be assessed in each area of the plant before renovations are made. For example, assume one is installing a second chiller in an area previously used for maintenance. You would want to ensure that sufficient ventilation would exist in this area to remove the water vapor introduced by the chiller and also control temperature in this area. In addition, the added ventilation may affect the overall air flow distribution scheme as shown in Figures 1 and 2. The potential impact of this change needs to be examined over the entire plant.

Fan Types

Each fan/blower assembly has a variable air velocity output. The output air velocity depends on the static pressure difference that the fan observes. Each fan has a distinct performance curve. A standard box fan blowing at 500 ft/min air velocity at 0.001 in. of H_2O static pressure will decrease to 25 ft/min air velocity at 0.01 in. of H_2O static pressure. A blower on a furnace may produce an air velocity of 1500 ft/min at 0.001 in. of H_2O static pressure and may produce an air velocity of 1250 ft/min at 0.01 in. H_2O static pressure. Flow rate out of a fan may vary significantly or very little with changes in static pressure. These considerations need to accounted for when making renovations. The goal should be to balance air flow rates in and out of each processing area to control air flow directions. In addition, installation of new equipment such as heaters or air conditioners can serious affect air flow patterns within the processing plant. These types of equipment can produce localized air flow patterns that may draw contaminated air into a pressurized area or counteract the existing air distribution system.

Pressurization

Pressurization or negative pressurization is used to control infiltration of air through room openings. Infiltration can be caused by pressure differences resulting from equipment operation, wind, or temperature differences. As an example, a 6 mph wind can produce an infiltration velocity of 400 ft/min on the high pressure side of the building (0.02 in. H_2O). Depending on the size of the opening from the outside a large amount of air could enter based on wind direction and speed. Because of this fact, it is usually recommended that no direct openings to the outside be designed into a processing building.

Water Vapor

Moisture production is a major consideration when designing ventilation strategies for poultry processing plants. The average worker will generate 0.3 lb to 1.0 lb/hour of water vapor while working (Paulson, 1991). In addition, if one is processing 250,000 chickens per day, approximately 300 to 400 lb of water vapor per hour is added to the air in the plant. In addition, during the sanitation shift all food contact surfaces are rinsed with hot water, significantly increasing relative humidity.

Condensation

Condensation (condensed water vapor) problems occur when the air temperature or surface temperature is lowered to below the dew point temperature. At this point water vapor will condense and form a fog in air and will wet surfaces; given sufficient time, moisture droplets will collect on equipment, ceilings, walls, and floors. Table 1 below shows dew points for given temperature and relative humidity conditions found in processing plants. One can visualize many situations where condensation can become a problem. An example of this would be the opening between the ice making area and the cutup area. The ice room is around 32 F and the process floor is at 80 F and 70 % RH. The cold air from the ice room will move across the floor into the process room. This will often create a thin ice layer on the floor in this area - hazardous condition for workers. In addition, warm moist air from the processing plant will convect into the ceiling area of the ice room creating a condensation problem, and a potential food safety issue when ice packing the product. This is just one example. From a food safety perspective, condensation is considered an adulterant and potential carrier of bacterial contamination, and should be eliminated. Three suggested ways to minimize condensation are 1) to insulate and install vapor barriers in roofs and walls and between areas or rooms with large temperature differences (e.g. freezer, refrigerator, and processing floor; 2) pressurize areas and install air curtains or other mechanical devices to keep cold air and warm air separate (0.01 to 0.1 inches of water); 3) design diffusers and exhaust to keep air moving between 100 and 150 ft/min on all walls and ceilings. It is also important to note that condensation may form on diffusers and therefore consideration needs to be given to their placement with respect to the processing operations in the room.

Worker Comfort

Worker comfort is a necessary requirement in all processing plants. An average adult doing heavy work produces 1724 Btu and 1.0 lb of water vapor per hour. For comfort it is suggested that temperature be maintained between 72 and 81 deg F with a 40 to 60% relative humidity. In addition, carbon dioxide levels need to be maintained below 0.1%. This equates to approximately 15 cfm of fresh air per person and requires between twenty and thirty air exchanges per hour (ACGIH, 1995).

Table 1. Summary of Dew-Point Temperatures for Measured Dry Bulb Temperatures and Relative Humidities (ASAE Standards, 1998).

	Relative Humidity (%)					
Dry Bulb Temp (F)	40	50	60	70	80	90
	Dew Point Temperature (F)					
30	11	15	19	22	25	28
40	19	24	28	31	34	37
50	27	33	37	40	44	47
60	35	42	46	50	54	57
70	45	51	55	59	63	67
80	54	60	65	69	73	77
90	63	69	74	79	83	87

Heating Load

Heat load is the combined energy loss/gain from the building, equipment, workers, through direct energy additions such as heating (sensible heat) or indirectly from moisture additions (latent heat). The total building energy requirements will be needed to size refrigeration and heating equipment. Also energy requirements for each process area will be needed to size air inlets and exits and conditioning systems. Recycling of air is an option that can be considered for cost savings; however, this will need to be addressed on a case by case basis. A good reference book on how to perform these calculations is ASHRAE's Handbook of Fundamentals(ASHRAE, 1989).

Bacteria Control

Bacterial control is challenging in processing plants. Air sampling is an important part to any well designed ventilation system. One must collect baseline microbial sampling data from air handling unit, ductwork, and equipment periodically to monitor the air handling systems integrity. The two standard practices in poultry processing plants are to filter air, both fresh and recycled, through a pre-filter and then a 95% efficiency or high efficiency filter. This will remove a 95% of all particulates 1 micron and larger. Bacteria, yeast and mold range between 0.2 and 10 microns. This filter is effective in removing most bacteria, yeast, and mold because they tend to attach to dust particles which are trapped onto the filters. Pre-filters typically consist of lower efficiency coarser media which can trap larger particles and increase the useful life of the filters. In addition to the high efficiency filters, High Efficiency Particle Arresting (HEPA) filters, and electrostatic filters, and cyclones are also used (Paulson, 1990).

Maintenance

A properly designed air handling system is a first step in controlling air borne contaminants, moisture and heat. Ventilation maintenance is the second step. In order to ensure proper operation of one's air handling system a cleaning and maintenance schedule needs to be written and carried out. Recommended practice is to clean and sanitize these systems as needed with a minimum of twice per year. The fans and exhaust intakes in poultry processing plants are usually outside the building. The proverbial " Out of sight, out of mind." seems to be the case in many facilities. Neglect in cleaning and sanitizing these areas is a serious food safety problem.

SUMMARY

The air handling system is an integral part of the poultry processing plant. When changes are being made to a processing plant one needs to consider the impact of these changes on the air handling system. The design of a proper air handling system for adequate control of moisture, dust, and microorganisms is critical for worker health, product safety, and overall plant performance. The current trend in red meat and poultry processing plant ventilation is toward positive pressure. Recent conversations with poultry processors suggest that many are considering and some are converting their processing facilities from negative pressure to positive pressure air handling systems because of the better control over air distribution, air infiltration, and the ability to filter make-up air. As processors continue with HACCP and focus on food safety, air handling is going to become a higher priority and positive pressure air handling systems offer greater flexibility than negative ventilation systems and can reduce potential food safety hazards that might occur as a result of the air handling system.

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AIR QUALITY INTERVENTION REQUIREMENTS EXTERNAL TO THE PROCESSING PLANT

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Air quality external to the poultry processing plant is impacted by many factors. The primary concern of the plant is to create an environment that contributes to meeting USDA requirements and producing wholesome products. Over the years, many processing plants that were once considered to be located outside of town have found that the city is now their neighbor. Newer plants often consider the city their first choice when siting the facility because of the availability of services that the city can provide. In either case, the plant doesn't want to become a public nuisance. Federal Air Quality requirements continue to tighten with respect to the products of combustion from boilers and particulate emissions. The processing plant, therefore, finds that it needs to balance its processing needs with being a "good neighbor" within the community and, at the same time, control regulated emissions to be a "good corporate citizen" by complying with emission limits for regulated pollutants. Potential issues include odors from processing and rendering, particulate emissions and emissions from combustion sources. This overview will describe the typical sources that processing plants must deal with and what measures should be considered in being proactive (intervention) to minimize their impact.

POTENTIAL ODOR SOURCES FROM PROCESSING

For a processing plant, the major sources of odor are related to the live bird delivery system and the by-product storage systems that surround the plant. The general yard area, the live bird storage area and the staging area for cage dumping typically collect feathers and manure which fall from cages being transported on the live haul trailers. DOAs removed from the cages deteriorate quickly. Live birds (runaways) that fall out of cages due to broken cage doors may fall anywhere in the yard area and might either die from exposure or from being run over. If not addressed, these carcasses can also cause odors. Blood is often stored in tanks outside the plant. Leaking valves can cause blood to be exposed and cause odors. DAF skimmings leaked from valves, presses, augers and pipes can also be a source of odors, as well as aged DAF skimmings stored too long in trailers. Condemned product or MDP bone residue waiting to be delivered to a rendering facility, especially if stored outside can also cause odors if held to long. All of these sources can be adequately addressed, however, and should be addressed every day of production.

Intervention Measures for the Yard Area, DOAs and Run-Aways

Good housekeeping is the key element to preventing odors caused by feathers, manure, DOA carcasses and condemned product. Cleaning the asphalted or concrete yard area thoroughly daily by sweeping and hosing is a must. No outside storage of DOAs should be allowed. Round up runaway birds and pick up any yard dead at the end of the day. Prevent dogs, cats and rodents from coming on site since they can kill the run aways as well as leaving urine and feces on site. Humane traps can be utilized to capture dogs and cats that have come on site and bait for rodents.

Intervention Measures for the Condemned, Offal and MDP Rooms

Product flow is the key for controlling potential odors from condemned product and MDP bone residue. Keep these by-products moving to their destination, either to an onsite rendering plant or to an offal room to be hauled to a rendering plant. Don't let the product age in the condemned product or offal rooms. Do not store any condemned product outside. The added heat will accelerate the decomposition and lead to odors more quickly. Conveying or pumping the by-products including bone residue to the rendering plant or offal room is one way to speed up its delivery. Sizing of the trailers that transport the offal is also a critical element. If the trailers are too large, the holding time will be too long before leaving the site and could therefore start to create an odor issue. Scheduling of departures of trailers is also important in keeping the by-products moving appropriately in a timely manner.

Intervention Measures for the Blood Storage Area

For this area, maintain blood tank pumps and valves in good condition so that leakage doesn't occur. Clean up any spills promptly since blood deteriorates quickly. Process or ship frequently (twice per day) or refrigerate the tank if it is to be held for an extended period of time.

Intervention Measures for the DAF Area

This area is similar to the blood storage area in that maintenance of the valves, piping and pumps is very important. Keeping spillage off the floor area and cleaning any spills up promptly will enhance this area since the DAF skimmings age quickly. Covering or enclosing the DAF equipment will also help since it will define the area to be kept clean and keep the product out of direct sun exposure.

Just as in the offal area, size trailers and schedule departure appropriately so that the trailers for skimmings will be dispatched frequently. Maintain the trailer seals to prevent leakage on to the concrete or asphalt yard area. Be sure that the trailers are washed before they are allowed to return to the plant site since a dirty trailer may be odorous before you even start to load it. Use of tankers is preferred when no dewatering of the skimmings is occurring, which helps for both spill prevention and odor control. For open trailers, do not overfilled to prevent sloshing product out of the trailer. The loaded trailers should be covered with tarps promptly before hauling, to contain odors and slow down aging. Wash the entire DAF area daily.

One method being tested to reduce DAF odors is to treat the processing wastewater with ozone prior to going to the DAF unit. Favorable results are being reported with this method.

POTENTIAL ODOR SOURCES FROM RENDERING

Rendering on the same site as processing adds a whole new dimension of complexity to controlling odors from the combined facilities. The primary sources for odors are the raw material by-products that it intends to process, how they are stored in the raw receiving area, and the effectiveness of its odor control system in treating low and high intensity odors (including the noncondensable gases) from the cooking process.

In the raw receiving area, aged product, either from the plant or from field dead can lead to odors. An undersized or poorly maintained low and high intensity scrubbing system will not be able to treat the gases adequately, leading to odors being emitted from the facility. Typically, room air is scrubbed in low intensity scrubbers while vapors from the perk pans and presses are treated in packed bed type scrubbers. The vapors from the cookers themselves are first condensed in air or water-cooled condensors, leaving only the noncondensable gases. If the condensors are dirty, the duct work plugged, nozzles plugged in the scrubber, the chemical mixing system is out of calibration or if the packed bed in the scrubber is plugged, the system will not be able to treat the gases effectively.

Processing and rendering plants often add additional processing equipment without addressing the effect on the pollution control equipment. This can cause the original pollution control equipment to then be undersized and lead to incomplete treatment of the odorous gases. Even under the best of conditions, the noncondnesable gases from cooking are among the toughest to treat and usually are treated by incineration in the boiler, a stand-alone incinerator, a chemical oxidation scrubber or a regenerative thermal oxidizer (RTO). If any one of the devices has an electrical, control or mechanical malfunction, odors could be emitted.

Intervention Measures for the Rendering Plant Raw Material

The key to minimizing odors from raw material is to process it promptly while it is still fresh. As in the condemned and offal rooms, keep the product moving. If equipment breakdowns occur, divert product to an outside renderer to minimize the backlog. Aged product tends to produce odors that are more difficult to scrub and result in a finished product that retains the odor, so it makes sense to divert field dead if at all possible.

Blood is also particularly odorous, so divert it also, if possible if you are unable to process it while fresh.

Intervention Measures for the Rendering Plant Pollution Control System

To ensure good odor control in a rendering plant, the employees and management must treat the pollution control system as a process system, where each and every component is important. Employees need to be well trained and understand the concept of the system. Critical components need to be monitored and inspected weekly, such as nozzles, pumps and valves in scrubbers, to ensure that they are not plugged and remain fully functional.

The condensors are a particularly important component of the system. The condensors receive the vapors that are driven off during the cooking process and, via water-cooled or air cooled condensors, condense the vapors to liquid. Ductwork, piping and fins on the condensors can become fouled, which reduces their efficiency dramatically. If the condensors are not functioning correctly, the incinerator or scrubber down stream will be overloaded and will not be able to treat the gases adequately. These components should be inspected and cleaned weekly. In sizing new condensors, this fouling should be taken into consideration so that the system will be more forgiving. If additional cooking equipment is added to the facility, it may be necessary to enlarge the condensors.

A portion of the vapor stream will not be condensed. These noncondensible gases are particularly odorous and are typically burned in the boiler flame, burned in an incinerator or RTO or scrubbed in a packed bed style scrubber. Since these vapors are quite odorous, it is prudent to have a secondary flow path for these vapors. For example, if burning the gases in the boiler is the primary path, when the boiler is on low fire or off, you would want to divert these gases to the high intensity scrubber.

The room air scrubbing system is utilized to keep negative air pressure in the processing and receiving rooms so that untreated air does not leave the facility. The design philosophy for air exchange rate in rendering plants has changed over the years, from 20 air changes per hour on older plants to 30 on newer facilities. Enclose as much of the process as possible. Location of inlet louvers and exhaust grilles is critical in obtaining an effective sweeping effect of the air throughout the rooms. Air is typically pulled through raw receiving to prevent potential odors from escaping. Door control is one the most critical aspects to manage in order to maintain the air balance incorporated in the original plant design. If doors are left open, the inlet air will be drawn through the doors instead of the louvered space around the perimeter of the building, and the sweeping effect will be impacted.

High intensity odors from hoods or pickup points over the perk pans and presses are treated in the high intensity packed bed scrubbing system. Monitoring of these scrubbers is important so that the odors are treated continuously. As with condensors, keeping the ductwork clean is essential. The pH, ORP, pressure drop across the packed bed, chemical concentration and the flow rate to the scrubber should be monitored hourly. Use of data loggers for verification and trouble shooting can be very effective. A descaler should be used in the scrubbers to minimize scaling. The chemical tank and scrubbers should be cleaned weekly. The calibration of the chemical pumps needs to be confirmed frequently. Pumps and valves need to be maintained. All of these components need to work together to provide an efficient odor control system.

Good public and air district relations are beneficial in keeping the rendering plant in good standing in a community. Be proactive by educating them as to how the system operates. Call them promptly when a malfunction occurs before they start calling you. Inform them as to what has happened and what you are doing to correct the problem. The more informed the local officials are situation, the better prepared they will be in handling complaint calls from the community. Public Nuisance issues have generally been left to local authorities, so the more positive perception you create, of being a proactive well managed organization with a state of the art odor control system, the easier it will be to handle the infrequent malfunction which may occur.

POTENTIAL ODOR SOURCES FROM WASTEWATER

Poultry processing plants use an extensive amount of water for sanitation purposes and use a variety of systems to treat the water once it leaves the processing plant. These systems can be vary from a primary screening and DAF system discharging to municipal systems, or pond/lagoon systems, to full secondary treatment system such as activated sludge plants discharging to streams or agricultural land. Any of these systems can develop odors when they are not operated as designed.

Intervention Measures for the Processing Plant Wastewater System

This is a very broad topic in itself, but there are some common threads that run among all of the types of systems that can be utilized. The obvious requirements are to maintain the pumps, valves and control system that handle the process flows. Training of the operators however, is one of the most important factors, and not just training in the mechanical and electrical aspects of the system, but also the chemical and biological aspects of the system. ***These systems are truly biological systems and not just bodies of water!*** Once the management and operators of the system treat it as a biological system, the higher the likely hood will be that it will be operated correctly. Keeping abreast of what similar industries and small municipal systems are doing to treat their water can also help broaden the perspective of the opportunities available. As plant requirements change or if the plant grows, the treatment system may also need to grow.

POTENTIAL PARTICULATE SOURCES FROM THE PROCESSING AND RENDERING PLANT

Since poultry processing begins with the receiving, holding and staging of live birds, the yard area can become a collector of particulate including dirt, dust, feathers and manure that falls from the livehaul trailers as they travel through the yard. The hanging area also creates dust and feather discharges. If this area is ventilated with exhaust fans, particulate may be discharged to the atmosphere.

Having a rendering plant onsite adds the dust and potential PM-10 from the finished meals that are stored and then loaded into trailers. A rendering plant might also have a direct-fired feather dryer that discharges particulate in its exhaust air stream. For particulate greater than 10 microns in size, the standard is typically based on an opacity standard, while PM-10 will be regulated on a pound per day basis.

Intervention Measures for Particulate from the Processing and Rendering Plant

Several measures can be taken to control particulate around the plant. Foggers at the perimeter of the holding shed and staging area can be very effective in controlling feathers and dust from leaving this area. Sweeping of the yard area and even neighboring streets with a street sweeper will help capture loose feathers.

If powered exhaust is used to draw air from the hanging area, this air can be exhausted through a wet cyclone to pull out feathers and dust. Cyclones on feather and blood dryer exhaust stacks will also be very effective in removing particulate. In the rendered meal storage and loadout area, filtered bin vents, fabric boots on the loadout drops and an enclosure around the load out area will aid in controlling dust from the meals.

One future impact will be the tightening of air board PM-10 regulations. Discussions are underway in many areas to consider reducing the level of control down to PM-2.5 which would require a higher level of filtration.

POTENTIAL EMISSIONS FROM COMBUSTON SOURCES FROM PROCESSING AND RENDERING PLANTS

Common sources that exist in processing and rendering plants include boilers, hot water generators, incinerators, RTOs, and gas fire dryers. These devices are considered sources because they each emit products of combustion which are Federally regulated such as NOx, SOx, CO, VOCs and PM-10. Because these pollutants are regulated, air district permits are required. These permits may take 3 to 6 months to obtain, so time is a major consideration when planning a modification or a new facility. These permits may establish several conditions of operation including monitoring and record keeping. These may seem like insignificant requirements, but if not followed, may lead to fines or shutdowns.

Intervention Measures for Combustion Sources from the Processing and Rendering Plant

Again, its is important to be proactive when it comes to the emissions from combustion sources. Get to know the staff of your air district so that they can relate to you on a personal basis rather than only as another industrial facility. They will be much more understanding and flexible when issues arise if they know you. Know the rules of the local air board and obtained the required permits. Modifications to facilities that add or delete pieces of equipment, even if they reduce emissions are usually required to go though the permit process. For new or modified sources, the process may take 3 to 6 month firm that the retrofit will meet the requirements and also will allow the burner to be tuned to work at the correct emission levels.

Permit operating conditions often include record keeping parameters. Inform and train your operators as to the requirements for keeping logs of required data.

POTENTIAL ZONING ISSUES RELATED TO AIR QUALITLY OUTSIDE OF PROCESSING AND RENDERING PLANTS

In siting a new facility, there are pluses and minuses for both the industrial and agricultural zones. Protection of the residents and the environment is important in both locations. In either location, similar strategies will need to be employed. Some of the basic considerations should include the following ideas. Develop procedures for site housekeeping and by-product handling and inform/train employees of these procedures from the very beginning. Show a commitment to the health and well being of the community. Keep the new plant set back from the property lines and screen the perimeter with fencing and landscaping to act as a buffer. Design the plant to be totally enclosed. Educate the local authorities, agencies and community members on the emission systems and controls which will be implemented to control dust, feathers, manure and odors. Offer field trips to facilities with similar equipment, especially if it will also have a rendering plant on site. Utilize "state of the art" equipment for rendering odor control, use an odor control company with an excellent track record in controlling odors and use an expert from the company providing the rendering plant odor control system to help describe the system. Excellent communication with the community and agencies involved will be the key to success for approval of a new plant.

MANAGEMENT OPPORTUNITIES

The attitude for keeping a processing and rendering plant operating with the best external air quality starts at the top with the plant manager. The manager should work to develop a mindset of personal ownership in the plant with his or her employees. The manager sets the tone by modeling good habits with situations as simple as picking up a piece of trash on the ground rather than walking by it. The manager should walk the site weekly (if not daily) with a critical eye, looking for abnormal situations. Start with a clean plant inside. Odors from inside the plant will end up outside. When employees are proactive in responding to spills, leaking valves, open doors, plugged nozzles, etc and react to them promptly, you will have a plant with a very pleasant atmosphere outside. And when it comes to the by-products, work only with fresh by-products by keeping them moving to their final destination.

RESEARCH OPPORTUNITIES

The primary research opportunities for air quality external to a processing or rendering plant are in the area of odor control, not just for processing and rendering, but also for DAF and wastewater treatment systems. Many organizations are continuing to working in these areas. Any new developments in equipment, chemical treatments, detection equipment, standardization of regulations or air dispersion modeling will help to advance the state of the art.

Emission requirements will no doubt become more stringent with time, so advancements will be needed to provide a higher level of emission control. The potential reduction of PM-10 requirements to the PM-2.5 level is one example of regulations tightening, as well as NOx levels being reduced to 9 ppm in some parts of the country. The poultry industry will need to continue to work closely with universities, equipment suppliers, agencies and professional/industry organizations to meet the demands of the future-processing environment.

POSTER PRESENTATIONS

THE THERMO DEPOLYMERIZATION AND CHEMICAL REFORMING PROCESS APPLIED TO AGRICULTURAL FEEDSTOCKS

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The Thermo Depolymerization and Chemical Reforming process is a patented process that converts hydrocarbon and organic materials into clean fuels and specialty chemicals. Waste, by-products, or low-grade organic material goes into the TDP process. Three separate streams come out: a clean fuel gas, a light organic liquid, and a solid product that can be used as fuel or fertilizer. The purpose of this article is to describe the TDP process, both the steps and the chemical transformations, to compare it to the processes of pyrolysis and gasification, and to summarize research to date on agricultural feedstocks.

THE TDP PRROCESS

There are five main steps in the TDP process: 1) slurring the organic feed with water, 2) heating the slurry under pressure to reaction temperature, 3) flashing the slurry to a lower pressure to release the gaseous products after the initial reaction is complete, 4) heating the dense slurry to drive off water and light oils from the solid product, and 5) separating the light oils from water. The process temperatures for the initial slurry phase of processing are between about 250°C to 350°C (480°F to 660°F). For the dense slurry processing stage the temperatures are near 500°C (930°F).

The individual steps of the TDP process have been well developed in other industries such as oil and gas processing, and the TDP plant looks like a small refinery operation. A photograph of the 7 ton-per-day unit located in Philadelphia is shown below (Figure 1).

There are no discharges to the atmosphere from the TDP plant. The only gaseous product is a medium-Btu fuel-gas that is used for fuel in small gas turbines located near the TDP plant for electric power generation. The oil product is typically a narrow range of light hydrocarbons or organic materials that can also be easily used for fuel, or converted into much higher value products. The solid products can either be a fertilizer that is rich in micronutrients or a fuel, depending on the carbon-forming character of the feedstock.

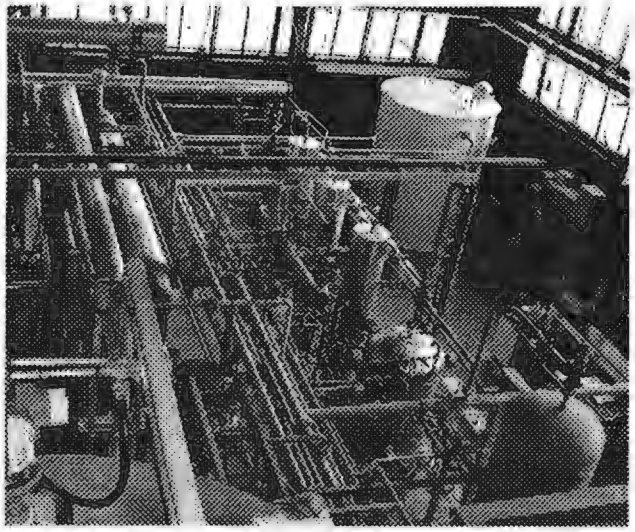

Figure 1. TDP 7 Ton Per Day Plant in Philadelphia, PA

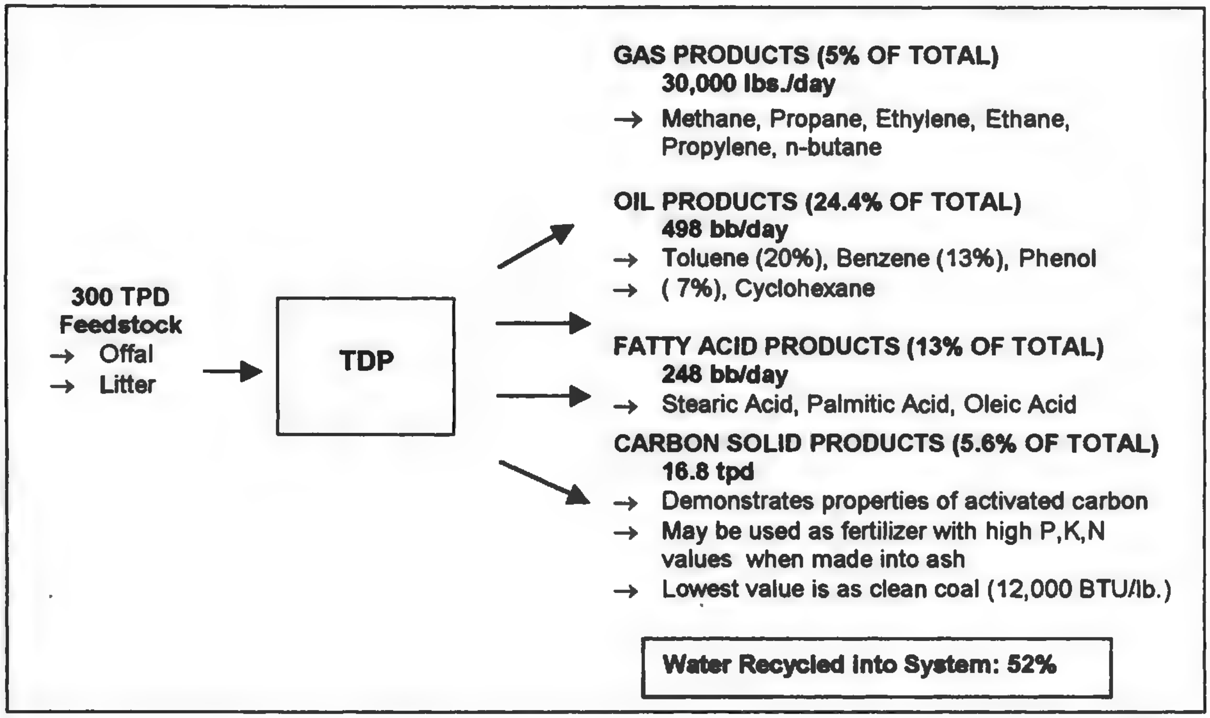

Figure 2. TDP Inputs and Outputs

After heat is recovered from the products they leave the TDP unit at about 100°C. With full heat recovery the overall energy efficiency based on the heating value of the products and the dry feedstock can be above 90%.

WHAT HAPPENS IN THE TDP PROCESS

To understand the TDP process it is necessary to remember that many of the materials in our everyday life are polymers, i.e. are made up of many small molecules that have been strung together in a chain. The paper that this article is printed on consists of a mat of individual wood fibers that are themselves made up of a long string of what are essentially sugar molecules. If you received this article electronically, a plastic box that consists of many, many individual small molecules bonded together surrounds your monitor screen. The food we eat is another example of a material that contains polymers. Each of these, and many more, become the waste and by-products of home and industry. The TDP process breaks down these polymers nearly to their smallest unit, hence the name Thermal Depolymerization. In addition, because the process occurs in a water medium, these small units are reformed into materials that can easily be separated from water. On the molecular level the individual links in the polymer chain are held together with chemical bonds. The TDP process breaks these bonds, and the two halves of the broken bond are either incorporated into the molecule or attach to hydrogen donated by the water slurry. This depletes the hydrogen from some of the organic molecules and enriches it in others. Both of the resulting materials are less soluble in water. This is the Chemical Reforming step of the TDP process. After the flash step they separate from the water just like oil or charcoal would.

The net result of the TDP process is that the solid, liquid, and gas product have relatively narrow chemical composition and can easily be separated from water.

HOW DOES TDP COMPARE TO PYROLYSIS AND GASIFICATION

Pyrolysis and gasification are alternative ways that can, and have, been used to convert organic wastes and by-products into fuels and chemicals. The basic principal of these and of the TDP process is that polymeric materials break down at high temperatures. This is just an extension of the every day observation that poorer cuts of meat are tender after cooking in a stew, or that wood logs in a fireplace burn to form a gaseous flame, some tar-like deposits in the flue, and a solid charcoal.

Pyrolysis is the process of heating the feedstock in the absence of air. A hot fuel-gas and a char are produced. Gasification involves the use of a fraction of the air or oxygen that would be required to completely burn the feedstock. A hot, voluminous fuel-gas is produced. Both processes break down the polymer chains just as the TDP does, with high temperatures.

The differences between the TDP and the other two processes is the ability of the TDP to work well with a wet feedstock, the ease of separating the products, the narrow range of the chemical constituents in the products due to chemical reforming, and the low temperatures of the gaseous product. Distributing the feedstock in a water slurry is central to the TDP process for ease of handling, for uniform heating of the slurry, and to make hydrogen available to the depolymerization products for chemical reforming. This is the key to making valuable products and ones that can be easily separated from water.

The oil products have always demonstrated at least 10% aromatics, while the solid product contains the minerals and ring-structured carbon similar to charcoal or toner carbon for laser printing. The low temperature of the gaseous products makes handling easy and avoids the energy loss often required for gas cleanup prior to use as gas turbine fuel. As well, the gas-fuel does not contain alkali metals such as sodium that are very detrimental to gas turbines.

PROOF-OF-CONCEPT TO DATE

Technical data is available on a wide range of feedstocks including manures, slaughterhouse waste, crude oils, and tires. This paper covers the research and commercialization efforts to date on the TDP applied to agricultural feedstocks.

Table 1. TDP Feedstocks

Agricultural Feedstocks	Petroleum Products	Waste Materials	Pulp & Paper	Pure Feedstocks
	Asphlatine		Black	Starch
Turkey Litter	Resids	Tires	Liquor	
Turkey Offal	Mayan Crude	Plastics		Cellulose
Cattle Bones	Tar Sands			
Pig Manure	Coal Fines			
Sausage				
Grease	Oil Shale			
Vegetable Oil				

In early proof-of-concept efforts, several versions of the TDP were designed, constructed, and tested on a wide range of feedstocks. Two batch reactors constructed using Parr bombs reside at the TDP LLC pilot plant and one is located at Hofstra University, while North Carolina State University is currently testing a one ton-per-day continuous flow unit. These research units have successfully reformed including tires, Mayan crude, asphaltines, plastic wastes, turkey litter and offal, pig manure, cattle bones and fats and greases into gas, oil and carbon solids.

Thermo-Depolymerization Process, LLC (TDP, LLC), a joint venture of the Gas Research Institute (GRI) and Resource Recovery Corporation (RRC) commissioned start-up of the 7 ton-per-day TDP pilot plant at the Philadelphia Naval Business Center on October 23rd, 1999. Startup of the plant followed a progression during which water was heated and pressurized to process conditions to test the pipes, fittings and seals for pressure leaks and functionality. Following completion of water testing, 1800 pounds of vegetable oil were fed directly into the TDP to prime and lubricate the system. As expected, the TDP reformed this oil into a fatty acid stream, a petroleum stream, and a natural gas stream, which was successfully fed into the turbo generators.

Next, 27,000 pounds of sausage grease was delivered to the site and fed into the TDP. The grease was run over several days to continue to train the plant operators and to break in and lubricate the system using a feedstock that would be similar to those planned for future testing. In November 1999, TDP, LLC ran a trial of turkey offal in the system. Running the turkey offal in the system allowed TDP, LLC to learn more about how different feedstocks react through the system and to begin to adjust the critical parameters to get the best results from the system. In January and February 2000, TDP, LLC conducted two trials on a mixture of pig manure and pig offal. Following the second of these trials, TDP, LLC decided to replace the original first stage heater with an improved design to facilitate handling of heterogeneous materials. In addition, it was determined that modifications to the flash vessel/separator after the first reactor would improve the quality of the oil/gas separation. These process improvements were completed in July 2000.

THE TDP APPLIED TO AGRICULTURAL FEEDSTOCKS

Mass Balances

Technicians record the mass balances for each TDP trial run on a dry weight basis. Gas is calculated by difference. Mass balances to date indicate that the percentage of conversion is dependent on the density of carbon in the feedstock i.e., coal which is very dense, converts almost 100% whereas the conversion of offal, with a high water content, averages 30-50%. Plastic waste also results in nearly 100% conversion. The addition of offal to cellulose-based feedstock such as hay and manure appears to result in a higher rate of conversion and in a greater quantity of oil produced as a percentage of the total. A representative sample of mass balances from TDP trial runs is provided in Table 1, Mass Balances of TDP Trial Runs.

Table 2. Mass Balances of TDP Trial Runs

Feedstock	Oil	Solid	Gas	Water (difference)
Turkey Offal	23.0	4.9	3.9	68.2
Turkey Litter	14.5	26.3	7.8	51.4
Pig manure	4.0	8.0	12.0	76.0
Pig manure and corn cobs	9.0	16.0	6.0	69.0

TDP Gas

The heating value of TDP gas from food and agriculture feedstocks ranges from 6,300 to 12,800 BTU per lb. (Net heat of combustion) in testing to date (Table 3). TDP gas is comparable to pipeline gas with a heating value of 10,000 BTU/lb., and can be used to drive micro-turbines, providing a source of distributed generation power. TDP gas sulfur levels from food and animal feedstocks tend to be low, and CWT does not anticipate that the turbine emissions will need to be "scrubbed" in order to meet emissions limits.

Table 3. Gas from TDP Runs: Food and Agriculture Industries

ANALYSIS	TDP Run	Date	Gross heat of combustion (BTU/lb.)	Composition	Elemental composition
Cattle Bones	CWT Batch	1999	10,097 (average)	GC-MS by Hofstra	✓
Turkey Litter	CWT Batch	1999	8,919 7,956 6,790	CG-MS by Hofstra	✓
ISU Pig Manure	Batch	1995	R111: 9,390 R109:3,658	Hydrocarbon C2-C6	

TDP Carbon Solids

The solid fraction of TDP products is a carbon solid with many potential uses. The lowest value use of TDP carbon solids is as a coal substitute. In analysis to date, the BTU value of TDP carbon solids ranges from 7,363 to 12,235 per pound. The higher value corresponds to the BTU value of coal, approximately 12,000 BTU/lb.

One potential use of TDP carbon solids is as activated carbon to be used as a filtering medium. Analysis of pore size and absorbency of TDP carbon solids from food and animal feedstocks indicates that this product has activated carbon characteristics. Researchers at Hofstra University are currently using TDP carbon solids as a column packing material for filtering the fatty acids derived from the TDP liquid fraction. TDP carbon also demonstrates properties that may allow its use as toner carbon.

Another high value potential use for TDP carbon solids from food and animal feedstocks is as a fertilizer. Carbon solid from the TDP has been analyzed by ultimate and proximate analysis and evaluated for use as a fertilizer by elemental analysis. The results in Table 4 show encouraging levels of nitrogen, phosphorus and potassium, and that the NPK values increase tenfold or more when the carbon solid is reduced to ash. The results from the 7-tpd pilot run in February 2000 are very promising with regard to producing a high value fertilizer if the carbon solid is reduced to ash.

Table 4. NPK Values for TDP Carbon Solid

Study	Nitrogen	Potassium K2O	Phosphate P2O5
ISU Study bench reactor:			
R-109	0.05	0.33	0.32
R-111	0.29	1.72	3.19
R-109 Ash	--	10.64	44.90
R-111 Ash	--	9.45	36.79
Pig Manure, Hay & Offal, 7-tpd Pilot	4.7	1.12	2.85

TDP Oil

The liquid product stream from food and animal industry feedstocks processed with the TDP results in two product streams: Oil, which may be blended or distilled into fuel or petrochemicals; and fatty acids or specialty chemicals (Table 5). A unique characteristic of the TDP technology is that it is designed to allow the liquid product to separate into these two different product streams, which are collected in different parts of the process. The fatty acids are collected first; if fatty acids are not drawn off, the system will reform the entire liquid stream into petrochemicals. However, as fatty acids are a higher-value product than most petrochemicals, it is desirable to optimize the system for maximum production of fatty acids. Five to 15% of the liquid fraction is generally fatty acids, based on analysis to date.

The TDP demonstrates the ability to split triglyceride fats, which are branched chain molecules such as vegetable oil or sausage grease, into straight chain structures like fatty acids. It has also demonstrated the ability to reform the straight chain fatty acids into petroleum products such as benzene and toluene and other petrochemicals. From a chemical engineering perspective, this is a remarkable feat. In GC-MS analysis completed by Hofstra University, the fractions tend to sort according to the polarity of the molecules. Hydrocarbons appear in the elution profile first, including toluene (20-40% is typical) along with benzene, ethylbenzene, and cyclohexane. Next alcohols are seen, including hexanol, phenols, and decanol, transitioning to fatty acids including palmitic, oleic and stearic acids.

The TDP produces oil which can be distilled into the three main petroleum fractions: Naphthalene cut (used as solvents and petrochemicals), gasoline & diesel weights (used as home heating oil, kerosene, and jet propulsion fuel), and heavier hydrocarbons (used as bunker fuel, industrial boiler fuel). Analysis of the oil fraction indicates comparable values to distillate fuel. Table 3 indicates that high percentages (60-70%) of these distillates tend to be the lightweight, highest value cuts. While limited testing has been performed on the products of TDP 7-tpd pilot runs, results tend to be similar to or better than those from batch runs of the TDP. These results support scale-up assumptions.

OPERATING PARAMETERS

Operating parameters for agricultural feedstocks are similar regardless of the feedstock. The range of operating parameters is illustrated in Table 6.

Fatty Acids

Instead of producing oil, the TDP can be made to produce fatty acids out of feedstocks that contain fats, such as grease or offal, by varying the operating conditions. Bench scale demonstrations indicate that fatty acids including stearic and oleic acids can be produced by running the first stage at a lower temperature and separating the heavy liquid fraction containing fatty acids prior to sending the remaining light liquid to the high temperature second stage reactor. Recent trials at the 7-tpd pilot plant indicate that fatty acid can be produced using the same techniques, with promising results for scale-up.

Table 5. Distillation of TDP Oil from Batch and 7-tpd Pilot Runs

TDP Reactor	Parr Batch	7-TPD Pilot	Parr Batch	7-TPD Pilot Reactor 2	7-TPD Pilot Separator 1	7-TPD Pilot Separator 3
Feedstock	Pig Manure, Offal & Hay	Pig Manure, Offal & Hay	Sausage Grease	Turkey Offal	Turkey Offal	Sausage Grease
API @ 60 ° F	21.1	25.0	23.3			29.0
Distillation (D-86)						
IBP	168	194	194	330	168	140
5%	--	-	-	380	210	325
10 %	268	478	384	430	404	450
15%	--	--	--	550	474	--
20 %	438	576	598	580	570	562
30 %	564	584	606	582	572	624
40 %	592	610	600	608	592	640
50 %	620	620	596	632	600	650
60 %	634	640	616	640	612	662
70 %	660	650	642	660	618	672
80 %	680	658	662	692	624	684
85%	--	--	--	700	640	--
90 %	688	--	--	--	644	690
Recovery Vol. %	92.0	86.0	86.0	88.0	93.0	94.0
Residue Vol. %	6.0	14.0	8.0	6.0	6.0	2.0
Loss %	2.0	--	6.0	6.0	1.0	4.0
Flash Point (° F)		102				
D-93: Sulfur Wt. Pct.		0.004				
D-240: BTU/lb.		16,962				18,504
D-240: BTU/Gal.		127,707				135,836
D-97: Pour Point		+32 F/0C				
D-442: Viscosity @ 100° F SUS/CSt		104.3F/ 21.52 C				
D-1319: Hydrocarbon Types Est. Vol. % of distillation overhead						
Saturates	32.6		27.1			61.6
Olefins	1.0		1.6			13.2
Aromatics	66.4	57.0	71.3			25.2

Table 6. TDP 7-tpd Operating Parameters

Feedstock	Temperature 1st stage	Pressure 1st Stage	Temperature 2nd Stage	Temperature 2nd Stage
Turkey Offal	200-300°C	200-700 psi	475-525°C	40 psi
Turkey Litter	⇩	⇩	⇩	⇩
Pig Manure				
Sausage Grease				
Grease Trimmings				

Safety of the TDP Process: Environmental Impacts

The TDP is a completely enclosed circulating system that operates at temperatures and pressures that are utilized in standard equipment. The design of the system ensures that there is no odor, dust, fumes, smoke, gas, or excessive vibrations or noise in the system. Temperatures only reach 300 ° C and standard equipment can handle temperatures that are much higher.

Safety of the TDP Process: Toxics

A report from the Southwest Research Institute showed that dioxin related compounds were found in the ash from the oil fraction considered to be the worst case for the detection for these compounds. In reviewing these findings, Dr. Stephen H. Safe, the Syd Kyle Professor of Toxicology at the Department of Veterinary Physiology & Pharmacology at Texas A&M, describes the overall levels of these compounds as among the lowest he has observed in ash samples from the combustion of diverse wastes and other organic materials. The TDP environment, which is a reducing environment (stripping oxygen molecules), is not conducive to the creation of dioxins and dioxin-related compounds, which require an oxidizing environment (i.e., though combustion).

SUMMARY

The Thermo Depolymerization and Chemical Reforming process is an emerging technology, which can beneficiate a wide range of organic waste and by-product materials including agricultural feedstocks to produce cleaner, higher value products. Using water as a medium improves both the process and the selection of available industrial equipment. Water is also the key to the chemical reforming process because it produces in each product stream a narrow range of products that readily separate from water. The process conditions are modest by industrial standards and the process is environmentally clean. Valuable fuels and specialty chemicals can be produced from low-grade feedstocks in an energy efficient way for on-site use or sale.

FIELD EVALUATION OF LITTER CONDITIONS IN TUNNEL VENTILATED BROILER HOUSES AT THE END OF THE PRODUCTION CYCLE

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INTRODUCTION

Broiler litter conditions were evaluated within one day of marketing of the flock in tunnel ventilated commercial broiler houses in Texas. This sampling time was selected due to the livelihood that litter conditions would be under maximal challenge at this time. As air quality in and near poultry production facilities becomes of increasing importance, it is necessary to more closely understand the extent and nature of variability of litter conditions within poultry houses.

MATERIALS AND METHODS

Two different farms were each sampled on two separate occasions, at each sampling time, 15 samples were collected from evenly spaced sites through two houses. Litter was analyzed for moisture, nitrogen, ammonia-nitrogen, phosphorus, and pH. Ammonia-nitrogen was selected for analysis on the basis that higher ammonia in the litter would directly correlate to higher ammonia release into the atmosphere. Nitrogen was determined using a LECO FP-428 Nitrogen Determinator (LECO Corp., St. Joseph, MI, 49085). Litter ammonia nitrogen was determined using KCl extraction process followed by colorimetric determination. Litter moisture of samples was determined by drying at 100 C for 24 h. Litter pH was determined by dilution of a 10 g sample of the litter in 40 mL of deionized water, followed by measurement with a direct reading pH meter.

RESULTS AND DISCUSSION

Results of the survey are presented in Figures 1-4. Each figure is an overhead perspective of the broiler house with data values shown in relation to the point at which they were collected. The number of observations averaged in each value are indicated in the footnote of the figures.

Litter nitrogen levels are shown in Figure 1, comparing means along the length of the house (within rows in the following table) there are significant differences in litter nitrogen (L-N) within each row. On the south side of the houses (top row of the table) L-N was significantly higher at 450 feet than at 150, 250 and 350 feet. In the middle of the houses, L-N was significantly higher at 350 feet than at 50, 150 or 250 feet. L-N at 50 feet was significantly lower than those at 450 feet. On the north side of the houses, (bottom row of the table) L-N was significantly higher at 150 compared to all other sites with the row. L-N at 50 feet was significantly lower than at all other sites within the row.

Figure 1. Litter Nitrogen Levels (%)

0 50 100 150 200 250 300 350 400 450 500

(feet)

South side of houses

	50	150	250	350	450	
Air Enters This End	3.42de	3.37ef	3.35ef	3.36ef	3.53bcd	Air Exits This End
	3.26f	3.35ef	3.34ef	3.54bc	3.46cde	
	3.33f	4.05a	3.61b	3.59b	3.59b	

North side of houses

Observations per mean = 40. Means with different letter differ significantly ($P<0.05$).

Comparing means across the house (within columns in the above table) there were significant differences in L-N within each column. At 50 feet, L-N was significantly higher on the south side of the houses. At 150 feet, L-N was significantly higher on the north side of the houses. At 250 feet, L-N was significantly higher on the north side of the houses. At 350 feet, L-N was significantly lower on the south side of the houses than in the middle or north side. At 450 feet, L-N was significantly lower in the middle of the houses.

Litter ammonia nitrogen levels are shown in Figure 2, comparing means along the length of the house (within rows in the following table) there are significant differences in litter ammonia nitrogen (L-NH_4) in all rows. On the south side of the houses (top row of the table) L-NH_4 was significantly lower at 350 feet than at 50, 150, and 450 feet, L-NH_4 was also significantly higher at 50 feet than at 250 feet. In the middle of the houses, L-NH_4 was significantly lower at 350 feet than at 50 and 150 feet. L-NH_4 was significantly higher at 50 feet than at 250, 350 and 450 feet. On the north side of the houses (bottom row of the table) L-NH_4 was significantly higher at 150 feet than at all other locations. L-NH_4 was significantly lower at 450 feet than at 50 feet.

Comparing means across the house (within columns in the following table) there are significant differences in litter ammonia nitrogen at all points except within the samples at 50 feet. At 150 feet, L-NH_4 was significantly higher on the north side of the houses. At 250 feet, L-NH_4 was significantly lower in the middle of the houses. At 350 feet, L-NH_4 was significantly higher on the north side of the houses. At 450 feet, L-NH_4 was significantly higher on the south side of the houses.

Figure 2. Litter Ammonia Nitrogen Levels (pm)

0 50 100 150 200 250 300 350 400 450 500
(feet)

South side of houses

	2032b	1902bcd	1705cde	1561efg	1955bc	
Air Enters This End	1875bcd	1762bcde	1373fg	1321g	1550efg	Air Exits This End
	1942bc	2343a	1694cde	1705cde	1643def	

North side of houses

Observations per mean = 16. Means with different letter differ significantly ($P<0.05$).

Litter moisture levels are known in Figure 3, comparing means along the length of the house (within rows in the following table) there are significant differences in litter moisture (L-H_2O) in all rows. On the south side of the houses (top row of the table) L-H_2O was significantly higher at 50 feet than at 150, 250, 350 and 450 feet. In the middle of the houses, L-H_2O was significantly higher at 50 feet than at 250, 350 and 450 feet. On the north side of the houses, (bottom row of the table) L-H_2O was significantly higher at 50 feet than at 250 and 350 feet. L-H_2O was also significantly lower at 250 feet than at 50 and 150 feet.

Figure 3. Litter Moisture Levels (%)

0 50 100 150 200 250 300 350 400 450 500
(feet)

South side of houses

	33.3a	24.9cde	26.1bc	24.5cde	24.6cde	
Air Enters This End	28.1b	26.0bcd	24.2cde	22.9de	24.7cde	Air Exits This End
	26.1bc	25.7bcd	22.3e	22.8de	23.5cde	

North side of houses

Observations per mean = 16. Means with different letter differ significantly ($P<.05$).

Comparing means across the house (within columns in the above table) L-H_2O was significantly different at 50 and 250 feet. At these sites, L-H_2O was significantly higher on the south side of the houses.

Litter pH values are shown in Figure 4, comparing means along the length of the house (within rows in the following table) there are significant differences in litter pH (L-pH) in the south and north rows. On the south side of the houses (top row of the table) L-pH was significantly lower at 50 feet than at 250k 350 and 450 feet. On the north side of the houses, (bottom row of the table) L-pH was significantly higher at 50 feet than at 150 feet.

Figure 4. Litter pH

0 50 100 150 200 250 300 350 400 450 500
(feet)

South side of houses

	50	150	250	350	450	
	8.13c	8.39abc	8.60ab	8.54ab	8.52ab	
Air Enters This End	8.49abc	8.54ab	8.55ab	8.52ab	8.64ab	Air Exits This End
	8.69a	8.30bc	8.41abc	8.46abc	8.38abc	

North side of houses

Observations per mean = 8. Means with different letter differ significantly ($P<0.05$).

Comparing means across the house (within columns in the above table) L-pH was significantly different only at 50 feet, L-pH was significantly higher on the north side of the houses than at the south side of the houses.

SUMMARY OF LITTER CONDITION SURVEY RESULTS

Where differences were detected, litter nitrogen levels generally tended to be higher on the north side of the houses and at 350-450 feet. Litter ammonia levels tended to be lower in the central portion of the houses (150-350 feet and the middle row). Litter moisture levels were significantly higher at the air entry end and south side of the houses. Litter pH results generally indicate a relatively high pH throughout the house. Small differences were detected but no consistent trends were observed.

These data demonstrate that litter conditions within a house varies significantly. These differences are likely due to the combined impacts of ventilation air flow, drinker management and evaporative cooling system operation.

THE USE OF LITTER PLUS® AS A BEDDING MATERIAL FOR BROILERS

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SUMMARY

Finding a reliable source of shavings for broiler bedding at an acceptable cost is often difficult. LitterPlus® (LP) is a bedding material produced from recycled wood pallets through patented grinding and processing systems. The objective of this study was to compare pine shavings and LP for use as broiler bedding material. Two broiler trials were conducted. In the first trial, male broilers were grown in litter floor pens with either 2 or 5 cm of either pine shavings (PS) or LP. There were 32 pens (50 birds per pen) with 8 replicate pens per treatment. All birds were fed the same feeding program: starter from 0-3 wk, grower from 3 to 6 wk and finisher from 6 to 7 wk. Feed consumption and body weights (BW) were measured by pen at 3 and 7 wk. Mean BW and feed conversion (FC) were calculated. A sample of birds (n=10) from each pen was evaluated for hock (HI) and foot pad (FP) condition and breast blister index (BI). Each pen was evaluated at the end of the trial for cake index (CI). At the completion of trial 1, all litter was removed from each pen and stored separately by type (PS & LP) until the next trial. In trial 2, each supply of stored litter was placed into 18 pens (36 total pens). The stored litter was then "top dressed" with new material. Male broilers were placed in each pen (50 birds per pen) and reared to 7 wk of age as in trial 1. There were two treatments in trial 2; PS and LP, with 18 replicate pens per treatment. Data were collected as in trial 1. Ammonia (NH_3) levels were determined in each pen at the end of each trial. All data were analyzed using the General Linear Models program of SAS (SAS, 1992). In trial 1, the effects of litter depth and type and the interaction on BW, FC, CI, HI, FP, BI, and NH_3 were determined. In trial 2, the effect of litter type was determined on these same measurements. Means were separated using least significant difference ($P \leq 0.05$). In trial 1, birds reared on 2 cm of bedding had higher (more discoloration) HI than those reared on 5 cm of bedding. Pens with LP had a higher CI (more caked litter) than those with PS at the end of trial 1. There were no other differences in bird performance or litter evaluation for trials 1 or 2. In conclusion, broilers reared on LitterPlus® perform as well as those reared on pine shavings.

INTRODUCTION

North Carolina poultry producers reared approximately 675 million broilers, 47 million turkeys and eight million broiler breeders in 1999 (UADA-NASS, 2000). This level of poultry production yielded approximately 60 million cubic feet of bedding material. Pine shavings are usually used as bedding for these types of poultry as well as some peanut hulls and sawdust. In other geographic areas of the country other types of bedding are used such as rice hulls and chopped straw. Finding a reliable source of these bedding materials at an acceptable cost is often difficult. Therefore, viable alternatives for pine shavings have been and will be considered by the poultry industry in an attempt to assure satisfactory and cost effective bedding supplies. In addition, disposal of litter based on agronomic rates is becoming more of a challenge.

Research and field trials have been conducted on a number of different materials to evaluate the feasibility of utilizing them for poultry bedding. Malone (1992) in his review article of materials used for poultry bedding included information on materials in addition to pine shavings such as sawdust, wood chips, wood fiber pellets, pine straw, hardwood bark, rice hulls, sugar cane bagasse, corn cobs as well as many other potential bedding materials.

The product LitterPlus® (LP) evaluated in the trials reported in this report is made from recycled wood material such as broken pallets and other clean soft wood waste originating from the packaging and other wood product industries. The pallets or other recycled wood are ground and the wood particles assembled into a loose fibrous mash which is then subjected to a patented thermal friction processed and dried. Utilizing recycled wood material for poultry bedding has considerable potential to assist in recycling this organic waste product.

The objective of this study was to determine the effect of using LitterPlus® compared to pine shavings as a bedding material for broiler chickens.

MATERIALS AND METHODS

Fresh LP and pine shavings (PS) bedding were evaluated for moisture retention, moisture release and microbial status. Moisture retention was determined by placing 50 grams of bedding material into a 1 mm grain screen and immersing it water for 30 minutes. The sample was allowed to drain for 30 minutes and weighed to determine the quantity of water the bedding material retained. Moisture retention was determine by allowing the sample to dry at room temperature and humidity and then weighing the sample periodically until the weight stabilized. The procedure was performed on three replicates of each bedding type. Microbial analysis was conducted to determine the quantity of aerobic, coliform and molds microbes in the two types of fresh bedding. General plate count procedures were used using TSA media for general aerobic bacteria, MaConkey media for coliform type bacteria and potato dextrose for mold enumeration.

Two trials were conducted to determine the effect of using LP compared to traditional dry PS as a bedding material for broiler chickens. The first trial compared broiler performance using two depths of bedding (2 cm and 5 cm) of LP and PS bedding. The second trial compared broiler performance using the used bedding of each type from the first trial. Fifty day old male broiler chicks (Arbor Acre X Arbor Acre strain) were placed in 32 pens (1.2 m X 3.6 m) for Trial 1. The four treatments were as follows: 2 cm of LP, 5 cm of LP, 2cm of PS, and 5 cm of PS. There were 8 replicate pens for each treatment. All birds were fed the same commercial type broiler diets (Table 1). Trial 2 utilized 36 pens of the same size with the same density (50 birds/pen) of day old male broiler chicks. This trial compared used second flock litter from the first flock for both LP and PS. Chicks were placed on 4 cm of used litter which was top dressed with 2 cm of the respective type of original fresh bedding. There were 18 replicate pens per treatment. The broilers were grown for 49 days for both Trials 1 and 2 during which mortality and feed consumption was recorded. At 3 and 7 weeks of age the broilers were weighed and average body weight (BW) and feed conversion (FC) was calculated by pen. At 7 weeks of age 5 birds per pen were examined by two persons and evaluated for breast blisters, leg (hock) and foot (foot pad) abnormalities. The scoring systems used are shown in Appendix A (breast blister), Appendix B (hock scores), and Appendix C (foot pad scores). Ammonia readings were taken in each pen at 7 weeks of age using Sensydine Ammonia indicator tube.

Data was analyzed using regression analysis of the General Linear Models Procedure (SAS, 1989). The means were separated using least significant difference procedure ($P \leq 0.05$).

RESULTS

Pre-Trial

Microbial Analysis of the original LP bedding (Table 2) found no bacteria with standard plate count procedure, no coliform type bacteria and only 1 mold colony on one replicate sample. In contrast the PS averaged 351.8 X 10^2 colonies with the standard plate count, 183.2 X 10^2 coliform type bacteria and 17.75 X 10^2 mold colonies per gram of original bedding used in Trial 1.

Moisture retention and release characteristic of Litter Plus and pine shavings are shown in Tables 3 and 4. Fifty gram samples of LP bedding retained 124 grams of water and PS 61 grams. LP lost 66 grams of water in 24 hours, 114 grams in 48 hours and 124 grams in 96 hours while shavings lost 44 grams, 61 grams and 63 grams respectively for the same time period.

Trial 1

There were no significant differences ($P>0.05$) among treatments for BW or FC at 3 or 7 wk (Table 5). Mean BW ranged from 844 grams to 857 grams at 3 wk while at 7 wk BW ranged from 3.23 to 3.3 kg. The FC ranged from 1.29 to 1.44 at 3 wk and 1.87 to 1.92 at 7 wk.

Table 1. Composition of Feeds Used for Rearing Broilers to 7 Weeks of Age.

Ingredient	Starter	Grower	Finisher
		%	
Corn	53.7	64.9	69.6
Soybean Meal (48%)	32.0	24.0	22.2
Poultry Meal	6.00	5.00	4.00
Poultry Fat	5.00	3.00	2.20
Limestone	1.00	1.30	0.70
Di-calcium Phos.	1.30	0.90	0.70
Salt	0.24	0.20	0.20
Mineral Premix	0.10	0.10	0.10
Vitamin Premix	0.20	0.15	0.15
Sodium Bicarbonate	0.24	0.15	0.20
Lysine	0.10	0.08	0.04
D.L. Methionine	0.22	0.20	0.10
Manganese sulfate	0.02	0.02	0.01
Monensin	0.075	0.075	---
Total	100	100	100
Calculated Analysis			
Crude Protein (%)	23.0	19.8	18.7
ME (Kcal/kg)	3193	3181	3201
Calcium (%)	1.00	0.93	0.90
Available P (%)	0.46	0.46	0.45
Methionine (%)	0.74	0.51	0.40
TSAA (%)	1.04	0.80	0.67
Lysine (%)	1.27	1.02	0.92
Sodium (%)	0.20	0.18	0.18
Feeding Schedule (Wk)	0-3	3-6	6-7

The mean caked litter indexes were as follows: 2 cm LP- 4.38, 5 cm LP- 4.88, 2 cm PS-3.31, and 5 cm PS-2.00 (Table 6). The litter cake index between the 2 cm Litter Plus and 5 cm Litter Plus and 5 cm pine shaving bedding was significantly different ($P \leq 0.05$). The litter cake for all treatments was limited to around the automatic fountain waterers

Examination of broilers in trial 1 at 7 weeks of age for carcass quality factors such as breast blister, foot pad abnormalities, and hock abnormalities only found hocks with red discoloration. The red discoloration probably resulted from irritation from resting on their hocks on the litter. The rate of hock discoloration (Table 6) was significantly higher for 2 cm of both LP and PS when compared to 5 cm of both LP and PS.

Table 2. Microbial Analysis of Original Bedding

Treatment	Replication	Standard Plate Count[1]	Coliform Count[1]	Mold Count[1]
Pine Shavings	1	359.8	178.2	24.0
Pine Shavings	2	343.8	188.2	11.5
PS Mean		351.8	183.2	17.75
Litter Plus®	1	0	0	0
Litter Plus®	2	0	0	1
LP Mean		0	0	0.5

[1] X 10^2 per gram of bedding material

Table 3. Water Retention Comparison of LitterPlus® and Pine Shavings

Treatment	Sample Size(g)	Water Retained(g)	% Original Bedding Weight
Litter Plus	50	124	247
Shavings	50	61	122

Table 4. Water Release Comparison of LitterPlus® and Pine Shavings

Treatment	24hrs. (grams)	Percent	48hrs. (grams)	Percent	96hrs. (grams)	Percent
LitterPlus®	66	54	114	92	124	100
Shavings	44	71	61	100	63	105

Table 7 shows the results of the microbial analysis of the litter for all treatments after Trial 1. There was no differences among treatments with the standard plate Total Heterotroph bacteria count all averaging 10^8 cfu, coliform counts averaging 10^6 cfu and Mold counts averaging 10^4 cfu.

Table 5. Body Weight and Feed Conversions of Broilers Grown on LitterPlus or Pine Shavings for Trial 1.

Treatment	Body Weights		Feed Conversion	
	3 weeks (gm)	7 weeks (kg)	3 weeks	7 weeks
2 cm. LitterPlus®	857	3.25	1.29	1.87
5 cm. LitterPlus®	853	3.23	1.32	1.92
2 cm. Pine Shavings	857	3.30	1.33	1.89
5 cm. Pine Shavings	844	3.22	1.44	1.92
SEM*	28	0.03	0.04	0.03

There were no significant differences among treatments.
*standard error of the mean

Table 6. Caked Litter Index Broilers Grown on LitterPlus® or Pine Shavings for Trial 1

Treatment	Cake Index	Hock Index
2 cm. LitterPlus®	4.38[a]	9.38[a]
5 cm. LitterPlus®	4.88[a]	8.75[b]
2 cm. Pine Shavings	3.31[ab]	9.38[a]
5 cm. Pine Shavings	2.00[b]	7.75[b]
SEM*	0.6	0.5

[a] Means within a column with different superscripts are significantly different ($P \leq 0.05$).
*standard error of the mean

Table 7. Total Heterotroph Bacteria, Coliform Bacteria, and Mold Plate Count for LitterPlus® (LP) and Pine Shavings (PS) at the End of Trial 1

Replicate	2 cm LP	5 cm LP	2 cm PS	5 cm PS
Total Heterotrophs[1]	1020	1133	998	1141
Coliforms[1]	44	148	63	109
Mold[2]	20	24	28	48

[1] $X\ 10^4$ per gram of litter
[2] $X\ 10^2$ per gram litter

Trial 2

There were also no significant differences (P>0.05) among treatments at 3 or 7 wk for BW for Trial 2 (Table 8). BW of broilers at 3 wk was 880 grams for both treatments. The BW at 7 wk was 3.08 kg for LP and 3.03 kg for PS. Likewise, there were no significant differences for FC at 3 or 7 weeks of age adjusted for the weight of mortality for trial 2 (Table 8). FC at 3 wk was 1.81 for LP and 1.89 for PS while at 7 wk, FC were 1.74 for LP and 1.75 for PS.

There was no significant difference (P>0.05) in total mortality for any treatments in either Trial 1 (15%) or 2 (12%; data not shown). The slightly higher than normal mortality was due to heat stress toward the end of each trial which impacted all treatments equally. There were no differences in breast blister score (data not shown), hock index, foot pad index, cake index, or pen ammonia levels among treatments for Trial 2 (Table 9).

In conclusion, the performance of broilers reared on LitterPlus as a litter bedding is equal to that of broilers reared on pine shavings.

Table 8. Body Weights and Feed Conversions for Broilers Grown on Used LitterPlus® or Pine Shavings for Trial 2.

	Body Weights		Feed Converstions	
Treatment	3 weeks (gm)	7 weeks (kg)	3 weeks	7 weeks
LitterPlus®	880	3.08	1.18	1.74
Pine Shavings	880	3.03	1.19	1.75
SEM*	4	0.2	0.02	0.01

There were no significant differences among treatments (P>0.05).

Table 9. Hock Index, Foot Pad Index, Cake Index, and Litter Ammonia for Birds Grown on Used Litter In Trial 2.

Treatment	Hock Index	Foot Pad Index	Cake Index	NH3
LitterPlus®	1.60	0.09	5.58	27.5
Pine Shavings	1.48	0.05	5.19	27.5

There were no significant differences among treatments (P>0.05).

REFERENCES

Malone, G.W., 1992. Evaluation of litter materials other than wood shavings. pp274-284 in: Proceedings of the 1992 National Poultry Waste Management Symposium. Auburn, AL.

SAS Institute, 1992. SAS User's Guide. Version 6.08. SAS Institute, Inc. Cary, NC.

USDA-NASS: U.S. Department of Agriculture National Agriculture Statistics Service

Appendix A.

Scoring System for Breast Blisters[1]

0=No indication of breast blister present.
1=Slight thickening of skin over keel.
2=A definite breast blister condition with a slight accumulation of fluid under skin.
3=A severe breast blister with a large accumulation of fluid under skin.

Appendix B

Scoring System for Litter Cake

0=No Cake
1=0 to 1 sq. ft.
2=1 to 2 sq. ft.
3=2 to 3 sq. ft.
4=3 to 4 sq. ft.
5=4 to 5 sq. ft..
6=5 to 6 sq. ft
7=6 ft. and up with some loose material
8=6 ft. and up without material

Appendix C

Scoring System for feet, legs and hock

0 = Nothing Present
1- 4 = Degree of Discoloration
5- 8 = Degree of Burns
9- 10= Degree of Infection

HEAT PROCESSING OF TURKEY LITTER FOR RE-USE AS A BEDDING MATERIAL

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SUMMARY

North Carolina laws regulating poultry litter (PL) land application require that PL be applied based on crop need and PL nitrogen content with monitoring of soil P, Cu, and Zn. Even with efforts to decrease fecal nutrient excretion, there is also a need to extend the useful life of current bedding materials and to develop alternative uses of spent PL. Current systems developed by Resource Enhancement Technologies, Inc., to heat treat PL may extend bedding life and offer alternative uses of PL. This process has several potential advantages: 1) PL can be treated and re-used on the farm, 2) a product can be produced which does not have to be land applied, and 3) a product can be produced that can be moved out of the area where it is produced. The objective of this study was to determine if heat processed turkey litter (TL) can be reused as bedding for turkeys. Pine shavings (PS) which had been used as bedding to rear Large White male turkeys from hatch to 20 wks was processed at 204° and 427° C in an enclosed system. Four litter treatments (LT) were used: 1) control - new PS (T1), 2) TL processed at 204° C (T2), 3) a 70:30 (w/w) mixture of TL processed at 204° or 427° C (T3), and 4) a 95:5 (w/w) mixture of TL processed at 204° or 427° C (T4). These LT were placed in 36 floor pens in a randomized block design to provide 9 replicate pens per LT. Thirty Large White turkey hen poults were placed in each pen on day of hatch. The birds were reared to10 wks. Mortality and feed consumption were monitored. Birds were weighed at 6 and10 weeks of age. Period and cumulative feed conversion (FC) ratios were calculated. Regression analysis of SAS, Inc. was used for data analysis. LS Means procedure was used to separate treatment means ($P \leq 0.05$). At placement, T1 hen poults (60 g) were heavier than T2, T3 or T4 (59 g) hen poults. At 6 wks, T3 hens were heavier than T1 (1.78 kg), T2 (1.80 kg) or T4 (1.81 kg) hens. At 10 wks, there were no differences in BW (5.42 kg) among treatments. There were no differences for 6 wk (1.44) 10 wk (1.78) or 6 to 10 wk (1.95) FC. LT did not affect mortality. Litter treated by the process used for this study produces a bedding material suitable for rearing market turkeys.

INTRODUCTION

Recent changes in North Carolina laws regulating the land application of poultry litter require that litter be applied based on crop usage and litter nitrogen content. Levels of other nutrients such as phosphorus, copper, and zinc are also required to be monitored. The possibility that land application of litter will be based on phosphorus rather than nitrogen is quite distinct. Even though efforts are under way to decrease fecal nutrient excretion, there is also a need to extend the useful life of current bedding materials and to develop alternative uses of poultry litter once its usefulness as bedding has ceased. Current systems developed by Resource Enhancement Technologies, Inc., to heat treat poultry litter may extend bedding life and offer alternative uses of poultry litter. This process has the potential to both sterilize turkey litter and to change its form and, therefore, create a new product. This new product offers several potential advantages: 1) a product of greater value than litter, 2) a product that does not have to be land applied which eliminates land application of excess nutrients, and 3) a product that will be moved out of the area where it is produced.

Objective

The objective of this study was to determine if heat processed turkey litter can be reused as bedding for turkeys.

PROCEDURES

Pine shavings which had been used as turkey bedding for one growth period were used in this study. Large White male turkeys had been reared on the bedding for 20 weeks. This litter was removed from the pens and stock piled for approximately 2 weeks. Portions of the litter were heat processed at either 204° or 427° C for reuse as bedding material. Four treatment litters were used: 1) control - new pine shavings, 2) turkey litter heat treated at 204° C, 3) a 70:30 mixture of turkey litter processed at 204° or 427° C, respectively, and 4) a 95:5 mixture of turkey litter processed at 204° or 427° C, respectively. The litter processing took place at the NCSU Animal and Poultry Waste Management Center waste processing facilities.

The litter treatments were placed in 36 floor pens in a randomized block design to provide 9 replicate pens per treatment. There were 3 rows of pens with 12 pens per row. One row of pens served as a block. There were 3 replicates for each treatment in each block (4 treatments x 3 blocks x 3 replicates per block = 36 pens). Each pen was approximately 60 ft^2. There was one tube feeder and one bell-type waterer in each pen. Additional temporary feeders and waterers were used during the first two weeks.

Thirty Nicholas Large White turkey hen poults were placed in each pen on day of hatch. Typical rearing techniques were used to rear the birds for a 14 week growth period. During this period standard industry type rations were provided. The feed (Table 1) was formulated initially by the principle investigators and then modified in consultation with the feed manufacturer which was Southern States. Monensin was used for coccidiosis prevention up to six weeks of age. No other growth promotants, antibiotics, or "feed additives" were used. Feed consumption, by pen, and mortality were monitored. Birds were weighed individually at 6, 10, and 14, weeks of age. Period and cumulative feed conversion ratios were calculated.

Litter treatments were was sampled for nutrient content (N, P, Cu, & Zn) at the beginning of the study and at 6 and 14 weeks of age. At weeks 6 and 14 the litter was sampled from each pen while at the beginning of the study the litters were sampled before placement into the pens. Litter was sampled for total hetertrophs and coliform bacteria at the beginning of the study and at weeks 6 and 14. The litter treatments were also sampled for *Salmonella* and *Campylobacter sp* at the beginning of the study and at week 14. At weeks 6 and 14, litter from pens in each block were combined by treatment into one composite sample providing 3 composite samples per treatment while at the beginning of the study the litters were sampled before placement into the pens. Ammonia levels were determined in 3 pens per treatment at the beginning of the study and at weeks 6 and 14. Overturned 5 gallon buckets were used to trap air in each sample pen for 1 minute before measuring for ammonia content.

Regression analysis of SAS (SAS, 1992) was used to analyze all data. LS Means procedure was used to separate treatment means ($P \leq 0.05$). Beginning body weight was used as a co-variate for body weight analysis at weeks 6, 10, and 14.

RESULTS

Body weights for the study are presented in Table 2. At placement, the poults chosen for the pine shavings treatment were significantly heavier (60 g) than poults chosen for the other treatments (59 g). This difference, although statistically significant, was considered minor and meaningless. However, these beginning body weights were used as co-variates for body weight analyses at weeks 6, 10, and 14. At week 6, treatment 3 (1.86 kg) hens were heavier than treatment 1 (1.78 kg), 2 (1.80 kg) or 4 (1.81 kg). There were no differences in treatment body weights at weeks 10 (5.41 kg) or 14 (8.68 kg). There were no differences in cumulative or period feed conversions (Table 3) or mortality (Table 4).

Nutrient analysis for week 6 is presented in Table 5. Even though no statistical analysis was performed on the baseline litter values, the pine shavings was noticeably lower in all nutrients surveyed which was expected. The treated litter had been used as bedding in a previous trial but the heat treatment was not expected to eliminate some, but not all, nutrients. The pine shavings litter had less total, ammonium, nitrate, and organic nitrogen as well as less phosphorus, copper, and zinc than any of the other treatments at week 6. There were no differences for ammonium nitrogen, phosphorus, copper, or zinc among treatments 2 - 4 for week 6. However, at week 6, treatment 4 had less total nitrogen, nitrate nitrogen, and organic nitrogen than treatments 2 and 3. At week 14 there were no differences in any of the litter treatments for any nutrient surveyed. There were no differences in ammonia levels among treatments at 0, 6 or 14 weeks of age. At 14 weeks of age the mean ammonia level was 5.4 ppm.

Table 1. Composition of Feeds Used for Rearing Hens to 14 Weeks of Age.

Ingredient	Starter 1	Starter 2	Grower 1	Grower 2	Finisher 1	Finisher 2
			%			
Corn	45.10	47.60	57.50	57.90	63.60	66.80
Soybean Meal (48%)	43.20	40.50	31.20	29.80	23.80	20.00
Meat & Bone Meal	6.00	5.00	5.00	5.00	5.00	5.00
Fat	1.00	2.25	2.00	3.80	4.10	5.00
Limestone	1.25	1.25	1.25	1.00	1.00	1.00
Phosphate	2.00	2.25	1.80	1.50	1.50	1.25
Salt	0.35	0.35	0.35	0.35	0.35	0.35
Mineral Premix	0.10	0.10	0.10	0.10	0.10	0.10
Vitamin Premix	0.20	0.15	0.15	0.15	0.15	0.20
Choline	0.20	0.15	0.10	0.05	---	---
Lysine	0.15	0.08	0.25	0.18	0.13	0.12
D.L. Methionine	0.26	0.22	0.18	0.16	0.16	0.10
Selenium Premix	0.05	0.05	0.05	0.05	0.05	0.05
Monensin	0.075	0.075	---	---	---	---
Total	100	100	100	100	100	100
Calculated Analysis						
Crude Protein (%)	28.0	26.0	22.6	21.8	19.3	17.6
ME (Kcal/lb.)	1302	1342	1382	1437	1473	1511
Calcium (%)	1.44	1.40	1.28	1.13	1.12	1.07
Available P (%)	0.74	0.76	0.64	0.57	0.58	0.52
Methionine (%)	0.72	0.65	0.57	0.53	0.50	0.42
TSAA (%)	1.16	1.07	0.94	0.89	0.83	0.73
Lysine (%)	1.83	1.66	1.52	1.43	1.21	1.09
Sodium (%)	0.19	0.18	0.19	0.19	0.19	0.19
Feeding Schedule (Wk)	0-4	4-6	6-8	8-10	10-12	12-14
Feed Form	C	C	P	P	P	P
C- Crumble						
P- Pellet						

Table 2. Body Weights of Turkey Hens Reared to 14 Weeks of Age on Different Litter Treatments.

Treatment	Week 0	Week 6	Week 10	Week 14
	- gm -	---------- kg ----------		
1	60[a]	1.78[b]	5.39	8.76
2	59[b]	1.80[b]	5.41	8.69
3	59[b]	1.86[a]	5.52	8.68
4	59[b]	1.81[b]	5.43	8.56
SEM*	0.5	0.02	0.04	0.07

[a]Different superscripts denote statistical significance ($P<0.05$) within each week.
*Pooled standard error of the mean.

Table 3. Feed Conversions of Turkey Hens Reared to 14 Weeks of Age on Different Litter Treatments.

Treatment	Week 6	Week 10	Week 14	Weeks 6-10	Weeks 10-14
1	1.44	1.79	2.19	1.23	3.66
2	1.45	1.78	2.22	1.22	3.80
3	1.43	1.77	2.28	1.21	4.24
4	1.45	1.77	2.21	1.20	3.80
SEM*	0.02	0.12	0.04	0.04	0.19

*Pooled standard error of the mean.

Table 4. Mortality (%) of Turkey Hens Reared to 14 Weeks of Age on Different Litter Treatments.

Treatment	Weeks 0-6	Weeks 6-10	Weeks 10-14	Total Mortality
1	5.83	2.92	0.83	9.58
2	5.19	2.59	0.74	8.52
3	2.08	1.67	3.33	7.08
4	4.07	2.59	1.85	8.52
SEM*	1.15	0.94	0.76	1.62

*Pooled standard error of the mean.

Litter bacterial analysis is presented in Table 6. The previously used litter had significantly higher numbers of total hetertrophs and coliforms than stock-piled or heat treated litter or new pine shavings. The stock-piled litter also had significantly higher levels of total hetertrophs than heat treated litter or new pine shavings. There were no coliforms detected in the stock-piled litter, new pine shavings or heat treated litter at the beginning of the study. In addition, there was no *Salmonella* or *Campylobacter sp.* detected in the new pine shavings or heat treated litter. At week 6, there were no differences in any of the litter treatments for total heterotrophs. However, treatment 1 which was the new pine shavings, had significantly higher levels of coliforms than any of the heat treated treatments. Treatment 3, which was the 70:30 mixture of turkey litter processed at 204° or 427° F, respectively, had higher levels of coliforms than treatments 2 or 4. At week 14, there no differences in total hetertrophs for any treatment. However, treatment 1, the new pine shavings, had significantly higher levels of coliforms than any of the heat treated litter treatments. There were also no differences among treatments for levels of *Campylobacter sp.* at week 14. Also at week 14, there was one composite sample for treatment 3 which had detectable levels of *Salmonella sp.* None of the other samples for treatment 3 or any other treatment had detectable *Salmonella sp.* levels.

It was concluded that heat treatment of previously used turkey litter produces a bedding equal to new pine shavings as a litter material for the rearing of commercial market turkeys.

REFERENCES

SAS Institute, 1992. SAS User's Guide. Version 6.08. SAS Institute, Inc. Cary, NC.

Table 5. Nutrient Assessment Results for Litter Treatments Sampled at Weeks 0, 6, and 14.

Treatment	Total N	NH_4	NO_3	Organic N	P	Cu	Zn
(Week 0)*	ppm						
1	6944	1213	70.2	5661	1479	6.9	46.3
2	41308	3106	365	37837	14947	70.7	500
3	41117	2079	192	38846	18142	77.2	595
4	40795	3037	346	37412	15995	74.2	551
SEM**	-	-	-	-	-	-	-
(Week 6)							
1	26596[c]	605[b]	150[c]	25842[c]	5872[b]	50.0[b]	311.8[b]
2	38418[ab]	1536[a]	270[ab]	36612[ab]	10849[a]	74.5[a]	456.6[a]
3	39197[a]	1280[a]	250[b]	37667[a]	11043[a]	77.4[a]	482.4[a]
4	36892[b]	1395[a]	300[a]	35197[b]	10914[a]	76.8[a]	462.1[a]
SEM**	808.1	103.0	12.3	810.3	637.1	2.1	11.7
(Week 14)							
1	56610	7421	20.0	49170	14555	91.3	561
2	52086	5810	49.2	46229	15781	84.8	580
3	50622	5874	23.5	44724	15447	85.4	576
4	53219	6268	35.8	46915	15514	88.0	583
SEM**	2363.6	0	0	0	649.4	4.5	26.7

[a]Different superscripts denote statistical significance ($P<0.05$) for each of the parameters listed.
[*]Only one sample taken for baseline (Week 0) per treatment, therefore, no statistical analysis performed.
[**]Pooled standard error of the mean.

Table 6. Microbial Results for Litter Treatments Sampled at Weeks 0, 6, and 14.

Treatment	Total Heterotrophs	Coliforms	Salmonella	Campylobacter
(Week 0)	---------- CFU ----------			
litter - house	8.38e+06[a]	1.50e+04[a]	-	-
litter - stockpiled	5.05e+06[b]	0.00e+00[b]	-	-
pine shavings	2.70e+04[c]	0.00e+00[b]	0	0
litter - low temp.	4.50e+04[c]	0.00e+00[b]	0	0
litter - high temp.	9.00e+03[c]	0.00e+00[b]	0	0
SEM*	6.32e+05	2.24e+03	-	-
(Week 6)	---------- CFU ----------			
1	1.52e+06	2.68e+05[a]	-	-
2	9.17e+05	5.80e+04[c]	-	-
3	3.63e+06	1.69e+05[b]	-	-
4	1.27e+06	7.47e+04[c]	-	-
SEM*	1.60e+06	5.59e+04	-	-
(Week 14)	---------- CFU ----------			
1	1.24e+07	8.09e+04[a]	0	2.50e+03
2	1.38e+07	1.97e+04[b]	0	1.17e+03
3	1.35e+07	1.49e+04[b]	1.67e+02	1.17e+03
4	1.39e+07	1.07e+04[b]	0	3.33e+02
SEM*	7.12e+05	2.82e+04	83.3	1.07e+03

[a]Different superscripts denote statistical significance ($P<0.05$) for each of the parameters listed.
*Pooled standard error of the mean.

DEHYDRATED POULTRY MEAL PRODUCED FROM FARM MORTALITIES

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Alabama ranks third in the nation in broiler production and in 1997 produced over 950 million birds (Poultry Times, 1998). Unfortunately, ranking third in broiler production also means Alabama is third in producing poultry wastes. While 19 million broilers are processed weekly in Alabama, over 800 tons of poultry carcasses must be disposed of weekly in an environmentally sound manner. For a flock of 100,000 broilers grown to 49 days of age and averaging 0.1% daily mortality (4.9% total mortality), approximately one ton of farm mortalities require disposal (Edwards and Daniels, 1992). Disposing of mortalities has been identified by the poultry industry as the most serious environmental problems that may limit the future expansion in Alabama.

There are four main methods of carcasses disposal in Alabama; incineration, composting, rendering, and open-bottom burial pits. Incineration is biologically the safest method of disposal, however it is expensive and produces air particulate pollution (Loehr, 1968). Composting dead birds has been shown to be biologically safe (Murphy and Handwerker, 1988) and produces a useful product, but the maintenance of a composter is extensive, requiring at least 30 minutes each day (Payne and Donald, 1989). Rendering of chicken carcasses is another acceptable method of disposal, but requires the close proximity of a rendering plant to be economically unfeasible. The easiest and least expensive method of carcass disposal has been open-bottom burial pits. However, concern for water quality, as well as the persistence of residues, has led to the banning of the construction of new burial pits in the State of Alabama since July 1996.

An alternative method of carcasses disposal involving grinding and drying of frozen farm mortalities has been developed in the State of Alabama.

PROCESS DESCRIPTION

Poultry production mortality is gathered by the farmer daily and placed in freezing units. As necessary, or at regular intervals, the frozen dead birds are collected in a modified garbage truck and transported to the mortality processing plant. The frozen carcasses are deposited into a large collection bin and transported to an icebreaker, which breaks apart the frozen block of dead birds. Once broken apart, individual carcasses are transported by conveyor to a large modified meat grinder and ground to a semi-fine consistency. The ground material is then transported by auger to a large, sealed storage bin, from which material can be drawn as needed. The ground material is transported to a large drum dryer and dried according to a proprietary procedure. The dried material is mixed with soybean meal then transported through an auger system, in which Termin8 (Anitox Corp., Nacogdoches, TX ®, an FDA approved, formalin-based feed treatment product is added. The finished product is then transported through another auger system and into a feather screening system, prior to being placed in storage bins, ready for transportation. Farmers involved in the system pay a fee for freezer rental and the transportation of their mortality to the carcass processing plant and pay electricity costs of the freezers located on their farms. Auburn University provided support to those involved in the creation of this project to monitor product quality and nutritional worth.

MICROBIOLOGICAL SAMPLING

Samples taken from successive batches of dehydrated poultry product were examined microbiologically for the presence of bacterial pathogens (human and poultry) both aerobic and anaerobically. Overall the material was determined to be relatively free of bacteria. Although bacteria were present in the material, their levels were low and below the threshold of statistical significance (< 250-500 cfu/g sample). Because of this, no data indicating quantification is included. Specific bacteria that were identified are given in Table 1. Although some actual pathogens were isolated, these were again below the threshold of statistical significance and no quantification data is included. Of the spore forming bacteria that were isolated, members of the Bacillus genus predominated.

Many of the bacteria recovered could be classified as environmental contaminants, possibly indicating post-processing treatment contamination. Since no attempt was made to identify the source of these bacteria, contamination from the environment (dust, insects, etc.) or equipment cannot be ruled out. Since the trailer was opened and not covered with any cover or tarp, the finished product stored by this method was subject to post-treatment environmental contamination. The company now treats the finished product with Termin8 (Anitox Corp., Nacogdoches, TX), a formalin-based feed treatment product.

Table 1. Bacterial Isolates Recovered From Recycled Poultry Product (Pooled Results).

Staphylococcus chromogenes	*S. simulans*	*S. arlettae*
Staphylococcus aureus	*S. sciuri*	
Klebsiella penumoniae		
Bacillus cereus	*B. licheniformis*	*B. mycoides*
Bacillus megaterium	*B. coagulans*	
Chryserobacterium gleum	*Flavimonas orzyihabitans*	*Brevundimonas diminuta*
Rhodococcus rhodochrous		
Sphingobacterium multivorum	*S. thalpophilum*	
Micrococcus luteus	*M. lylae*	
Pseudomonas putida	*P. fluorescens*	
Alacaligenes faecalis	*Enterobacter cloacae*	*Acinetobacter baumannii*

NUTRITIONAL ANALYSIS AND SUITABILITY AS A FEED INGREDIENT

Composite samples of dehydrated poultry meal were obtained from finished, stored product and refrigerated for storage prior to nutrient analysis. Subsamples either were or were not screened through no. 4 and 8 screens to remove feathers and other large particles. It was found that 10.6% of the material was retained on the #4 screen and 23.8% was retained on the #8 screen. In general, 1/3 of the material was large particle. The company involved has installed a grinder and screen to remove a large majority of the feathers. The product currently being produced would most closely match the nutritional profile of the screened sample.

Samples of the screened and unscreened materials were submitted to the Auburn University Soil Testing Laboratory for nutrient analysis (Table 2). Nutrient levels are presented on a "as is" and dry matter basis. We are most interested in the results "as is" as that is how most ingredients are handled for monogastric feed formulations. Crude protein levels were approximately 2% higher for the product with feathers. Interestingly, little difference was demonstrated in digestible protein or total digestible nutrients between screened and unscreened samples (73.16 vs. 74.05% TDN). Calculated metabolizable energy levels were reasonably high at 2820 Kcal/Kg for the screened samples and 2860 Kcal/Kg for the unscreened samples.

Fat and ash content are high compared to traditional poultry byproduct meals. This reflects inclusion of whole birds in the process rather than separation of rendered products. Calcium and phosphorus levels were noticeably lower in the screened samples compared to the unscreened. This probably reflects the removal of larger bone fragments through the screening process. Levels of essential minerals such as zinc, manganese and copper are sufficiently high as to warrant consideration in formulation. Copper and iron levels were higher in the unscreened samples. This may reflect increased mineral levels either in feathers themselves, or in the larger chunks of material (bone, for instance) that were screened out. Iron and potassium levels are mildly high and need to be factored into feed formulations to avoid excesses.

Nutrient analyses compiled from these samples were used to construct an ingredient matrix within the Agridata Feed Formulation Program for use in feed formulation. Sample broiler starter and grower feeds were formulated using this program to examine the worth of this ingredient in relation to other typical feed ingredients. In general, dehydrated poultry meal priced equal to soybean meal under current pricing conditions. Under these circumstances, dehydrated poultry meal was worth approximately 99% of the price of soybean meal. These results were shared with the company in question for their use in pricing and selling their product.

Table 2. Dehydrated Poultry Meal: Proximate Analysis and Selected Minerals

Nutrient	DPW w/out Feathers As Is	DPW w/out Feathers Dry Matter	DPW w/Feathers As Is	DPW w/Feathers Dry Matter
Crude Protein (%)	48.40	50.19	50.27	51.50
Digestible Protein (%)	41.61	43.14	43.30	44.36
Moisture (%)	3.55	-	2.39	-
Dry Matter (%)	96.45	-	97.61	-
Crude Fiber (%)	2.00	2.07	2.02	2.07
Crude Fat (%)	17.64	18.29	17.60	18.03
Ash (%)	7.72	8.00	7.81	8.00
Tot. Dig. Nutrients (%)	73.16	75.86	74.05	75.86
Metabolizable Energy (Kcal/Kg)	2820	2930	2860	2930
Net Energy L (Kcal/Kg)	1680	1740	1700	1740
Net Energy M (Kcal/Kg)	1840	1910	1860	1910
Net Energy G (Kcal/Kg)	1150	1190	1160	1190
Calcium (%)	0.76	0.79	1.13	1.16
Phosphorus (%)	0.91	0.94	1.07	1.10
Potassium (%)	1.42	1.47	1.38	1.41
Magnesium (%)	0.18	0.19	0.18	0.18
Manganese (ppm)	28	29	27	28
Zinc (ppm)	64	66	63	65
Copper (ppm)	19	20	34	35
Iron (ppm)	542	562	711	728

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USE WATER WISELY
A HANDS - ON DEMONSTRATION TO ILLUSTRATE THE USE OF WATER

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More than water goes down the drain when we use, and use inefficiently, water in the poultry industry. The costs for water appropriation and wastewater treatment are now significant costs for an operation. The trend has been, and will be, for these costs to increase. Water quality and the quantity available are also of concern today. Water cutbacks often make the headlines in periods of drought.

The Environmental Services Department recognized a need to educate our associates in the proper and efficient use of water. A portable demonstration unit was assembled from used materials found at the various plant sites. A stainless steel tank was modified to serve as the basin for the demonstration unit, see Figure 1. A used pump was fitted with a pressure regulator to supply the water. The various discharge arrangements used range from a piece of pipe with holes drilled in it to specific nozzles used in the particular plant, see Figure 2. The water is reused for the entire demonstration.

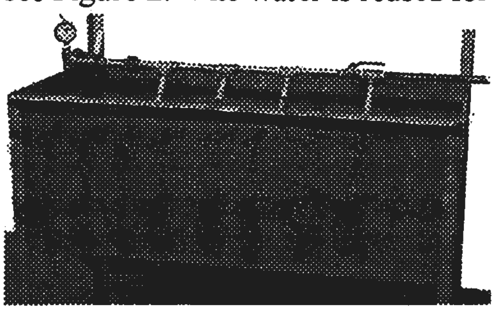

Figure 1

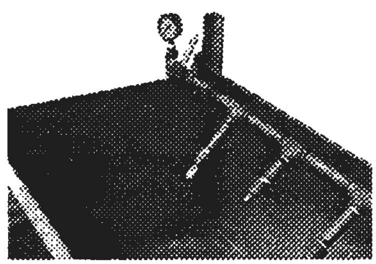

Figure 2

The unit is portable and can be easily set up in any plant conference room or training area. Individualized training sessions are developed based on the type of operation and water used. A short classroom session starts the demonstration. Handout materials and plant specific information is presented. The demonstration quickly turns to hands-on. Associates will get their hands wet measuring and calculating water flow.

The hands - on session illustrates several major points in the use of water. The first demonstration uses a pipe with a series of holes drilled in it. The system pressure is set at 20 psi. Volunteers use several one gallon buckets to capture water from the various holes for a measured amount of time. The quantity collected is compared for the different openings. The flow rate is calculated in gallons per minute by dividing the gallons of water collected by the measured length of time, expressed in minutes. It is easy to see that the largest opening has the greatest flow rate. Next the pressure is increased to approximately 40 psi. A different group of volunteers collects the water once again for a measured amount of time. The flow rates are calculated for the second time. It is easy to see that the flow is greater from the larger holes. It is also easy to see that the flow is greater from all the openings at the higher pressure.

The third demonstration uses a discharge header fitted with different nozzles. The water flow is once again captured in buckets for a measured amount of time. The flow is compared for the different types of nozzles. The nozzle flow is also compared to the calculated flow for a new nozzle, illustrating the effects of wear. A ball valve is installed prior to one of the nozzles to illustrate the effects of an attempt to control the flow. The throttled flow is compared to a similar nozzle and a hypothetical need. The discharge header can be easily modified to illustrate any configuration needed, such as a gooseneck or specific type of nozzle.

The session usually lasts 30 to 60 minutes depending on the needs of the plant and the questions that are asked. Thoughts and ideas flow as freely as the water. In summary, the demonstration illustrates four key points: the larger the hole, the more water is used; the higher the pressure, the more water is used; use the right nozzle for the job; and watch out for control valves.

ENVIRONMENTAL AND ECONOMICS IMPACTS OF ALTERATIVE BROILER WASTE MANAGEMENT STRATEGIES FOR DUCK CREEK WATERSHED, TEXAS

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The Texas Institute for Applied Environmental Research (TIAER) is engaged in an Environmental Protection Agency (EPA) funded project designed to investigate the environmental and economic effects of alternative waste management practices for broiler operations in Duck Creek, a small watershed of 97,455 acres in eastern Texas. Components of this research include water quality monitoring, a description of the current regulatory environment, a nutrient budget, a description of the current status of broiler operations and water quality, economic and environmental computer simulation of enhanced waste management scenarios, and an analysis of policy implications. Broiler operations have only recently moved into this watershed, thus it provides a good baseline and the possibility of implementing effective waste management strategies before environmental problems arise.

Duck Creek is a tributary of the Navasota River, which later joins the Brazos River. The watershed is dominated by range, pasture, and hay production, with only one small town lying partially within the watershed. In 1995, Sanderson Farms, Inc. opened a chicken processing facility in Bryan, Texas. In the ensuing years, Sanderson Farms contracted with nearby farmers to grow chickens, and numerous broiler operations soon commenced operation in the region. Nine operations consisting of 52 chicken houses are located within Duck Creek. Each house grows flock of 27,500 chickens approximately six time a year, hence, around 8.58 million 5.5 lb broilers are gown in the watershed annually. These operations also produce around 10,400 tons of nutrient rich chicken litter annually, which is applied to pasture and hayfields, either on-site or on neighboring farms. The effects of the land application animal manure, including chicken litter, on water quality has recently come under close scrutiny, especially in regions of the country (e.g. the Delmarva Peninsula) where facilities have been in operation for many years and suitable land for application is limited.

TIAER will analyze a baseline scenario and several enhanced waste management practices using the Comprehensive Environmental and Economic Optimization Tool (CEEOT). CEEOT is a modeling framework that integrates economic and environmental components. Environmental components include a landscape model, Agricultural Policy Environmental extender (APEX), and a water and nutrient fate and transport model, Soil and Water Assessment Tool (SWAT). Economic components include the Farm Economic Model (FEM), and a regional input-output model, the IMpact PLANning tool (IMPLAN).

Enhanced waste management scenarios to be simulated include phosphorus (P)-based land application rates, a P index land application rate, addition of Phytase sources to feed, addition of Aluminum Sulfate (Alum) to litter strips, riparian buffer zones, haul off scenarios, and expansion scenarios. Application of CEEOT to theses waste management practices will allow their comparison from both economic (cost-benefit) and environmental perspectives. The impact of alternative strategies on in-stream ambient P concentrations and soil buildup of P will be of particular interest since it is probable that P is the limiting nutrient in Duck Creek.

Simulations of enhanced waste management strategies will proceed during the next several months, however, two components of the research have already been completed and will be reported upon. First, the regulatory status of broiler operation at both the federal and state (Texas) level has been investigated. Secondly, nutrient budgets for nitrogen and phosphorus for the watershed have been completed. Results of the nutrient budget indicate that even at relatively low application rates, much of the P applied to pasture and hayfields is not taken up by crops and therefore is not removed from the watershed. Papers for both of these research segments will be available at the Symposium from the author: 1) *Regulatory Status of the Broiler Industry in Texas*, and 2) A Nutrient Budget for the Duck Creek Watershed, Texas.

Completed and scheduled research for this scientifically rigorous ongoing project will lend insights into how to manage broiler waste in ways that are consistent with environmental quality and economic feasibility, both now and for the future.

UTILIZATION OF HEN MORTALITIES AS A RUMINAL BYPASS PROTEIN

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INTRODUCTION

A flock of 100,000 hens (8% mortality per year) will produce 12 tons of hen mortality annually. Normally broiler mortality is 3-5% over the production cycle (Lomax and Malone, 1988) or approximately 0.1% per day. A flock of 50,000 broilers grown to 49 days of age that averages 0.1% daily mortality (4.9% total mortality) will produce approximately 2.4 tons of carcasses (Blake *et al.*, 1990). Disposal of these poultry farm mortalities means the loss of a tremendous amount of organic matter (Blake and Donald, 1992). Malone *et al.* (1987) estimated that fresh broiler carcasses contain approximately 51.8% of protein, 41.0% of fat, and 6.3% ash on a DM basis. Researchers have tried to recycle poultry mortalities into feed ingredients for poultry by rendering, extrusion, or fermentation (Tadtiyanant *et al.*, 1993; Patterson *et al.*, 1994; Kim and Patterson, 2000b). However, since bovine spongiform encephalopathy (BSE) occurred in the United Kingdom, recycling dead animals or by-products into feed ingredients for same species has become less acceptable to the public. Thus, utilization of poultry mortalities or poultry by-products as feed ingredient for other species might be better a nutritional recycling niche.

One of the high ruminal bypass proteins from the poultry industry is feather meal. Many researches have demonstrated that feather meal was a good alternative protein source for ruminants (Goedeken *et al.*, 1990; Cunningham *et al.*, 1994). However, there is little information available on the treatment and recycling of dead hens as a protein supplement for ruminants. Therefore, the objective of this study was to evaluate the effect of enzyme or NaOH treatment of hen mortalities with fermentation on the dry matter and protein digestibility of hen meals by the ruminant.

MATERIALS AND METHODS

Treatment and Sample Preparation

Ninety 65-wk-old Shaver 2000 hens were used for this experiment. There were three treatments for this experiment: control hen meal (C-HM), enzyme treated hen meal (E-HM), and NaOH treated hen meal (N-HM). Birds were killed by cervical dislocation and after 5 h, 10 dead birds were placed in a mixer with rubber picking fingers. For the enzyme treatment, 10 dead birds were treated with 0.0256 g of INSTA-Pro enzyme per 1g of feathers and 2.5 L water for 12 h at 21 C. Feather weight was determined to be 4% of dead bird weight. In the NaOH treatment, 10 dead birds were incubated with s.5 L of 0.4 N NaOH for 2 h at 21 C. During incubation, the mixer agitated dead birds vigorously. After incubation, feathers and carcasses were collected and ground. Sugar (10%) was added to the ground birds for fermentation and blended thoroughly with an electric paddle. Untreated control ground birds, and fermented enzyme or NaOH treatments were autoclaved at 124 kPa, 127 C for 90 min. After autoclaving, autoclaved samples were dried in a forced air oven at 60 C until a constant weight was reached, and ground in a hammer mill and stored at –20 C until they were analyzed and incubated In-situ. Autoclaved end-products (C-HM, E-HM, and N-HM) were used to evaluate digestibility's of dry matter (DM) and protein by In-situ nylon bag incubation compared to soybean meal (SBM).

In-Situ Nylon Bag Incubation

Two ruminally cannulated Holstein cows (7 and 9 year old) were used for this experiment. There were four treatments: soybean meal (SBM), control hen meal (C-HM), enzyme treated hen meal (E-HM) and NaOH treated hen meal (N-HM). Each nylon bag contained 5 g of sample and eight bags per each treatment were inserted into the rumen. After 1, 2, 4, 8, 12, 24, 36, and 72 h of incubation, bags were removed. Sample bags were rinsed with cold water until the rinse water was clear and then dried in a forced air oven at 60 C until a constant weight was reached. Total nitrogen content and dry matter were determined before and after incubation to estimate the ruminal digestibility of hen meals (AOAC, 1990). Al animal care procedures were carried out as described in the protocol approved by The Pennsylvania State University Institutional Animal Care and Use Committee (95%027A0).

RESULTS AND DISCUSSION

The CP levels of the C-HM and SBM were significantly higher than the E-HM and N-HM and the ether extract (EE) level of the C-HM was significantly higher than all others ($P<.05$) (Table 1).

The EE level of the SBM was lowest among the ingredients. There were no significant differences in CP or EE between the E-HM and N-HM ($P>.05$). These results indicated that although the enzyme and sodium hydroxide treatments enhanced storage time and preservation, there were negative effects on CP and EE concentrations of hen mortalities compared to the C-HM. The nutritional concentrations of these hen meals were somewhat different from commercial hen meals. Christmas *et al.* (1996) reported that the rendered whole-hen meal contained 55.73% CP and 22.9% fat. Kersey *et al.* (1997) estimated that the CP and fat levels of spent hen meals varied from 65 to 74% and from 8 to 11%, respectively. Douglas and Parsons (1999) evaluated spent hen meals that contained from 56 to 71% of CP and from 14 to 18% of fat. The hen meals from this study (C-HM, E-HM, and N-HM) contained lower CP and higher fat levels than other commercial hen meals. However, the hen meals treated for preservation from this study had similar CP levels to SBM. The different nutritional concentrations are due to different processing conditions. The commercial rendering plants extract the fat from hens because it makes processing easier and increases protein level. The extracted fat is also used for a highly digestible energy feed supplement.

Table 1. The Chemical Composition of Control Hen Meal (C-HM), Enzyme Treated Hen Meal (E-HM) and NaOH Treated Hen Meal (N-HM) (DM Basis)

Treatment[1]	CP	EE
	------------------- (%)	-------------------
C-HM	49.38[a]	36.43[a]
E-HM	39.11[b]	30.45[b]
N-HM	40.66[b]	28.13[b]
SEM	48.75[a]	1.49[c]
Pooled SEM	0.93	1.18

[a-d]Means within a column with different superscripts differ significantly ($P<0.05$).
[1]Autoclaved fresh hens (C-HM), enzyme treated fermented and autoclaved hens (E-HM), NaOH treated, fermented and autoclaved hens (N-HM), and soybean meal (SBM).
[2]Ether extract = EE, n = 3 per mean.

In the present study, the E-HM and N-HM had less CP than the C-HM, indicating the enzyme and the NaOH treatments reduced the CP levels of hen meals. Papadopoulos *et al.* (1985) findings are in agreement with this result. They treated feather meals with NaOH (0.2 to 0.6%) for various lengths of time (30 to 70 min). An increase in processing time and NaOH resulted in a significant reduction in CP.

Table 2 shows the amino acid concentrations of SBM, control, enzyme and NaOH treated hen meals. The Lys, Thr, Arg, Ile, Leu, and Val levels of the C-HM and SBM were significantly higher than the E-HM and the N-HM ($P<.05$). The Met, Cys, and Gly levels of the C-HM were significantly higher than the SBM ($P<.05$). The N-HM was significantly lower in Met, Lys, His, and Phe levels than the E-HM ($P<.05$). These results indicate that the C-HM has similar or higher amino acid concentrations compared to SBM, whereas, enzyme or NaOH treatment reduced amino acid concentrations. The NaOH-treatment depressed amino acid quality more than the enzyme treatment. Papadopoulos *et al.* (1985) findings are in agreement with these results. They found that the Cys, Lys, and Met levels of feathers were reduced as NaOH concentrations increased. De Grott and Slump (1969) also indicated that Cys and Lys levels of casein were reduced with alkali treatment. Thus, the present study indicates that NaOH pretreatment for feather breakdown has negative effects on nutritional quality of hen meals. In this study, the E-HM and N-HM were fermented for 21 d at 25 C. Although amine production was not measured in the present study, some studies indicated that amines generated during fermentation corresponded with reduced concentrations of some amino acid. Sander *et al.* (1996) indicated that the level of amino acids decreased s the levels of biogenic amines increased during 70 d fermentation of poultry carcasses. Specially, the concentrations of Phe, Lys, and Tyr were significantly reduced during fermentation.

Table 2. The Amino Acid Concentration of Control, Enzyme and NaOH Treated Hen Meals Compared to Soybean Meal

Amino Acids	C-HM1	E-HM	N-HM	SBM	Pooled SEM
	(g AA/100g CP)				
Methionine	2.06^{a}	1.56^{b}	1.36^{c}	1.50^{bc}	0.05
Cystine	2.20^{a}	2.01^{ab}	1.77^{b}	1.67^{b}	0.07
Methionine + Cystine	4.26^{a}	3.57^{b}	3.13^{c}	3.18^{bc}	0.06
Lysine	5.78^{a}	4.78^{b}	3.92^{c}	6.29^{a}	0.14
Threonine	3.95^{a}	3.63^{b}	3.57^{b}	3.93^{a}	0.05
Arginine	6.37^{a}	4.67^{b}	4.45^{b}	7.56^{a}	0.11
Isoleucine	4.41^{a}	3.87^{b}	3.77^{b}	4.89^{a}	0.06
Leucine	7.39^{a}	6.33^{b}	6.14^{b}	7.92^{a}	0.07
Valine	5.82^{a}	5.07^{b}	5.15^{b}	5.67^{a}	0.09
Histidine	2.16^{a}	2.26^{a}	1.83^{b}	2.68^{a}	0.05
Phenylalanine	3.89^{a}	3.32^{b}	3.12^{c}	5.20^{a}	0.03
Glycine	8.65^{a}	7.87^{b}	7.62^{b}	4.40^{c}	0.16
Serine	4.92	4.94	4.65	4.59	0.11

[a-c]Means within a row with different superscripts differ significantly ($P<0.05$).
[1]Control hen meal (C-HM); enzyme treated hen meal (E-HM);p NaOH treated hen meal (N-HM): soybean meal (SBM), n = 3 per mean.

Figure 1 shows the ruminal DM degradation of control, enzyme, and NaOH treated hen meals, and soybean meal. From 1 to 4 h, the DN degradation of SBM was lower than E-HM and N-HM. However, after 8 h, the DM degradation of SBM was considerably increased and was significantly higher than the others from 12 to 72 h (P<.05). The DM degradation rates of the E-HM and N-HM were significantly less than SBM for most of the period from 12 to 72 h (P<.05). During the entire experimental period, the C-HM showed the lowest DM degradation among the treatments.

Figure 2 shows the ruminal protein degradation among treatments. The trend of protein degradation was similar to that of DM degradation. The SBM had lower protein degradation than the E-HM and the N-HM within 4 h. After 4 h, the protein degradation of SBM was increased yet not significantly different than the E-HM or the N-HM from 24 to 72 h. The CP degradation of the C-HM was significantly lower than the E-HM and the N-HM during the entire experimental period and lower than the SBM from 2 to 72 h, expect for 4 h (P<.05).

These results suggested that the C-HM was more resistant to ruminal degradation meaning more intact protein could reach the small intestine compared to SBM. Although the E-HM and N-HM had similar or lower DM and CP degradation rates, they had much less resistance to ruminal degradation compared to the C-HM. The higher resistance to ruminal degradation of the C-HM may be due to remaining intact feathers on the

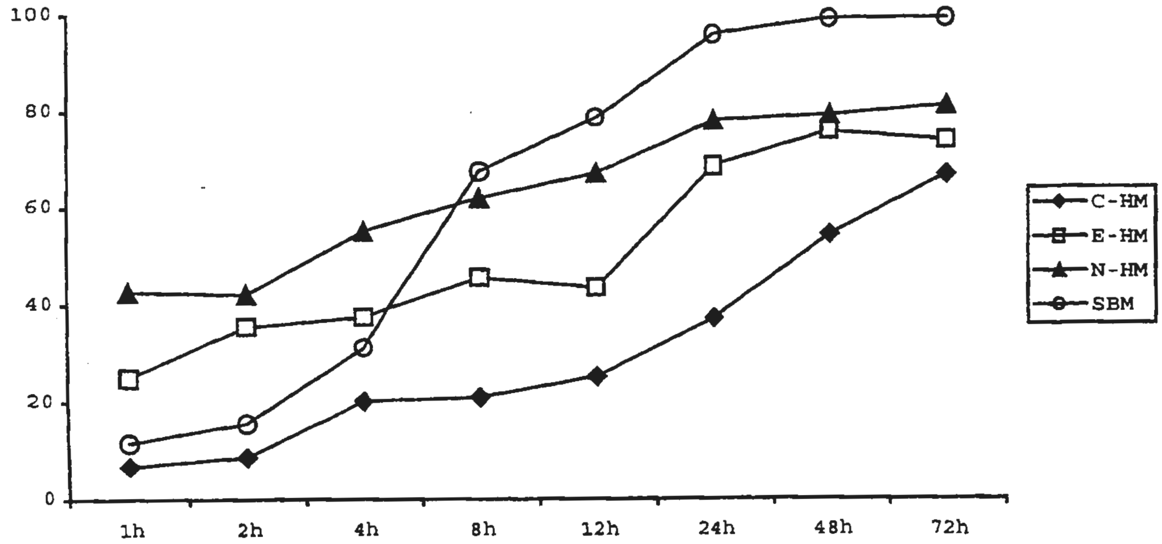

Figure 1. The Ruminal DM Degradation of Control, Enzyme, and NaOH Treated Hen Meals, and Soybean Meal

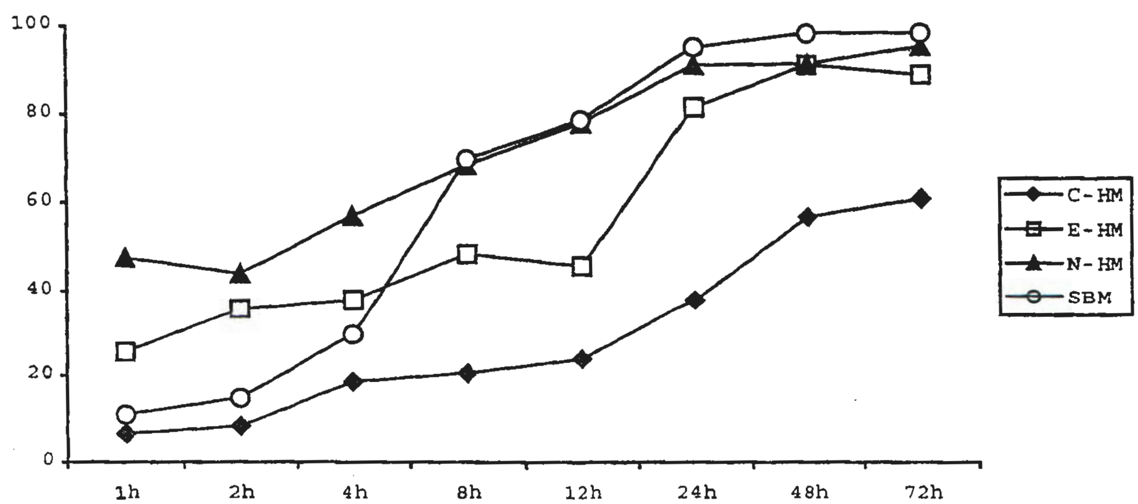

Figure 2. The Ruminal Degradation of Control, Enzyme, and NaOH Treated Hen Meals, and Soybean Meal

carcasses. Feathers constitute approximately 10% of the body on a dry weight basis (Webster *et al.*, 1996). Keratins have a high degree of crosslinking by cystine disulfide bonds. This crosslinking results in high resistance to gastrointestinal digestion (Parry *et al.*, 1997). However, the enzyme- or NaOH-treated hen meals were more susceptible to ruminal degradation because these treatments broke down the crosslinkages of feathers during pretreatment. Papadopoulos *et al.* (1985) indicated that pepsin digestibility of feathers increased as NaOH concentrations increased. Kim and Patterson (2000a) also indicated that NaOH and feather-digesting enzyme treatments improved feather solubility. Perhaps, for ruminants, hen meals should not be treated with an enzyme or chemicals to retain high resistance against ruminal digestion.

In addition to poultry mortalities, spent hens or hatchery waste could also be a good protein source for ruminants. Approximately 240 million laying hens are maintained in the United States at any time and 14 million laying hens are retired and available for processing annually (Lyons and Vandepopuliere, 1996). Thus, Haque *et al.* (1991) suggested that the utilization of the spent hen as a feed ingredient could reduce a potential disposal problem and provide a positive economic return. Many researches have demonstrated that poultry moralities and spent hens could be alternative protein sources for poultry by rendering, extrusion, or fermentation (Patterson *et al.*, 1994; Cai and Sanders, 1995; Douglas *et al.*, 1997). Another possible protein source is hatchery waste. Deshmukh and Patterson (1997) evaluated the feeding value of fermented hatchery waste for broiler chickens, indicating that nutrient dense hatchery by-products can be preserved with fermentation up to 21 d and support broiler live performance and carcass yield as dietary ingredients equal to or better than a corn-soybean meal control. Again, however, the public perception of recycling poultry mortalities, spent hens, or hatchery waste as feed ingredients for poultry would be less acceptable. Therefore, utilization of these poultry by-products as feed ingredients for ruminants would be better nutritional recycling strategy.

CONCLUSIONS

The present study suggested that hen mortalities have potential as an alternative protein source for ruminants because they are a high protein by-product with a good amino acid profile and have some resistance to ruminal degradation. However, further research is necessary to evaluate the effect of hen meals on the growth performance and milk production of beef and dairy cattle in the future. The present study showed another possibility of recycling hen mortalities into a feed ingredient for other species.

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THE EFFECTS OF FEEDING LOW PROTEIN DIETS ON AMMONIA EMISSION AND TOTAL AMMONIACAL NITROGEN IN BROILER LITTER

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ASBSTRACT

Broilers were fed one of four dietary treatments consisted of four levels of crude protein (CP): a conventional High CP diet (Hi), a very Low CP diet (Low), and two intermediate CP diets (M-Hi and M-Low) obtained by mixing the High and Low CP diets. Respective CP levels used in the grower and finisher diets were as follows: Treatment Hi – 23.0% and 22.5%; Treatment M-Hi – 20.85% and 20.8%; Treatment M-Low – 18.5% and 17.5%; and Treatment Low – 16.3% and 15.0%. All diets were formulated to the same minimum digestible amino acid (AA) levels in the ratios to lysine similar to those suggested by Baker (1994). Levels of threonine, tryptophan and arginine were increased slightly above minimum levels. Trial completion dates were August, October and December, with three weeks between flocks.

Results of three trials indicate that a diet with reduced CP and supplemental AA may achieve satisfactory bird performance. Body weights at day 42, in Trials 1 and 2, were significantly heavier for Hi and M-Hi treatments compared with M-Low and Low treatments. In Trial 1, feed intake for Hi and M-Hi treatments were significantly greater but not in Trails 2 and 3. In all 3 trials, birds on the Low CP treatment had significantly poorer feed conversion; there was no difference between M-Hi and Hi diets. After three flocks raised on the same litter, pens for birds on the Hi CP diet exhibited significantly greater concentrations of equilibrium NH_3 gas. Mean litter pH ranged from 6.90 to 8.78 over the three trials, with the Hi CP treatment having the highest pH and the Low CP diet having the lowest pH. While the diets used in this study are not yet optimal, they have demonstrated the lower CP diets can be used to control waste N and equilibrium NH_3 gas.

INTRODUCTION

Broiler litter is comprised of a mixture of fecal material and organic matter, typically wood shavings, chips, or rice hulls. Many commercial operations completely replace litter only after several flocks have been raised; and rely on a combination of vigorous mixing, de-caking and addition of a small volume of fresh litter material between flocks. As a consequence, nitrogenous compounds will accumulate and be further degraded by bacteria. Moisture, pH, temperature, and ionized ammonia (HN_4^+) contribute to NH_3 volatilization from the litter surface. Elevated room NH_3 concentrations are associated with increased respiratory stress for both poultry and workers, and control NH_3 concentration is done chiefly by ventilation, exhausting room air to the outside.

Enhanced utilization of dietary CP can be accomplished by fine tuning diets to better match birds' nutrient requirements, primarily by ensuring that at a given energy density there are sufficient concentrations of all limiting essential amino acids (AA). In principle, if one knows the proper levels of AA to feed, then one might be able to achieve comparable bird growth and feed conversion efficiencies with reduced dietary CP. Optimal AA profiles depend on genetics, environment, and interactions with other nutrients.

The objective of this research was to test the hypothesis that reducing dietary CP below current commercial levels, with simultaneous enhancement of AA levels, will result in similar bird performance, reduced litter N and reduced NH_3 volatilization from litter, when evaluated over multiple flocks raised on the same litter.

MATERIAL AND METHODS

Corn-soybean meal grower and finisher diets were formulated based on previous work (Cantor *et al.*, 1998; Ferguson *et al.*, 1998a,b; Gates *et al.*, 1998a,b; Hussein *et al*, 2000a,b) Twelve replicate groups of 24 chicks were assigned to each of four treatments. Chicks were housed in floor pens (122 x 183 cm; 4 2 6 ft) equipped with tube feeders and nipple drinkers (3 nipples/pen). All chicks were fed the same broiler starter diet during days 1-17. The experimental grower and finisher diets were fed during days 18-35, and 35-42, respectively. Respective CP levels used in the grower and finisher diets were as follows: Treatment Hi – 23.0% and 22.5%; Treatment M-Hi – 20.8% and 20.0%; Treatment M-Low – 18.5% and 17.5%; and Treatment Low – 16.3% and 15.0%. All diets were formulated to the same minimum digestible amino acid levels in the ratios to lysine similar to those suggested by Baker (1994). Threonine, tryptophan and arginine were increased slightly above minimum levels which had shown responses in previous studies (Hussein *et al.*, 2000a; Baker, 1994). Diets in Trials 2 and 3 had L-glycine added to meet the glycine+serine levels suggested in NRC (1994). The two intermediate diets were formulated by 1:2 and 2:1 mixing of the Hi and Low treatments, yielding a medium-high CP diet similar to current commercial mixes and a medium-low CP diet that is below values currently used.

After each growout, birds were removed from the room and litter characteristics were obtained over the course of the following two days. Gaseous measurements included: equilibrium ammonia gas, carbon dioxide and methane obtained with a photoacoustic infrared technique according to the procedures outlined in Gates *et al.* (1997, 1998a), Ferguson *et al.* (1998a,b) and Hussein *et al.* (2000b). In this technique, an inverted sampling container is placed over the litter and its contents are continuously sampled until equilibrium concentrations are realized. This process requires typically 20-40 minutes. Full details are provided in the references cited.

Sampled litter properties included: moisture content (MC), pH and total ammoniacal nitrogen (TAN) obtained according to the methods described in Liberty *et al.* (2000). Litter pH reported in this study was obtained using a soil pH probe, wetting samples with distilled de-ionized water to achieve 60% moisture content (Liberty *et al.*, 2000). Litter samples and equilibrium gas concentrations were taken from an area equidistant between feeder and drinker. Room air temperature and litter temperature at surface and about 3 cm beneath surface was recorded during gas sampling. Surface and subsurface (3 cm) litter samples were taken from each pen after equilibrium gas concentrations were measured. TAN, pH and MC values reported in this paper were determined from averages of surface and subsurface samples.

Flocks were started in late July, mid-September and early November, 1999. Minimum ventilation (approximately 0.75-1 cfm/bird) was provided with one or two variable speed exhaust fans operated by a static pressure controller. Hot weather during some of Trial 1, and nearly all of Trial 2, resulted in maximum ventilation (6.5 cfm/bird) during the grow out; cool to cold weather during Trial 3 resulted in minimum ventilation for the entire flock (approximately 0.75 to 1 cfm/bird).

RESULTS AND DISCUSSION

Bird performance data are given in Table 1, along with means comparisons. Dietary treatment affected body weight ($p<0.001$) in Trials 1 and 2, but not Trail 3. For Trials 1 and 2, body weights were significantly greater for Hi and M-Hi treatments compared with the M-Low and Low treatments. Feed intake was significantly different among treatments in Trial 1, but not affected by diet in Trials 2 or 3. In all three trials, birds on the Low CP treatment had reduced feed conversion efficiency but there was no difference between M-Hi and Hi diets. There was also a significant difference between M-Low and M-High diets in Trial 2, but not in Trials 1 or 3. Further effects to fine-tune these diets are planned; however, the similar performance of the M-Hi and M-Low diets is promising for demonstrating that reduced dietary CP with properly formulated nutrient profiles can give near equal production results.

Equilibrium NH_3 gas concentration, litter TAN, and litter pH are presented in Table 2. Litter surface temperature prior to sampling is plotted Figure 1. There was a temperature rise during each day for Trail 2 (15-21°C), but stable, cool conditions for Trial 3 (15-16°C).

The main effect of dietary CP on equilibrium NH_3 gas concentration was significant; HN_3 decreased with level of CP in diet. For Trials 1 and 3 (Table 3), and for a pooled analysis (not shown) over all three trials, the mean NH3 concentration from Hi treatment pens was significantly greater than means of pens with the other three diets. Mean equilibrium NH_3 gas measurements from pen with Hi and M-Hi diets were significantly different, but M-Low and Low CP treatments were not. The Low CP diet means differed from both High and M-Hi means. The large variability noted in earlier trials (Ferguson *et al.*, 1998a,b; Gates *et al.*, 1997, 1998a,b; Hussein *et al.*, 2000b) was also evident in these studies, but 12 replications it was demonstrated that treatment effects exist. There was a trend for mean equilibrium NH_3 gas concentration to increase over the three trials. The range in measurements (Table 2 lists mean values and min/max values) was largest for Trial 1 and for the Hi and M-Hi treatments; variation was reduced appreciably by Trail 3 for all treatments. Of note also is the strong effect of maximum ventilation (6.5 cfm/bird) experienced during Trial 2, which resulted in a drier litter and little measurable equilibrium NH_3 gas.

For NH_3 to be available in gaseous form, pH must be sufficiently high so that ammonium is converted to ammonia. Also there must be sufficient moisture for bacteria to produce ammonia and to promote transport to the litter surface. Litter pH (Table 2) clearly increased with increased dietary CP over the three trials; since reduced pH results in greater ammonia fraction of TAN this could also explain increasing NH_3 concentrations. TAN is the mass concentration sum of both ammonia-N and ammonium-N, expressed in mg/kg dry litter (i.,e., ppm). TAN was unaffected by dietary treatment on new litter (Trial 1), but showed a strong response during Trail 2 despite no significant differences in NH_3 concentrations. Litter pH was significantly different among treatments, with the Hi CP diet having the greatest pH and the Low treatment having the lowest pH in all three trials. Although not shown, litter MC also was significantly affected by dietary treatment with higher MC associated with the higher CP treatments.

Equilibrium CO_2 and CH_4 gas concentrations from Trials 2 and 3 are presented in Table 3. The mean CO_2 concentration for pens under the Hi CP treatment in Trial 2 was significantly greater than the other pens, but no treatment effects were found in Trial 3. There was no treatment effect on CH4 in either trial but there was a noticeable difference in concentration between the two trials. Mean CO_2 measured in Trial 3 was about 4,100 ppm vs 2,600 ppm for Trail 2. Methane was approximately doubled in Trail 2 compared to Trial 3, with mean concentrations of about 11 and 4 ppm, respectively.

The relation between equilibrium NH_3 gas, TAN, pH and MC for all diets and trials was explored. A descriptive regression model relating NH_3 and pH (Pooled over all treatments) showed both linear and quadratic coefficients were significant. For TAN regressed against pH, only a linear term was significant. A regression of NH_3 against TAN, pH, and MC were all significant. Pooled over all treatments, this latter regression gave:

$$NH_3 = 2337.02(57.162)+0.0673(0.0083)TAN+49.366(8.75)pH-615.258(125.9)MC \quad (1)$$

With adjusted R2=0.70. The values in parentheses are standard errors of regression coefficients, each was significant at $p<0.0001$. Standard error of prediction ($\sigma_{y|x}$) was 39.4 ppm. United for NH_3 and TAN are ppm; and decimal moisture content. While not applicable for general predictions, this relation demonstrates that, for these data, TAN and pH had a positive correlation with equilibrium NH_3 gas. MC is negatively correlated, in agreement with Ferguson *et al.* (1998a) but in contrast with other work (Ferguson *et al.*, 1998b; Carr *et al.*, 1990). Moisture contents in these trials (16-25%) were much lower than in the previous studies. As an example of relative weights of inputs, for TAN-2,000 ppm, pH=7 and MC=0.20, the predicted equilibrium NH_3 gas concentration = 20 ppm; a 10% increase in TAN, pH and MC results in 54.5 ppm (+173%) and 33.5 (+67%) increases, and 7.7 ppm (-61%) decrease, respectively, in the predicted NH_3 concentration.

Since equilibrium NH_3 gas is obtained *in situ* and at the litter surface, this method is indicative of gaseous concentrations to which birds are exposed. Birds at rest breathe this gas, particularly those birds resting their beaks on the litter while sleeping, and during periods of low ventilation or poor interior air mixing. Concentrations measured from certain treatments in this study are well above OSHA thresholds for human exposure, and exceed the generally recommended guidelines of 30-50 ppm for the broiler industry. Birds challenged by exposure to high levels of ammonia exhibit respiratory distress, and increased incidence of diseases such as ascites. As a bird's health is challenged, it becomes less mobile and more likely to rest with a posture that places its beak near the litter surface and thereby enhancing exposure to litter gasses. Equilibrium NH_3 gas at the surface is rapidly diluted above the boundary layer at the litter surface; however, NH_3 gas concentrations at bird level may approach the values reported here during periods of low ventilation, without noticeable NH_3 at caretaker heights. This is especially true if air velocities near litter surface are sufficiently low for a laminar boundary layer to exist, which is likely the situation even during high ventilation rates because high bird densities prevent substantial convective mixing at litter surface.

CONCLUSIONS

Based on the work reported in this study, we conclude the following:

1. A diet with reduced dietary CP and enhanced essential amino acids can achieve satisfactory bird production performance.

2. After three flocks raised on the same litter, concentrations of equilibrium NH3 gas, litter TAN, pH and MC were significantly greater in pens with birds on a high CP diet.

3. Mean litter pH ranged from 6.9 to 8.78 over the three trials, corresponding to Hi CP and Low CP diet treatments, respectively.

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Table 1. Effect of Dietary Crude Protein on Average Body Weight at Day 42, and Feed Intake and Conversion Efficiency During Grower Phase (Days 18-43)

	Body Weight (g)			Feed Intake (g)			Gain/Feed Ratio		
Protein Treatment	Trial 1	Trial 2	Trial 3	Trial 1	Trial 2	Trial 3	Trial 1	Trial 2	Trial 3
High	2,151^{a}	2,2361	2,018	3,029^{a}	3,028	2,821	0.528^{a}	0.573^{a}	0.561^{a}
Medium-High (M-Hi)	2,160^{a}	2,242^{a}	2,016	3,044^{a}	3,046	2,846	0.527^{ab}	0.573^{a}	0.555^{ab}
Medium-Low (M-Low)	2,053^{b}	2,148^{b}	2,013	2,899^{b}	2,990	2,878	0.517^{b}	0.511^{b}	0.546^{b}
Low	1,942^{c}	2,071^{c}	1,953	2,845^{b}	2,960	2,852	0.490^{c}	0.530^{c}	0.523^{c}
Pooled SEM	18.0	16.0	16.0	28	23	28	0.0033	0.0026	0.0031
P for ANOVA F-test	<0.001	<0.001	NS	0.02	NS	NS	<0.0001	<0.0001	0.0006

^{a,b,c}Means within a column with no common superscript differ significantly (LSD, P<0.05).

Table 2. Effect of Dietary Crude Protein on Mean (Minimum-Maximum) Equilibrium Ammonia Gas Concentration, Litter Total Ammoniacal Nitrogen and Litter pH

	NH_3 (ppm)			TAN^{+} (ppm)		PH		
Protein Treatment	Trial 1^{+}	Trial 2^{1}	Trial 3^{+}	Trial 1	Trial 2	Trial 1	Trial 2	Trial 3
High	129.9^{a} (0-321)	5.5 (0-45)	160.7^{a} (56-296)	2079 (1203-3297)	1616^{a} (1216-2245)	8.24^{a} (8.6-7.7)	7.35^{a} (6.8-8.3)	8.78^{a} (7.7-8.6)
Medium High (M-Hi)	87.5^{b} (2-314)	5.0 (0-36)	57.7^{b} (13-160)	1874 (696-3680)	1502^{ab} (1189-2126)	7.92^{ab} (7.1-8.5)	7.24^{ab} (6.7-8.2)	8.21^{b} (7.1-8.5)
Medium Low (M-Low)	33.3^{bc} (0-124)	0.0 (0-1)	42.4^{bc} (14-91)	1478 (627-2217)	1234^{c} (1015-1518)	7.76^{b} (7.2-8.3)	6.96^{bc} (6.6-7.3)	8.14^{b} (7.3-8.3)
Low	15.2^{c} (1-52)	0.0 (0-0)	15.2^{c} (7-27)	1547 (806-2822)	1282^{bc} (958-1615)	7.42^{c} (7.0-8.1)	6.90^{c} (6.5-7.5)	7.65^{c} (7.0-8.1)
Pooled SEM	22.7	2.7	12.8	206	82.1	0.11	0.11	0.08
P for AVOVA F-test	<0.01	NS	<0.0001	NS	<0.004	<0.0001	<0.05	<0.0001

^{a,b,c}Means within a column with no common superscript differ significantly (LSD, P<0.05).

Table 3. Effect of Dietary Crude Protein on Mean (and Range from Minimum to Maximum) of Equilibrium Methane and Carbon Dioxide Gas Concentration

Protein Treatment	CH^4 Trial 2[1]	CH^4 Trial 3[+]	CO^2 Trial 2[1]	CO^2 Trial 3[+]
	(ppm)		(ppm)	
High	11.2 (6-27)	5.0 (2-12)	3037 (1000-6930)	5139[a] (3340-9290)
Medium High (M-Hi)	11.0 (6-21)	4.0 (0-8)	2516 (1420-4800)	3845[b] (2380-5290)
Medium Low (M-Low)	21.1 (7-17)	3.1 (0-7)	4870 (1040-22620)	3875[b] (2100-5780)
Low	8.9 (5-13)	3.4 (0-10)	2766 (1270-8360)	3550[b] (2210-5180)
Pooled SEM	1.2	0.9	350	707
P for AVOVA F-test	NS	NS	NS	0.004

[a,b]Mean within a column with no common superscript differ significantly (LSD, $P<0.05$)

[+]n=12 pens/treatment.

[1]n=6 pens/treatment: day 2 had negligible readings.

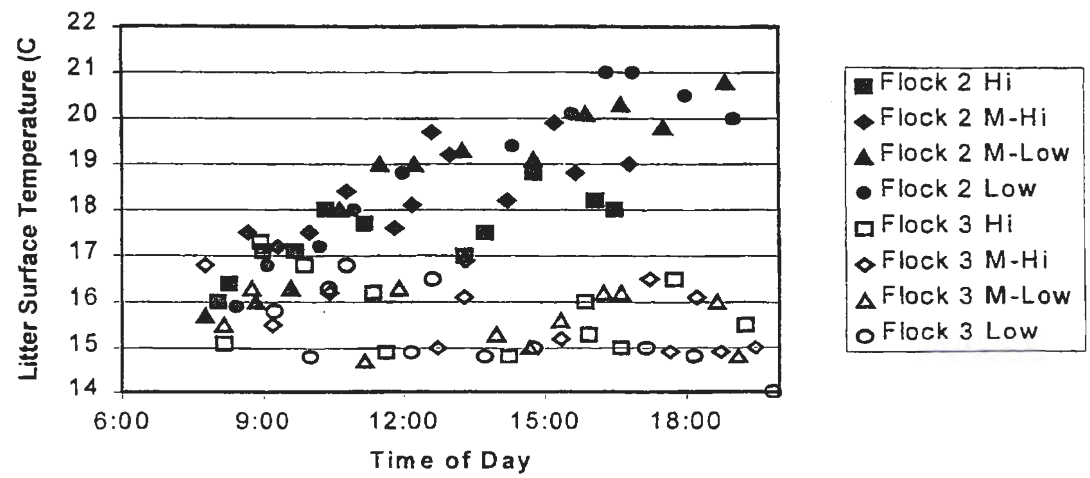

Figure 1. Litter Surface Temperature Obtained from Trials 2 and 3. Trial 2 Data Illustrate Effect of Daytime Heating; Trial 3 Data Taken During Cold Weather.

POTENTIAL NUTRIENTS AVAILABLE FROM MANURE TO PRODUCE ADDED VALUE PRODUCTS

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During the last century there have been numerous changes in the United States. One area of major change is production agriculture. We've gone from many diversified crop and livestock farms to relatively few farms with much of production controlled by a few thousand family farms and corporations. The economic stimuli that led to fewer less diversified farms also encouraged the poultry and swine industries to vertically integrate and to concentrate production.

Animal manures are now more geographically concentrated. The nutrients used to produce our crops are primarily taken from geologic resources. The result is increased nutrients in today's environment.

Innovative ways of converting animal waste into marketable products either directly or through the production systems that utilize the nutrients are needed to geographically balance nutrient availability with nutrient needs. This poster presents a set of maps of the estimated U.S. phosphorus removal by harvested crops and the phosphorus available from animal manures. The maps also show the distance the nutrients must be transported from major supply areas to find offsetting demand for the nutrients. The maps are based on the 1997 Agricultural Census production, the phosphorus content of the crops, and the estimated phosphorus in animal manures by county from confined livestock production systems.

POULTRY WASTE TREATMENT FOR ENERGY AND PERTILIZER PRODUCTION USING THERMOPHILIC ANAEROBIC DIGESTION

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The problem of disposing of poultry waste in large, intensive, rearing-houses coupled with the poultry processing centers provides for a potential opportunity derived from waste pollution. The organic fractions contained in poultry waste provide nutrients and energy for microbes to convert that energy into biogas and the residual solids and liquids into organic fertilizers. The experience gained in operating the West Virginia Department of Agriculture sponsored thermophilic anaerobic digester has promoted the notion that such systems can provide an excellent return on capital expenditure. Coupled with pollution control and nutrient management the rivers of the Eastern Seaboard can be significantly reduced in contained organic as well as inorganic pollutants. It has been shown (Stafford, 1987) that three major requirements are essential for the efficient operation and control of waste management systems. They are: 1) recognition of the fundamental basis for the control; 2) knowledge of the system constraints and limitations; and 3) use of control strategies consistent with requirements 1) and 2). A software package has been developed, which comprises these elements and includes control of multi-function computer interface units, control of the remote site and home-based computers. Such was developed for the digester sites at Moorefield, WV and the details reported, (Kispert, Stafford and Wentworth, 1996).

OPERATIONAL PARAMETERS OF THE THERMOPHILIC ANAEROBIC DIGESTER

The pilot scale thermophilic unit (Figure 1) had a volume of about 10,000 gallons and was fed poultry waste suitably diluted to 10% total solids and at an usual hydraulic retention time of 8-10 says. The digester was operated in automatic mode with full computer control, with mixing and feeding patterns pre-programmed, together with the control parameters, such as biogas yield, methane %, and volatile fatty acid concentrations among others. The digester slurry overflows to a vibrating screen separator, the solids being utilized for fertilizer especially during feeding trials for agricultural crops. A general review of digestion potential as a strategy for poultry waste management will be summarized. Waste input/output operational parameters for the thermophilic anaerobic digester pilot plant will be reported. These include biogas yield (Figure 2), energy production capability, solid and liquid fertilizer production and the associated reduction in pathogen levels.

CROP FERTILIZER TRIALS

The fertilizer value of digester solids are being evaluated in field trials of several vegetable crops, blueberries and a pasture grass mix. The digester solids (digested litter) are being compared to a bridge fertilizer (palletized municipal sludge, harmony products, Inc., Chesapeake, VA); commercial fertilizers formulated for each crop and an untreated control. The effect of fertilizer treatment on blueberry yield is given in Table 1 and Figure 3. Data on corn, tomatoes, kale and turnips will be available at the end of the growing season.

CONCLUSION

The advantages of using digested poultry litter for such applications are: 1) that no offensive odor is produced; 2) ground water run-off pollution is eliminated; 3) the fertilizer characteristics are enhanced with the nitrogen provided as slow release; 4) pathogen levels within the original poultry waste are reduced by up to seven logs; 5) increased land application rates can be tolerated without scorching the crops; and 6) cattle may graze immediately if used for pasture fertilizers.

Table 1. ANOVA of Fertilizer Treatment Effects on Blueberry Yield

Source	DF	SS	MS	F
Fertilizer Treatment	3	41627.41	13875.8	0.70*
Error	18	357597.5	19866.53	
Total (Adjusted)	21	399224.9		
Total	22			

*Term not significant at alpha = 0.05.

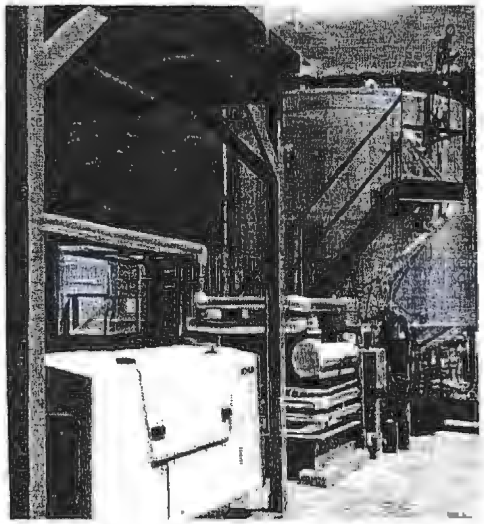

Figure 1. Thermophilic Anaerobic Digester Computer Control.

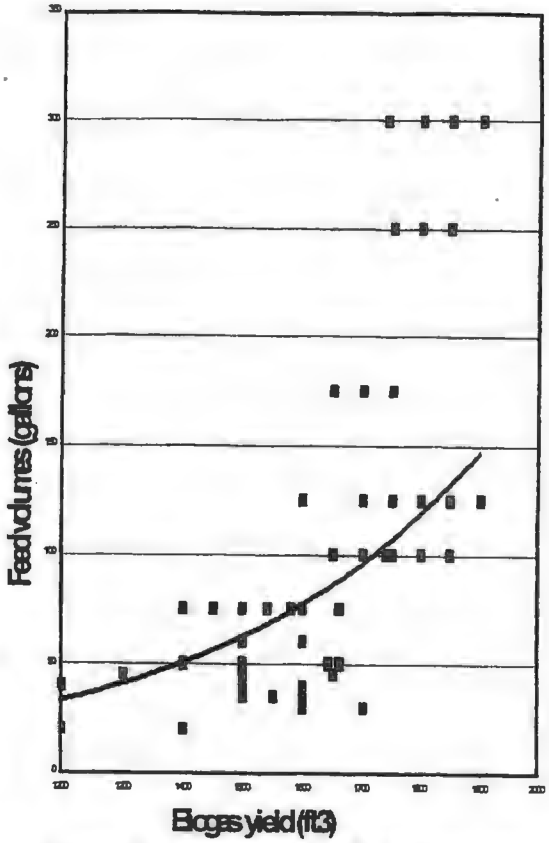

Figure 2. Bogas Yield as a Function of Waste Feed.

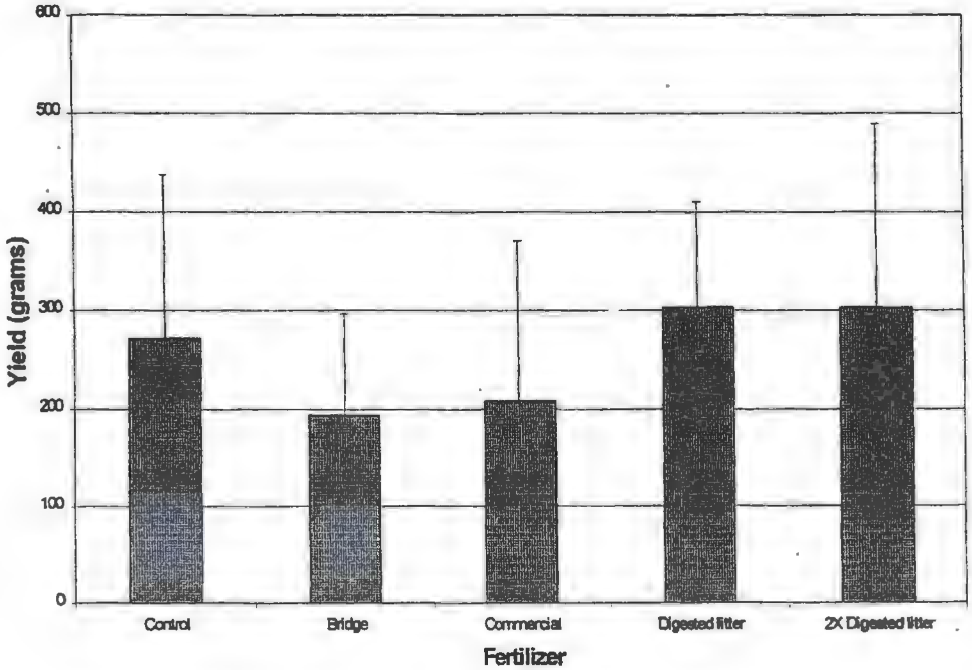

Figure 3. The Effect of Fertilizer Treatments on Blueberry Yield

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