PROCEEDINGS

1998 National Poultry Waste Management Symposium

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

A Decade of Leadership, Innovation, & Cooperation

Casey W. Ritz

Proceedings

1998 NATIONAL POULTRY WASTE MANAGEMENT SYMPOSIUM

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1998 NATIONAL POULTRY WASTE MANAGEMENT SYMPOSIUM

DATES:

October 19 - 21, 1998

Location:

Holiday Inn and Northwest Arkansas Convention Center
Springdale, AR

PREFACE

Early in 1987, an informal meeting was held to discuss poultry waste management and the need to organize a national meeting on the topic. Since this time, five National Symposia have been held in 1988, 1990, 1992, 1994 and 1996. 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 Sixth National symposium and proceedings, the Program Committee hopes to further the understanding of waste management issues and provide some solutions to the betterment of our national environmental resources.

The 1998 Symposium begins with a general session covering topics on the horizon including regulatory implications of the clean air and clean water acts. Concurrent sessions devoted to poultry 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 Program Committee wishes to thank all persons, exhibitors and 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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Acknowledgements

The organization and administration of a successful symposium requires the diligence and cooperation of many individuals and organizations. This symposium is no exception. The 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.

The organizing committee would like to recognize 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

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The 1998 National Poultry Waste Management Symposium is a continuation of the highly successful series started in 1988 by Extension specialists from throughout the United States. the purpose at that time, and today, was to address emerging issues related to the management of poultry by-products from production and processing facilities. The primary audience continues to be decision makers---mid-level or higher corporate managers, and independent and contract farmers---and others interested in effectively addressing environmental protection concerns.

Even though significant progress has been made, some basic issues today are not much different from those in 1988, with some more precisely defined by government agencies (e.g., manure and carcass ownership, environmental justice) or others (toxic dinoflagellates; nutritional alternatives and alternative manure uses; food safety; output based approach to nutrient management; nutrient management plans). Other issues require continued attention. A holistic or systems approach to development and interpretation of regulations would improve credibility for federal and state regulatory agencies and enhance capacity for a team approach with agriculture for the common goal of long term environmental protection.

However, certain situations inhibit this capacity for a holistic approach to preserving our environment. For example, commercial fertilizers are not part of the US EPA purview. Also, the effects of combined sewer overflows (CSO's) or leaking municipal or private septic systems, other sources of raw sewage, or other sources of nutrients entering our waters may not fully be accounted for when defining the influence of nutrients on naturally occurring situations such as the Pfiesteria outbreaks, or the hypoxic area (dead zone) in the Gulf of Mexico. Rather, the media, public and political decision makers are allowed to believe the only or primary cause of the Pfiesteria situation is animal manure. This could be poultry, swine, or perhaps cattle, depending on the State. The hypoxic situation in the Gulf of Mexico is triggered by a microbial response to total nutrients (including commercial fertilizers), and while considered severe and expanding by many experts, neither the siltation nor the potential causes make the evening news. Many people do not realize that while farmers pay for commercial fertilizer, they generally do not have a full spectrum of choices when applying this product. There may be one, or perhaps a few nutrient concentration options for nitrogen, phosphorus and potash (K) that the farmer may purchase. These options may or may not meet the precise phosphorus needs of the crops and thus account for a portion of residual nutrients in the soil or applied manures. This situation is not a fatal flaw in our system, but appears to many to be misrepresented or misunderstood, which can lead to inappropriate beliefs and decisions by the public and policy makers. Decisions that affect our environment and future generations must be made on science and reasonable understanding, not misinformation and politics.

One rarely hears agriculturalists discuss whether we need to address environmental issues. Discussions are of how we will develop programs and cooperate with various agencies to improve the management of environmental situations. Or, there is intense concern about the degree of fairness and consistency of environmental regulations. Farmers try to determine the most appropriate and expedient mechanism to minimize any environmental impact of practices. Economics play a large role in decisions, particularly for small farmers, so the availability of cost share or other assistance programs are very important options.

Even though we probably should refer to the manure, litter, sludge and other by-products of producing and marketing poultry as a resource, and provide a better term than "waste" to describe these materials, the debate over terminology appears to have subsided. Regardless of semantics, it is important to remember we can not treat these by-products of production or processing as waste and something which must be disposed of as cheaply as possible, and possibly with marginal regard for the environment. Properly utilized, poultry residuals have nutrient value as a soil amendment or a feedstuff, and are a necessary results of utilizing animals as a high quality source of nutrients for humans. Only by focusing our efforts on pollution prevention while optimizing the overall returns from waste management, and by maintaining a "good neighbor policy" is it possible to realize the potential of these recyclable nutrients as a valuable resource.

Recycling and obtaining the optimal utilization of inputs (through not wasting wastes) not only can optimize profits, but are environmentally friendly. Good management practices are also an important part of maintaining a good neighbor policy, and help prevent regulatory agencies from having a valid reason to mandate production practices for agriculture.

The goal of the symposium is to provide timely and thought provoking presentations on the latest waste management issues. Previous meetings have included poster presentations, with the author's comments included in the proceedings; commercial exhibits; and an industry tour for the processing and production sections. All registrants receive a copy of the proceedings at the door. These programs were very successful, and are continued this year. We have refocused this year's program to address current and projected requirements of the poultry system. While the special evening sessions extend the day length, significant feedback indicated the need to address the issues of manure and carcass ownership and litter treatment. Mutually beneficial arrangements between integrators and growers are not only possible, they are essential to the maintenance of our animal agricultural system.

The program for 1998 will include presentations in a general session (e.g., toxic dinoflagellates; Electrical generation from residues; food safety; nutrient management issues; establishing new operations; media issues); a production session (e.g., soil health; nutritional alternatives; nitrogen source determination); and a processing session (e.g., commercial egg issues; TMDL; secondary treatment technologies; decantability of DAF sludges; air quality; public policy and regulations; and HACCP).

Because of the tremendous success of including insight from an international speaker in 1994 and 1996, we have decided to continue this popular feature. Dr. J.A.H.H. (Jo) Voet will discuss the MINAS system (Mineral Accounting System) used in the Netherlands. MINAS provides an accurate calculation of the surpluses of nutrients per farm, and thus is their system to define livestock (animal) units. Their government places an emphasis on a scientific approach based on nutrient output to define animal units and related land requirements or waste processing regulations and to define penalties. He will also provide his viewpoints on an overview of the waste management systems in Holland during the last five years---what succeeded and what failed.

The primary purpose of this series of meetings is to address current and projected educational needs 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 2000 meeting, please contact the coordinator or any committee member. Also, if you would like to volunteer as a committee member for future programs, we welcome your participation. We have selected Maryland as the site for the 2000 meeting.

Participants at the symposium have been provided a copy of the proceedings. Additional copies are 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 interest in pollution prevention and environmental management. We hope the next few days will add to your capacity to understand current problem areas, and your ability to address future environmental challenges.

A CITIZEN'S GUIDE TO UNDERSTANDING PFIESTERIA

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Harmful algal blooms (HABs) are of growing national concern due to indications that their frequency and magnitude have been increasing in estuarine and coastal waters of the United States and throughout the world. Cyclic and episodic occurrences of oxygen depletion, HABs, fish kills and illnesses in people (who have eaten seafood or been exposed to toxic blooms) have forced the scientific and management communities to address the complex and poorly understood problem of the effects of land-use practices in coastal watersheds on water quality and living resources in coastal estuarine and marine ecosystems. This fact sheet is intended to provide information about Pfiesteria and similar dinoflagellates and what it may mean for agriculture.

FISH KILLS - 1998

As of September 1, there have been, relative to previous years, only limited reports of fish kills in North Carolina during 1998. In the Lower Neuse River Estuary (below New Bern), there have been confirmed reports of scattered fish kills. Cast netting performed by the North Carolina State University Aquatic Botany Laboratory has indicated that approximately 30% of sampled fish had lesions. Phytoplankton samples indicated levels of presumptive Pfiesteria ranging from 75 - 1,000 cells/milliliter of water. In Maryland, a single episode, lasting two to three days, occurred at the mouth of a creek on the Wicomoco River, resulting in less than 100 dead Menhaden.

FISH KILLS - 1997

The Maryland fish kills of 1997 were far greater in magnitude and frequency and occurred in three locations. There were similarities in each but they could not be called identical.

Pocomoke River: Two fish kills were recorded during August. Regarding the fish kills in early August, on Wednesday Aug. 6, 1997, approximately 10,000 fish were found dead or dying between Shelltown and Pocomoke Sound. These fish had lesions that were typical of those caused by *Pfiesteria piscicida*. On Thursday and Friday (8-7-97 and 8-8-97), kills of nearly 1,000 fish occurred but on Saturday only a few hundred fish died. This decline is also typical of a Pfiesteria 'attack'. A second Pocomoke river closure occurred Aug. 29.

Kings Creek: Sick fish were observed Wednesday August 10 and subsequently, a portion of this a Manokin River tributary was closed. Maryland officials announced that a "Pfiesteria-like microorganism" was preliminarily identified in one of 10 water samples taken Sept. 10 and 11 from Kings Creek.

Chicamacomico River: Sick fish were observed Saturday Sept. 19. Governor Glendening ordered a six-mile stretch of the Chicamacomico closed yesterday afternoon. Parts of the Pocomoke, which was closed Aug. 29, and Kings Creek which was closed Wednesday September 10, remained off limits to fishing, swimming, and pleasure boating until the end of September 1997.

The closed portion of the Chicamacomico is about 20 miles northwest of Kings Creek and about 35 miles northwest of stricken parts of the Pocomoke. In Maryland, officials close waterways that contain 20 percent or more fish with lesions because of the potential health threats to humans.

THE NATURE OF PFIESTERIA

What is Pfiesteria piscicida? Pfiesteria is a microbe, called a dinoflagellate, that has been found in North Carolina, Florida, Delaware, and Maryland. A dinoflagellate is neither a plant or an animal, although they may sometimes appear like one or the other (Pfiesteria is as predatory as any animal, but it can also phosynthesize like a plant after dining on algae). Pfiesteria was named in honor of the late Dr. Lois Pfiester, who contributed much of what we know today about the complex life cycles of dinoflagellates.

Is it in other East Coast states? Maybe. It is very difficult to identify this microbe so, if a catastrophe doesn't occur, no one has a reason to look very hard. Many dinoflagellate species can be identified with a light microscope fairly readily. Unfortunately some of the smallest species (less than 20 microns in length, including Pfiesteria), are difficult to recognize and enumerate by this method. [Twenty microns is about eight ten-thousandths of an inch.]

In addition to problems of identification, the challenge of understanding the environmental factors that control the growth, distribution and toxicity of Pfiesteria is made all the more difficult by the organism's life cycle and by its multiple modes of nutrition.

<u>Origins of Pfiesteria</u>. Where did this thing come from? Evidence is lacking. We have no evidence to indicate that this is an exotic invasive species. We have scant evidence that a dinoflagellate that was probably Pfiesteria was found in the Bay in 1972. A scientific panel evaluated this and other evidence and indicated that "It and other Pfiesteria-like organisms ... are probably indigenous." There is mounting evidence that there is more than one species of organism active during a Pfiesteria kill and we are now beginning to talk of Pfiesteria-like organisms or Pfiesteria-complex organisms.

<u>Red Tide?</u> Is this related to a 'red tide' or a 'brown tide'? Not exactly. Red tides and brown tides are dinoflagellates also. However, they are toxic in concentrations of several thousand organisms per milliliter of water, whereas Pfiesteria is toxic at approximately 200-300 organisms per milliliter of water. The red tide organisms have an endotoxin that acts on ingestion or respiration. Pfiesteria gives off one or more exotoxins into the water column. Pfiesteria is a microbe that exhibits some plant-like characteristics but, in fact, feeds on algae during part of its life cycle.

<u>Pfiesteria Life Cycle Stages</u>. Why do we care about the life cycles of a microscopic creature? There is a certain amazement about something that has more than 20 different forms. After all, humans have only one form that just grows larger and insects may go through no more than three or four forms. But the forms that Pfiesteria goes through have more than academic importance. Some forms feed on algae. Some forms are stimulated by inorganic phosphorus. These functions, which relate to nutrients, are one of the links to land-based activities.

Pfiesteria has a complex life cycle that includes at least 24 flagellated, amoeboid, and encysted stages or forms. These stages include benthic (bottom dwelling) and pelagic (in the water column) stages, vegetative and cyst stages, and flagellated and amoeboid stages. Both the flagellated and amoeboid forms are known to be toxic to fish. The size range of these stages extends from 5 to 450 microns.

Amoeboid stages can be found in the water column as well as among the bottom sediments. They feed on other organisms (bacteria, algae, small animals) or on bits of fish tissues by engulfing their prey. The nontoxic benthic amoeboid stage is apparently the predominant form under most circumstances.

Flagellated stages (vegetative or asexual cells, sexual cells or gametes, and motile sexual products or planozygotes) can also engulf similar prey, but more often they feed, instead, by attaching to prey cells using a cellular extension called a peduncle and suctioning the prey contents. Some flagellated stages are capable of kleptochloroplastidy (adoption of algal and/or plant-like nutrition by retaining the chloroplasts that obtained from algal prey). Nontoxic stages are reported to have mixotrophic (utilize both organic and inorganic food sources) capabilities.

The cyst (dormant) stages include a variety of outer coverings, range in size from 7 to 60 microns, and do not forage for food (and may not feed at all). The cysts form when conditions are poor for the organism, whether that means unfavorable temperatures, salinity, or other ambient conditions. The cyst, commonly occurring in the bottom sediments, is relatively protected and simply waits for conditions to improve.

A simplified summary of the biological jargon is that Pfiesteria consumes organic matter, can steal a part of algae and use it to get energy from light, changes forms rapidly, and sometimes lives in the water and sometimes in the sediment. The majority of the life stages are as algae-consuming dinoflagellates in the water column. There are three or four stages where the microbe becomes a hazard to fish.

<u>Toxic Pfiesteria</u>. What makes Pfiesteria suddenly become a fish killer? "Suddenly" is a key description. Studies leave little doubt of a direct correlation between outbreaks and some sudden kills of certain fish species in the field. Fish kills caused by Pfiesteria usually occur in the warmest part of the year, and often precede low dissolved oxygen levels in the estuaries.

Pfiesteria often makes its living as a nontoxic predatory animal, becoming toxic when it detects enough of some substance that live fish excrete or secrete into the surrounding water. When fish (e.g., a large school of oily fish such as Atlantic menhaden) swim into an area and linger, their excreta triggers encysted cells to emerge and become toxic. Active amoeboid and flagellated cells which are present also become toxic in the presence of the fish excreta. The small cells swim toward the fish prey and excrete toxins into the water which make the fish lethargic so that they tend to remain in the area.

The toxins also injure the fish skin. As the skin is destroyed, open bleeding sores and hemorrhaging often occur, which results in the, by now, easily recognized lesions. Once fish are incapacitated, Pfiesteria feeds on the sloughed epidermal tissue, blood, and other substances that leak from the sores. When the fish are dead, flagellated stages transform to amoeboid stages and feed on the fish remains or, alternatively, if conditions become unfavorable (e.g., sudden storm), Pfiesteria cells make protective outer coverings and sink out of the water column as dormant cyst stages. All of these changes can take place in a matter of hours. These fish kills can be lethal for undefined periods as long as schooling fish remain in the vicinity.

The kill on the Pocomoke effected a school of menhaden; an oily fish that travels in densely packed schools. Most of the fish killed in North Carolina and the Pocomoke were menhaden. It may be more than coincidental that menhaden, the primary species observed in fish kills, is the only affected species that filter feeds on and ingests phytoplankton and is also afflicted with lesions that frequently appear near the anus. The location of these lesions might reflect localized responses to the discharges of the toxic remains of ingested Pfiesteria cells.

However, any fish in the area will be affected. Thus, rockfish, bluefish, croaker, spot and gray trout were also killed. The lesions due to Pfiesteria are bloody ulcers that eat out the flesh and create a hole. The most common location for lesions on menhaden is near the anal opening, but lesions can occur elsewhere. Lesions due to other causes may be raised, appear as abrasions, or be wart-like.

Dramatic kills occur when Pfiesteria concentrations are above approximately 250 cells per milliliter. This is referred to as a lethal level and is typified by the Aug. 6 kill. At counts of 100 to 250 cells per ml, lesions may occur but the fish may not be killed outright (eventually, fish with holes in them will die). This is called a sub-lethal level and is probably what occurred in the Rappahannock and Chicamacomico.

<u>Nutrient Effects</u>. Researchers at NC State focus on the nutritional ecology of Pfiesteria and have demonstrated a strong positive correlation between Pfiesteria populations and algal biomass and inorganic phosphorus levels, which means that as levels of algae and phosphorus increase, Pfiesteria

populations increase. Furthermore, Pfiesteria are highly stimulated by both inorganic and organic N and P enrichments. The stimulation can occur either directly or indirectly (mediated, for example, by the abundance of algal prey that Pfiesteria consumes when fish are not available).

In the absence of fish, transformations among the various stages of Pfiesteria appear to be influenced by the availability of microbial prey, which constitute organic nutrients. Thus, the effects of nutrient enrichment on Pfiesteria are complex because it is not directly stimulated by inputs of inorganic nutrients, but it feeds on creatures that are stimulated by inorganic nutrients. In other words, the effects of nutrient enrichment in nature are mediated by the responses of prey species. There appeared to be a threshold P level of .1 mg/l. Monitoring data at Pocomoke City show P levels of 0.11 to 0.18 mg/l. It is unclear whether low (chronic) levels of toxin(s) are produced more or less continuously or just under the influence of the presence of (high) densities of fish.

<u>Optimum Environmental Conditions</u>. Optimum environmental conditions for Pfiesteria growth (with the exception of the presence of fish) are also conditions that promote the growth of a broad range of microbial species, most of which are non-toxic. The question of what specific environmental factors or cues may trigger the development of toxic stages of Pfiesteria is still under investigation.

In the field, development of toxic stages of Pfiesteria has been reported to occur in the presence of fish schools in nutrient rich, calm, shallow and poorly flushed estuarine environments over a temperature range of 55°F to 90°F (12-33°C). At warmer temperatures, flagellated forms predominates and at lower temperatures an amoeboid stage predominates.

Aquarium studies have identified several water conditions necessary for the "dinoflagellate bloom." The optimum water conditions are:

*Approximately 15 parts per thousand salinity,
*High in nitrogen,
*High (greater than 0.1 part per million) in phosphorous,
*Approximately 25C (77F), and
*High concentrations of fish biomass.

This does not mean that, under other conditions, the microbes won't survive. These are just the optimal conditions and these conditions are where a fish kill is most likely. When these conditions are met, the microbe can exit the sediment, cause a fish kill, pass through an ameobic stage as it settles to the bottom, and return to a cyst stage in matter of one to four days. This means that there may be no evidence of Pfiesteria in the water column once all the fish have died, in other words, when we humans finally notice. Samples taken in the Pocomoke during active kills indicate Pfiesteria was present.

HUMAN HEALTH

In a North Carolina laboratory, the neurotoxin was responsible for some adverse neurological symptoms and short-term memory loss in two lab workers. Here, it was discovered that the neurotoxin could become an aerosol and, hence, influence human health.

Researchers at Duke University Medical Center (1996) have found that a toxic one-celled organism common to North Carolina's estuaries causes serious learning and memory impairment in rats. For two months after toxin injection, the rats had a learning deficit, but other behaviors did not appear to be affected. The researchers indicate that this is the first step toward determining if there is a similar effect in humans.

On the Pocomoke, several people have claimed an assortment of medical problems, including lesions. A team of medical experts has studied these individuals. Some of these individuals had impacted brain function that was documented by PET scans. However, since the toxin has not been identified, diagnosis is very difficult. While this research continues, the state has closed sections of the Pocomoke, Kings Creek (Manokin tributary),and the Chicamacomico River.

After examining 28 people who developed ailments from possible exposure to Pfiesteria, medical researchers found the most consistent problems to be difficulties with memory and learning, said Dr. Glenn Morris, head of the medical team. However, method of entry to the body is unknown, concentrations cannot be discussed because the toxin is unknown, and how the toxin(s) cause the neurological problems is unknown.

The effects of Pfiesteria and their toxins on human health are unclear. There are reports that Pfiesteria produces an airborne toxin(s) that causes symptoms such as short-term memory loss, and that contact with water where Pfiesteria or fishkills have occurred, can result in the development of skin lesions.

The July/August 1998 issue of the North Carolina Medical Journal contained an article by two NC Dept. of Health and Human Services scientists reporting no conclusive evidence of negative health effects from exposure to Pfiesteria. A report due to be published soon in The Lancet on MD studies reaches an opposite conclusion. [Assoc Press]

SEAFOOD CONSUMPTION

The evidence concerning the safety of Maryland seafood is actually a lack of evidence. Dr. Donald E. Schmechel of Duke University said that it is suspected that people probably can't get sick from eating fish that have survived or shellfish nearby. Otherwise, "our impression is that there should be a lot more people ill," said Trish Perl, an infectious disease specialist at the Johns Hopkins School of Medicine.

From North Carolina officials indicated that no cases of seafood poisoning have been reported from eating fish exposed to Pfiesteria. Nor has there been evidence of tainted shellfish, oysters or crabs on the market.

According to preliminary findings of a research study at Duke University, "no information is currently available regarding the consumer health risks due to incidental exposure of fish or shellfish harvested in close proximity to fish kills."

In a report to the Maryland Department of Health and Mental Hygiene, a six-member team of doctors said that there is no evidence to suggest that people could become ill by eating seafood.

Governor Glendening continues to emphasize that "Maryland seafood remains safe."

Although there is no evidence that Pfiesteria affects human health through the ingestion of seafood products, this possibility cannot be ruled out based on the information available.

Because of the uncertainty, the State of Maryland recommends a common sense approach: consumers should never eat fish that exhibit evidence of sores or disease. Do not eat fish that seem diseased or dying when caught. Consumers should completely cook finfish and crabs. Normal precautions should be taken when eating raw shellfish.

INSIGHT ON THE WORKING OF THE POULTRY INDUSTRY

The farmer raises chickens and gets paid by the integrator based on the percentage of the chicks successfully brought to market and the quality of the product. The integrator owns the chicks, provides the feed and medicine, and transports the chickens (as chicks, to the farmer and as marketable chickens to the processing plant). Additionally, the integrator may aid in financing the chicken houses. The farmer owns the dead chickens that don't make it to market and the manure. Previously, the manure was viewed solely as a benefit because of the fertilizer value. Most poultry farmers have been responsible in storing and then using chicken waste produced each year as fertilizer.

The State of Maryland has been extremely proactive in using Nutrient Management to minimize pollution from agricultural operations that incorporate animal waste in their fertility program. MDA indicates that over 50% of the poultry farms on the Lower Shore utilize these plans.

Farmers voluntarily follow these nutrient management plans, which analyze the needs of their soil and crops, fertilizing their fields with chicken manure in carefully calibrated amounts, and storing the rest under sheds to prevent runoff. Agricultural experts credit these plans with reducing applications of fertilizer. Farmers also may apply for state funding for sheds that shield chicken manure from the rain, preventing the waste from being washed into waterways.

Without knowing the cause of the Pfiesteria problem, farmers fear, state officials may impose costly regulations on them without getting the results they seek.

"Agriculture's taken the brunt of the finger-pointing," said Lambertson, who chairs a local bank board and tends 2,300 acres and 42,000 chickens. "We're saying there may be other parts of the problem. You've got to look at the whole package." Some expressed fear for their livelihood. "Are we going to be regulated to the point we can't produce chickens?" asked Lambertson. "How aggressive is it going to be?"

Ultimately, farmers fear that poultry companies will move their operations to other states with less stringent regulations unless the problem is addressed on a National basis.

THE NON-FARMER VIEWPOINT

A summit was held in Raleigh, NC in December of 1997 to evaluate Pfiesteria research needs and management actions. The resulting "Raleigh Report" provided a fairly balanced view of the problem in North Carolina. A similar meeting was held in Maryland earlier (Oct. 16, 1997) and was reported as the Cambridge Consensus. The conditions and conclusions are not greatly different between Maryland and North Carolina. It was concluded that decreases in nutrient loading (both organic and inorganic forms of nitrogen and phosphorus) will reduce eutrophication and, thereby, lower the risk of toxic outbreaks of Pfiesteria-like dinoflagellates, hypoxia, and fishkills. However, sufficient scientific information does not exist at present to quantitatively determine causal relationships, with confidence, between specific nutrient sources and rates of nutrient inputs (that can be attributed to particular land-use practices) and the occurrence of toxic events attributed to Pfiesteria.

Given current levels of understanding, attempts to manage nutrient loading should be considered for all major sources of both organic and inorganic forms of nitrogen and phosphorus. These include: (i) deforestation (releases stored nutrients and reduces nutrient retention efficiency), (ii) human wastes, (iii) artificial fertilizers, (iv) the storage of animal wastes and their use as fertilizer, (v) urbanization, and (vi) atmospheric deposition.

More immoderate opinions have also been promoted: "The problem has been clear to many who say Pfiesteria is killing fish and sickening people in the Pocomoke River. Control pollution in the river -- which comes mainly from agriculture -- and you might control the microbe, many environmentalists contend". Governor Glendening said some farming practices that are now voluntary likely would become mandatory and a commission he appointed, headed by former governor Harry Hughes, developed recommendations supporting such measures. The Water Quality Improvement Act of 1998 has, in part, borne out his predictions.

IMPLICATIONS FOR AGRICULTURE

What, if any, is the connection to agriculture? At this point, the evidence becomes less clear. Because of the unusually wet conditions of 1996 (and the previous two years), in 1997, the Pocomoke River had both lower salinity and lower pH, making it difficult to separate natural and human-induced effects. According to the scientific panel convened at Salisbury State to evaluate the Pfiesteria question, "Although there is, at this time, no demonstrable cause and effect linkage, nonpoint source inputs from agriculture activities could be implicated." The facts that prompted the panel to make this statement are:

1. High nitrogen and phosphorous are a necessary condition for exponentially expanding dinoflagellate development.

2. These conditions are found in the Pocomoke River.

3. Pfiesteria seems to respond particularly well to aquatic phosphorus levels, which are present in the river and soil test phosphorus is very high in the region.

4. There is recent scientific evidence which indicates that high land-based phosphorous levels result in increased dissolved phosphorous in water.

The prevailing theory is that nutrients enter the water throughout the watershed from nonpoint sources. The Pocomoke is a "black water" river which means the water, much of which passes through swamps, is laden with a dark stain from tree and leaf decay. This dark stain inhibits light from penetrating the water very far. Hence, algae cannot utilize the nutrients very well, due to lack of light. Furthermore, the Pocomoke flows fairly deep and rapidly. This makes the river system a good collector of nutrients, but keeps algae from utilizing the nutrients. As the river approaches the Pocomoke Sound, the water flow spreads out much wider, which slows the flow down. Tidal water moves up into the river and the Sound itself is not as deep as the river. The increased salinity helps to settle out solids, which improves light transmission, allowing more algae activity. The shallow, slow moving water allows more light transmission, again allowing more algae activity. The tidal inflow is clearer water which also allows more algae activity. Therefore, the Pocomoke Sound is the place where algae can utilize the nutrients that have been collected throughout the entire Pocomoke river system. Because Pfiesteria feed on algae most of the time, Pfiesteria are in the Sound in large numbers, utilizing the algae. When schools of Menhaden migrate up the Pocomoke to spawn, the opportunistic Pfiesteria become toxic to feed on this new source of food. The result is a visible fish kill.

Research, has documented a linkage between Pfiesteria and both human sewage and swine effluent spills. Joanne Burkholder's work has linked North Carolina's Pfiesteria problems to high levels of nutrients, especially phosphorus, in the water. An article in the Sunday, Aug. 10,1997 Baltimore Sun names poultry 'manure' as the suspect for the fish kill. Numerous subsequent articles have made similar connections. While this is totally undocumented, the strong relationship between Pfiesteria and phosphorus and the large amount of organic waste in the lower Eastern Shore region will continue to make agriculture the "principal focus" of the state study as recommended by the scientific summit in Cambridge during October of 1997. The point that must be reinforced is that the relationships are based on nutrients, not on the animal source of the nutrients. There is nothing unique about poultry manure. It is simply the prime suspect for nutrients in the Pocomoke watershed. In another watershed, a sewage treatment plant or urban dwellers could be the leading nutrient generator and hence the prime suspect. So far, we don't know just what factors are most important in triggering Pfiesteria outbreaks. It is easy for concerned people to link Pfiesteria to their favorite environmental villain (hog farms, golf courses, sewage, septic fields, etc.). No doubt each of them is involved in one way or another. But there are yet no data allowing us to apportion responsibility.

There is some circumstantial evidence that agricultural nutrients are responsible for a significant portion of the nonpoint source nutrient loads. The 1990 census indicated that there were 16,698 people living in the Pocomoke watershed. Allowing for a growth rate of 2.5%, the 1998 population is an estimated 20,345. An average waste generation of 1.5 lbs/day results in human generated manure load of approximately 11,140,000 lbs. The 115 million chickens produced in the watershed each year produce approximately 0.42 lbs of waste/lbs of body weight. The average bird weight in 1996 was 4.7 lbs which yields 227,000,000 lbs of manure per year. Poultry produces approximately 20 times the waste that human population produces. Approximately 42% of the human waste is put through a sewage treatment plant which removes a significant portion of the nutrients. Approximately 57% of the population are on septic systems which remove phosphorus but do not treat nitrogen well. It is safe to assume that the human nutrient load is somewhat reduced. The poultry waste is land applied. This too reduces the nutrient load. Hence the assumption is that land application does not perform more than 20 times better than waste treatment systems and so the poultry industry contribution to nonpoint source pollution is significant.

Unlike North Carolina, where major rivers have become increasingly polluted by the rapid and widespread expansion of hog farms in recent years, nutrient levels in Bay tributaries are generally steady or improving. This may explain why fish kills of 400,000 to 500,000 fish that North Carolina has been experiencing has not occurred here in Maryland. However, there is an alternative explanation. It is possible that the Chesapeake is near the Northern-most edge of their climate range and the environment is such that Pfiesteria will not really proliferate in the Bay. At this point, we are out of scientific evidence to determine, more accurately, cause and effect links. We are also short on scientifically based answers to the question: What should we do?

MARYLAND AND NORTH CAROLINA RESPONSES

Whereas Tar Heel officials organized a fish fry in 1995 to demonstrate that the Neuse's seafood was safe, Maryland shut down fishing, boating and swimming on a five-mile stretch of the Pocomoke and enforced the ban with armed patrols. Maryland organized the state's best doctors to examine watermen and convened a summit of 60 top scientists to discuss the river's condition. And unlike their counterparts in North Carolina, Maryland officials have actively enlisted the help of JoAnn Burkholder, an N.C. State University aquatic botanist who helped discover Pfiesteria.

"The state of Maryland has just been light-years more proactive," Burkholder said. "I got involved because I found it a refreshing change from my own state."

DEVELOPMENT OF MARYLAND'S PLAN

On September 11, 1997, as part of a broadening plan to deal with the problem, the governor appointed 11 people to a commission that was chaired by former governor Harry R. Hughes. The commission includes representatives from the General Assembly, local governments, agricultural, and environmental fields.

Subsequently (Feb., 1998), three major bills and two more minor bills were introduced. The major topics in the bills were: Nutrient Management Plan Requirements, Technical and Financial Assistance, Penalties, Regulation Development, New Certification programs, and new Waste Management Technology incentives and funding.

The Maryland General Assembly passed the Water Quality Improvement Act (WQIA) of 1998 during the closing hours of the 1998 session. All agricultural operations with annual incomes greater than $2,500 or more than eight animal units (one animal unit equals 1,000 pounds live weight) must have and implement a nitrogen and phosphorus-based nutrient management plan by a prescribed date. This legislation applies to all traditional farms, not just poultry or livestock. It would also appear to apply to vegetable growers, organic producers, nurseries, green houses, turf grass producers, certain horse farms and any other agricultural operation. Anyone who applies nutrients to property of three or more acres for non-agricultural purposes (lawns, gardens, beds, etc.) or to any state property must do so in a manner consistent with the recommendations of the University of Maryland, Cooperative Extension Service.

There will be a difficult adjustment period as farmers come to terms with both mandatory plans and the change to phosphorus-based management at the same time.

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NUTRIENT MANAGEMENT AND NUTRIENT DISTRIBUTION AS AFFECTED BY SOIL TYPE AND MANURE CONTENT

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Land application of animal manures for the benefit of agricultural production has been practiced for thousands of years. In the last decade, efforts to control agricultural non-point source pollution have focused on the concept of nutrient management planning (NMP). Nutrient management planning seeks to maximize agricultural production while minimizing the environmental impact of agriculture, especially the animal production sector, by accounting for the nutrients excreted in animal manure. As our understanding of the nutrient content of manures and their interaction with the environment has grown, NMPs have become more complex. Early efforts at nutrient management focused mainly on the type of crop grown with little importance placed on landscape or soil type. Soil properties as well as manure chemistry must be considered when soil type and nutrient distribution are included in nutrient management plans.

NUTRIENT MANAGEMENT

Efforts to encourage farmers to manage animal waste as a valuable fertilizer began in the 1980's with the development of farm scale nutrient balances by researchers in Florida and Pennsylvania. Out of these efforts, nutrient management programs at both the state and national levels have developed. The driving forces behind the development of these programs were the water quality problems in the Chesapeake Bay and other water resources.

N Based Nutrient Management

The early focus of nutrient management was to limit manure applications to the N need of the crop grown. Early NMPs were simple educational tools that directed the farmer to apply certain amounts of manure to certain crops. The N requirement for most agricultural crops is well established, which makes it easy to base manure application rates on N content for a "typical" yield. The problem with this approach is that actual yields will vary widely from field to field and farm to farm. This variability is principally due to differences in soil properties. Nitrogen based nutrient management has proven effective at reducing nitrogen losses to the environment (Bishop, 1994), but plans that only consider N may lead to environmental problems associated with other nutrients, salts, and heavy metals.

P-Based Nutrient Management

With wide spread adoption of erosion control practices, such as conservation tillage and cover cropping, movement of particulate bound P to surface waters has been greatly reduced. Recent research has shown; however, that levels of soluble phosphorus in runoff waters may actually be increased (Robinson and Sharpley, 1996; Sharpley, 1995; Mozaffari and Sims, 1994b; and Heathman *et al.*, 1995). These researchers, and others, report that soils with long histories of manure application tend to release more dissolved P than similar soils that have received only inorganic P fertilizers. The increase in soluble P is believed to result from the overloading of the P adsorption capacity of these soils.

Soil phosphorus is present in many forms including dissolved P, organic P, absorbed P, and occluded ("fixed") P. The capacity of a soil to adsorb and then "fix" P is related to the soil's Al, Fe, and Ca constituents. The insoluble compounds (particulates) to which P is adsorbed are the sources of the water pollution associated with erosion and transport of soil particles to surface waters.

Soluble P levels increase when the capacity of a soil to fix P has been exceeded through excessive application of P (Eghball *et al.*, 1996). When manures are applied in conjunction with soil conservation practices, soluble P losses may increase. This results from the build up of P in the surface layer of fields that are never plowed or are in permanent hay/pasture systems. This situation is problematic when manure is applied at rates calculated to meet N needs. Poultry manure typically contains similar quantities of N and P, but manure rates that supply sufficient N will overapply P because plants need much more N than P.

There has been, in recent years, increasing interest in basing nutrient management recommendations on the nutrient most limiting (N or P) rather than only on N. One of the driving forces behind this movement is the increasing number of large-scale fish kills in waters along the Mid-Atlantic Coast. A new organism, *Pfiesteria piscicida*, has been identified as the cause of many of the fish kills. Nutrient enrichment is believed play a role in activating Pfiesteria's lethal behavior (Burkholder *et al.*, 1995). In response to this, the State of Maryland has passed the "1998 Water Quality Improvement Act" which requires that all farmers with more than eight animal units adopt a P based NMP by the end of the year 2005.

Phosphorus-based nutrient management will require that land application of animal manures be limited by either crop P removal or soil P limits. Manure application rates will decrease by approximately 2/3 under crop removal limitations, and may not be allowed at all if limited by soil P concentration. In a recent study of dairy and dairy/poultry farms in Rockingham County, Virginia, Pease *et al* (1998) concluded that net farm income would increase by 5 to 10 percent with N-based NMP and decease by up to 40 percent with P-based NMP.

In addition to questions about the economic viability of P-based NMP, there are technical questions about the scientific basis of P-based NMPs. A complex relationship between soils, climate, and management controls the loss of P from agricultural operations. Traditional soil P tests may not be suitable tools for predicting P losses. Sharpley and Smith (1995) reported an increase in the Ca-P fractions of soils receiving heavy, prolonged manure applications. The dissociation of these insoluble Ca-P compounds by standard acid extractants may overestimate both the plant available P and the potential for P release in runoff. The University of Delaware has developed a "P indexing" system that quantifies eight site characteristics to calculate the risk potential for P loss (Sims, 1997). This "site index" can be used to develop P fertilization plans. Development of similar indices will likely be necessary in other states that are considering P-based NMP.

Site Specific Nutrient Management

Nutrient management programs around the country have begun to develop site specific NMPs in response to increased pressure from both the federal government and regional initiatives, such as the Chesapeake Bay Agreement. Site specific plans take into account all the factors that vary from field to field and the effect these factors have on crop yield and nutrient utilization. Soil maps, topographic maps, soil tests, and manure tests, in addition to the usual manure production estimates, are typically included in a site specific NMP. The inclusion of information from the site helps the planner develop reasonable crop yield goals. Manure nutrients can be distributed to the fields that can best utilize them when manure contents and soil test levels are known. Through the analysis of the detailed information obtained for a site specific NMP, limiting manure constituents other than N may be identified. However, the planner must be aware that standard soil tests may not be suitable for determining when other limitations are warranted.

One of the key elements in site specific NMP is yield estimation. Estimating yield accurately is difficult, and some early NMPs were written based on a "standard" yield estimate for each crop. Because this does not allow for variability from field to field due to soil differences, some states have tried to develop yield estimates that can be matched to individual soils.

Virginia has developed a yield estimation system called VALUES (Virginia Agronomic Land Use Evaluation System, Simpson *et al.*, 1993). The VALUES provides soil series specific yield estimates for most of the agronomic crops grown in Virginia. VALUES estimates are based on both actual and extrapolated soil series specific yield data collected over a twenty-year period.

SALTS AND HEAVY METALS

The accumulation of salts and heavy metals from land applied municipal and industrial sludges, and their effect on plant production, are well documented (e.g., Valmis *et al.*, 1985; Roca and Pomares, 1991), but few researchers have studied the bioavailability of heavy metals or salt effects from poultry manure application.

Salts

The plant-available forms of essential nutrients are salts, but plant growth can be inhibited, and even halted at high salt concentrations. Poultry litter can contain high concentrations of soluble salts, and heavy application rates can lead to growth-inhibiting levels of salinity (Shortall and Leibhardt, 1975). Hileman (1971) reported that high salinity and NH_3 concentrations caused by poultry litter application were the causes of toxicity and yield reduction in corn forage. Few other researchers have investigated the potential for damage to agronomic crops from salts in poultry litter. Salts from heavy applications of poultry litter caused the death of both collard and cabbage seedlings (Lu and Edwards, 1994).

Little research on the effect of salts in poultry litter on agricultural crops has been published because most poultry production in the United States is concentrated in the humid eastern and southern states where abundant rainfall rapidly lesches salts from the rooting zone. Salt build up in western soils with a history of litter application could be a problem. Perhaps the idea of salts-based NM may be appropriate in field with salinity problems.

Heavy Metals

The potential beneficial use of poultry manure as a fertilizer and the potential water quality problems associated with over application have fostered extensive research. This research has concentrated on the N and P contents of poultry manure, but some research has shown that heavy metals may also pose a problem. Mitchell *et al.* (1992) reported that fields in Alabama with a long history of poultry manure application had toxic levels of Cu and Zn.

Watt *et al.* (1994) investigated the bioavailability and uptake of heavy metals from poultry litter by Sudax (*Sorghum bicolor L.*) grown in pure quartz sand, Cecil (clayey, kaolinitic, thermic Typic Kanhapludult) and Lakeland (thermic, coated Typic quartsipsamment) soils. Sudax grown in the Cecil soil accumulated toxic amounts of Mn, which may have been due to reducing conditions in the clayey Cecil soil. No other deleterious accumulations of heavy metals were observed. However, an analysis of several Georgia "field" soils in this study demonstrated high levels of Cu,Mn, and Zn. The authors concluded that possible soil contamination by heavy metals from poultry litter requires monitoring.

Heavy metal concentrations in poultry litter can vary considerably, making if difficult to draw generalized conclusions from the available research. For example, researchers have reported Cu concentrations of <100 mg/km (El-Sabban *et al.*, 1969; Blair, 1974; Warman, 1986), 100 to 500 mg/kg (Long *et al.*, 1969; Kunkle *et al.*, 1981), and greater than 500 mg/kg (Mitchell and Brown, 1992). Concentrations of other metals (Zn, Mn, Al, and Fe) showed similar variations. These variations are likely due to differences in feed formulations and pest control practices.

Although there are no current regulations directed at heavy metals in animal manure, the current push to develop site specific NMPs may bring more attention to this issue. Soil and manure testing required by site specific NMPs can provide a vast pool of information on the heavy metal content of soils and manure. These data can be used to monitor metal concentrations of soils subjected to manure application. The complex relationship between metals in manure and their availability to crops is not well understood and should be the subject of further research.

SUMMARY

The concept of nutrient management is continually evolving, from its beginnings in efforts to encourage farmers to account for the nutrients in manure to the field by field management plans of today. The effect of animal agriculture on the environment is under scrutiny from government agencies and environmental groups. Regulations have been recommended that will require mandatory NMPs. Some of these plans will be based on manure constituents other than N. With is in mind, the scientific community must develop systems that will help agricultural producers comply with new regulations and maintain profitability.

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A NEW SYSTEM FOR MINERALS ACCOUNTING IN THE NETHERLANDS AND THE EFFECTS OF IT ON THE NATIONAL SURPLUSES

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On 1 January 1998 will come into effect new regulations about manure policy in the Netherlands. The so-called MINAS, Minerals Accounting System, is aimed at farms posing the highest risk to the environment. Minerals accounting makes farms with high stocking densities account for their mineral management. Why did the Dutch government come to such a system?

HISTORY

Dutch agriculture has developed into one of the world's leading industries. Contributing factors have been the extensive know-how of farms and growers resulting from research, extension and education, the high and constant quality of Dutch produce. There is however, a drawback to the development of production became the cultivation techniques, the manure surpluses and the vast amounts of pesticides used in conventional farming affect the quality of soil, water and air. Table 1 shows the estimated national surpluses of Phosphate in Holland.

Because of excessive animal manure production and application, the Dutch government tries to tackle the nutrient problem by a phased approach. This approach is a three-phase approach that started in 1986. The phase approach means that the farmers and the agriculture industry are given sufficient time to develop and introduce solutions designed to reduce the nutrient burden on the environment to acceptable levels.

Table 1. Estimates of National Manure Production and Sales in 1996, 1998, 2002 and 2005 (m kg P_2O_5) on the Basis of the Proposed Standards.

	1996	1998	2002	2005
Phosphate Production	206	200	190	185
Surplus per Farm	88	92	87	86
Redistribution	71	69	49	49
Export/Processing	14	15	20	20
National Surplus	3	8	18	17

Phase 1 (1987-1990) was aimed at achieving stabilization of the problem and preventing animal manure production from further enlargement. Under the Soil Protection Act Standards were defined the maximum amount of animal manure to be applied per hectare. Initially, these standards were set at such level as to ensure that all the manure produced nation-wide could be disposed of. Primarily the standards were based on Phosphate because of the (relatively) constant amount produced per animal and its stable character that facilitates the control of the regulations.

Phase 2 (1991-1994) was aimed at a gradual reduction of the burden placed on the environment by tightening the maximum application standards. However, tightening the maximum application standards may result in manure surpluses. This is why the extent and rate at which these standard are tightened are tailored to enable the development of solutions for surplus reductions or environmentally acceptable manners of disposal. An example is the reduction of mineral excretion through a reduced mineral intake via feedstuffs.

Phase 3 (1995-2000) is aimed at a further reduction of manure and fertilizer applications to realize a balanced application of fertilizers and manure in regard to both phosphorus and nitrogen by the year 2000. This means that the amount of minerals applied will match crop demand in order to prevent structural accumulation of phosphorus in the soil.

Moreover, the (unavoidable) nitrogen losses are not to exceed the levels indicated in the water quality standards for sustainable environmental quality. During Phase 2 and 3 the amount of minerals spread per hectare had to decrease substantially both nationwide and regionally. This aim the farmers try to reach by reducing the minerals in the feedstuffs by tailoring the diet more accurately to the animal's need. Besides that, manure was transported from regions with manure surpluses to regions with manure shortages. Even though, nationwide a surplus still remained. Therefore on-farm and large-scale manure processing factories are being developed by private and co-operative enterprises that make export ready products.

MINERALS ACCOUNTING SYSTEM: (MINAS), STARTING FROM 1 JANUARY 1998

Initially, regulations about the application of manure were taken nationwide. In order to make every farmer responsible for his own manure problem a more individual system to each farm has been introduced: the so-called Minerals Accounting System (MINAS). This system is more sophisticated than generic application standards. For instant there is a big difference in crop uptake and production. The final aim is: "the right amount of fertilizer on the right place at the right time". This why the Dutch government, together with agribusiness, has worked out this new regularly system to replace the mandatory and prohibitory provisions. The government states with the MINAS the maximum losses that are allowed in view of the environmental goals. Although, in the beginning, this system was used as an extension and management tool, from 1 January, 1998 it has become compulsory.

Working System

In a minerals accounting system farmers keep a record of the exact amount of minerals they use and the quantity of minerals that leaves the farm in animals, crop sales, milk, fodder and manure. Each year farmers send in a provisional assessment based on their mineral accounting. This is comparable to an income tax assessment.

If the farm mineral input (feed, fertilizers, etcetera) exceeds mineral output (crop, met, milk, eggs etcetera) the Mineral Accounting will show a mineral surplus. The total surplus comprises losses to ground and surface waters, air and soil.

However, not all losses are harmful to the environment and this is why the mineral surplus is compared to the surplus that is acceptable from the environmental viewpoint. The government, taking account of environmental goals and specific (farm) circumstances sets this level. Non-acceptable losses are settled by means of a levy. The levy forces the farmer to lower their mineral surplus to the level of the environmental goals. Separate levels are set for phosphorus and nitrogen. Table 2 shows the figures for loss standards.

Table 2. Survey of Mineral Legislation in the Netherlands.

Mineral	1998	2000	2002	2005	2008/ 2010
Phosphate loss standard (kg/ha)	40	35	30	25	20
Nitrogen loss standard (kg/ha)	300	275	250	200	180
Low Levy (Dfl 2,50) for Phosphate loss/ha from-to	40-50	35-45	30-40	25-30	
High Levy (Dfl 10) for Phosphate loss/ha: above	>50	>45	>40	>30	
Levy Nitrogen loss/ha. Dil 1,50					
Registration obligatory at LU number	2.5	2.5	all	all	all

Minerals accounting is an input-output look-keeping system that will relate total application of manure (including fertilizers) to production. If a farm exceeds the so-called 2.5 Animal Units, 2.5 AU, (this is an equivalent of 205 laying hens or 427 broilers per ha), he is forced to report its mineral losses. If a farmer exceeds the loss standards for phosphate and nitrogen, the surpluses will be fined. In 1998,m about half of the farms will start the MINAS. In the next 4 years every farm has to participate in the MINAS (except the very small farms). During the next 10 years regulations will be more severe, the fines for losses higher, the loss standards lower. The ultimate aim of the MINAS is a nationwide balance of minerals.

In the following example for laying hens and broilers is shown what implication the MINAS given to individual farms.

Layers

This farm has 25,00 laying hens, with 5 ha maize. The layers are kept in cages. Besides the deposed manure on the maize, all the manure has been delivered from the farm. The average of laying hens is 24,686. They started with a weight of 1,316 gram. This farmer started with 25,625 layers on 1st of January.

Table 3. Example of MINAS Bookkeeping for Layers.

Layers							
INPUT				OUTPUT			
	Amount /kg	Phosphate	Nitrogen		Amount /kg	Phosphate	Nitrogen
Feed[1]	1087000	14918	30445	Eggs	429250	2060	8242
Pullets[2]	26625	513	923	Mortality[3]	1878	28	111
Fertilizer			300	Maize	250000	350	1075
				Manure	626000	12914	19306
Total		15430	31668	Total		15353	28733

[1]Pellets.
[2]Ca. 18 weeks.
[3]Layers over 19 weeks.

Broilers. Ca. 35,000 animals' average, which equals ca 235,000 animals yearly delivered.

Table 4. Example of MINAS Bookkeeping for Broilers.

Broilers							
INPUT				OUTPUT			
	Amount /kg	Phosphate	Nitrogen		Amount /kg	Phosphate	Nitrogen
Feed[1]	733456	8946	23400	Eggs	234718	4694	12205
1 Day old Chickens	26625	74	246	Mortality Chickens	5800	2	6
Fertilizer		1192	5664	Broilers	5937	119	308
				Arables	41 ha	2665	6765
				Manure	626000	12914	19306
Total		10212	29058	Total		10212	29058

[1]Pellets.

THE EFFECT OF MINAS ON THE MINERAL SURPLUSES IN THE NETHERLANDS

The introduction of MINAS influenced the quote of minerals that could be placed on the soil. The reason is that farmers are much more accurate with the amount of manure they put on the soil on their own farm. They don't want to pay a levy. On the other hand, farmers with Arables are becoming very precise due to, for instance, last year's introduction of a system in which paying for sugar beets are related to the contence of nitrogen. What is the accepted surplus of all farms?

Table 5. Influence of the MINAS on the Surpluses of P_2O_5 in Holland (year:2000).

Farm Level Surplus	
Pigs	43,4 million kg P_2O_5
Poultry	27.4 million kg P_2O_5
Cattle	10,9 million kg P_2O_5
Total Surplus	81.7 million kg P_2O_5
Cattle manure surpluses placed on pastures	Minus 10,9 million kg P_2O_5
Structural surplus (till September)	81.7 million kg P_2O_5
Restricting pig production (per 1st of September 1998) 10% reduction of all pigs in Holland	81.7 million kg P_2O_5
Surplus (before placing on arable Land)	81.7 million kg P_2O_5
Use of P_2O_5 on arable land in Holland	
Total Surplus	66,37 million kg P_2O_5
Placed on arable land (70% of acceptation)	41,0* million kg P_2O_5
Stays surplus in Holland	25,37 million kg P_2O_5
Solution: Shrinking of animal production, reduction of P_2O_5 in feedstuff or export of manure.	

*70% acceptance means: 100% of arable land farmers accept 60 kg P_2O_5 per ha. This is much more than the situation in 1997.

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MARKET ANALYSIS OF COMPOST: CENTRALIZED AND SPECIALIZED COMPOSTING

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The livestock industry in the United States is in a process of economic transformation. Technologically advanced production facilities are rapidly replacing traditional pastoral farms. Referred to as Confined Animal Feeding Operations (CAFOs), these facilities often house thousands of animals enclosed in relatively concentrated areas. In general, CAFOs are more economical than smaller livestock operations; however, they produce enormous amounts of animal waste in the form of effluent and manure. Nutrients in animal waste, primarily phosphorus and nitrogen can contaminate groundwater, rivers and streams. Livestock induced run-off is a source of water pollution in many parts of the United States, and affected communities are seeking solutions to help improve water quality.

Options for abating livestock-induced run-off appear limited to refinement of existing farm managerial practices, or removal of wastes from adversely affected areas. However emerging evidence points to the importance of including other options. Research from the Texas Institute for Applied Environmental Research (TIAER) demonstrates that livestock waste treatment and processing methods such as composting may provide greater reductions in nutrient run-off than implementation of enhanced land management practices. In addition, when compared to inspection based regulatory programs, processing manure into a marketable commodity may offer a more economical and a less intrusive option for government to assure regulatory compliance.

In 1997, the Brazos River Authority (BRA) initiated activities to examine the feasibility of a livestock-waste treatment and processing facility to be located in Erath County, Texas. With roughly one quarter of the state's dairy population, Erath County has one of the largest concentrations of dairy cows in the state of Texas. Currently there are approximately 87,000 cows in the County that generate approximately 800,000 tons of manure each year.

After eliciting local support, and securing funding commitments from the State of Texas, EPA, USDA, and the City of Waco, Texas, the BRA selected the engineering firm of Camp, Dresser and McKee (CDM) to conduct a study entitled "Erath County Animal Waste Management Study." The Project Research Team was comprised of BRA, CDM and TIAER. A Technical Advisory Committee (TAC) consisted of members from various agencies, communities in the watershed, regional dairy producers and research experts who reviewed project activities and research.

STUDY OBJECTIVE AND METHODOLOGY

The study objective was to assess the feasibility of processing, exporting, and marketing large quantities of dairy manure from Erath County. Removal of animal waste from the area is anticipated to reduce excessive levels of manure run-off in regional water supplies. To achieve the study objective the Project Research Team accomplished a number of tasks. TIAER provided information regarding the generation and location of animal waste in the County and assessed current waste management practices.

CDM provided an evaluation of processing technologies, potential facility sites and analyzed costs associated with a number of different alternative facilities. TIAER and CDM identified potential funding sources and evaluated financing strategies for the proposed facility. Finally, TIAER conducted a thorough investigation of existing and potential markets for compost and related products.

The marketing component of the study is essential given that sales from processed manure are crucial for the long-term sustainability of a facility. In order to evaluate markets for processed dairy manure, TIAER collected information through a comprehensive literature review and a survey of regional businesses and institutions. Data obtained include: information on product types; consumer preferences; traditional and potential consumers; product and competing product prices; quality standards; seasonal sales patterns; and current quality demanded in regional markets. In addition, the Project Research Team conducted on site tours and evaluations of composting facilities in Texas, California, Colorado, Florida and Idaho. TIAER and the BRA also held round table discussions with private sector compost producers from across the nation.

Table 1. Collectable Dairy Manure Estimates for Erath County.

	Lactating Cows	Calves	Total
Animal Weight (lbs)	1,400	400	NA
Manure production per animal	3.07	0.88	NA
Number of contributing animals	48,023	14,407	62,430
Total Manure Generation			
Dry tons per year	147,431	12,678	160,109
Wet tons per year (50%	294,861	25,356	320,218
Cubic yards per year	491,435	42,261	533,696
Total Collectable Manure			
Dry tons per year	63,395	6,339	69,734
Wet tons per year (50%	126,790	12,678	139,468
Cubic yards per year	**211,317**	**21,130**	**232,447**
Cubic yards per contributing	**4.40**	**1.47**	**NA**

Notes:

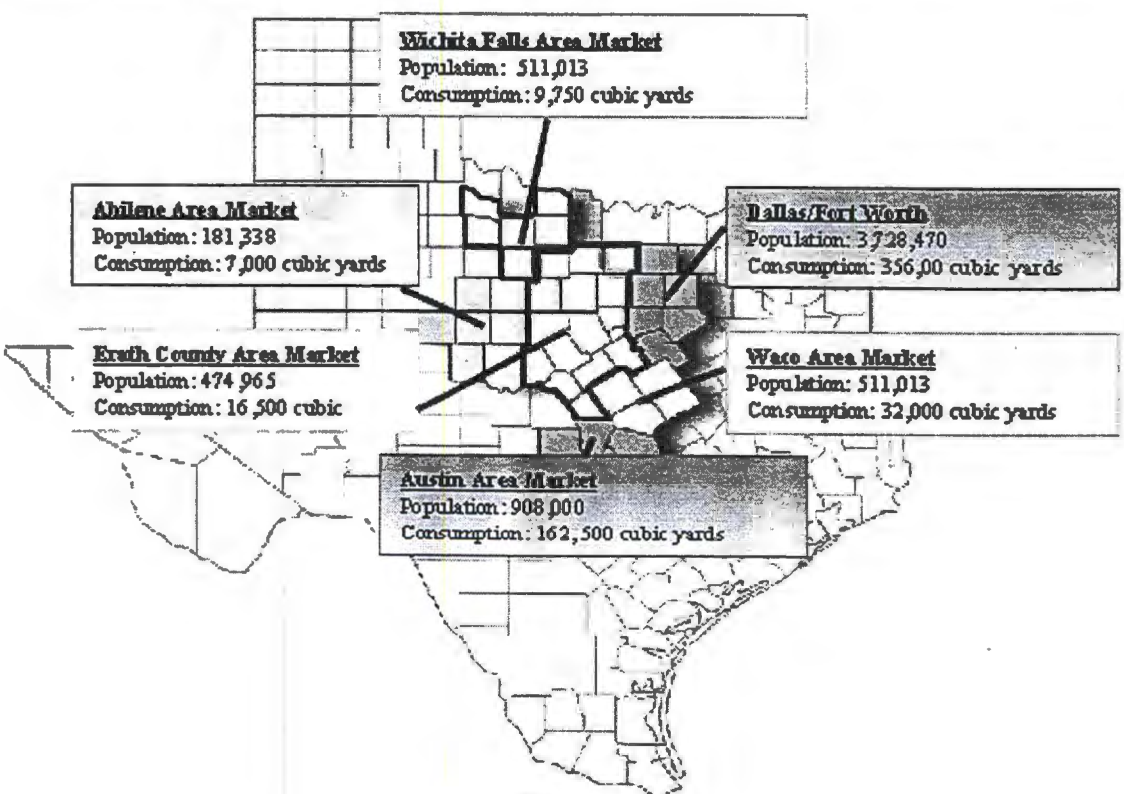
- Animal weight and production rates are those of the American Society of Agricultural Engineers (ASAE), 1991. Production rates assume a herd with 83 percent of animals lactating on any given day, and 3 calves per cow.
- Wet tonnage assumes 50 percent moisture content. Density per cubic yard is assumed to be 1,200 lb/cubic yard.
- Collectable manure estimates assume that 43 percent of lactating cow manure and 50 percent of calf manure can be collected.

RESULTS OF MARKETING ANALYSIS

Status of Compost Markets

The Project Research Team assessed numerous processing technologies and identified compost as the product that offers the maximum potential for cost recovery. Compost is the material that results from controlled decomposition of organic materials such as plant debris and animal manure. Producers market compost as an organic soil amendment with the ability to improve chemical, biological and physical characteristics of soil and growing media.

On a national level, compost has become standard within the "green" industry and is increasingly available. Industry experts and compost producers expect national markets for the product to grow substantially in the next five to ten years. Projected growth results from waste reduction mandates as the goal of local and federal governments and an increase in public environmental awareness. In north central Texas demand for compost is robust and primarily in large urban areas. TIAER estimates that consumers in north central Texas purchase approximately 584,000 cubic yards of compost each year. The majority, over 90%, is sold in the large metropolitan areas of Dallas Fort Worth and Austin. Overall, the landscaping industry appears to be the largest consumer. TIAER estimates that landscape architects and bulk material suppliers account for around 75% of annual compost consumption in the regional market. Homeowners and gardeners account for 20-25%. Golf courses and agricultural growers use the product on relatively limited basis. The regional market as defined by TIAER along with consumption estimates for sub-regional areas are illustrated below.



In and around major urban markets, there are numerous well-established producers, and as a result there is no supply shortage. Market penetration on a large scale will require significant displacement of existing products. Competition with established producers is compounded by other factors. For example, lack of industry standards or product regulations contribute to the manufacture and sale of low cost and low quality compost. This suppresses market prices and makes cost recovery more difficult for producers who manufacture high quality composts. In addition, Erath County is 70 to 150 miles away from major urban markets such as Dallas, Fort Worth, and Austin. High transportation costs relative to product value limit access to these active markets.

The Potential Role of the Private Sector

Market constraints for an Erath County product have limited private sector composting activity in the country. Although many entrepreneurs are attracted to the area given the large supply of raw material, very few have achieved any degree of success. The majority of compost producers interviewed by TIAER and the BRA conclude that large-scale centralized composting is currently not profitable. Ms. Jane Witheridge, CEO or Organics Management Company (OMC), stated: "There is a gap in the product value and cost to process manure for distribution outside the generation zone [Erath County]."

Private sector producers that operate in the County will likely target low volume, high return markets. The goal of the entrepreneur is profit, not water quality. Centralized composting is currently not an option. Without adequate profit incentive, the private sector requires either public subsidization or regulations that force dairy operators to provide raw material at economically feasible rates. For example, under current regulations dairy operators apply cow manure to forage and pasture land. In the event that regulations severely restricted or prohibited land application, dairy operators would be forced to export excess manure. As Ms. Witheridge noted:

"Absent implementation of incentives or enforcement action against the generators, [dairy operators] the free market will take its course. OMC is committed to managing organic application to commercial and agricultural lands in Texas, and we remain interested in Erath County. Without more security, it will take us longer to implement the necessary protection in our investment. My best estimate for when this would occur is within the next three to five years."

In general, private sector efforts in Erath County are not expected to expand rapidly in the near future. It is unlikely that composters who do locate in the county will export manure on a scale sufficient to greatly impact water quality.

Projected Revenues and Cost of Centralized Composting

In the short run, sale of Erath County compost is possible but on a limited basis. It is unlikely that existing markets will absorb the sheer volume of available manure compost. CDM calculated that a facility capable of composting the available amount of dairy manure in the County would have an annual production capacity of 116,219 cubic yards. Sales of this magnitude would require a market penetration of approximately 20%, which is highly unlikely during the initial years of production. Due to the limitations in existing markets, the Project Research Team proposed the construction of a smaller pilot facility that could expand as markets develop and sales increase.

TIAER identified potential high volume outlets that if developed aggressively, could absorb large volumes of Erath County compost. Markets with the greatest potential are the Texas Department of Transportation (TxDOT) and agricultural growers in surrounding counties. The proven success of compost as an erosion control material has encouraged TxDOT to use compost in future projects. Engineers and maintenance representatives from regional TxDOT offices expressed considerable interest in the use of compost for local roadway construction and maintenance activities. In addition, based on market research and experiences of compost producers and agricultural growers, there appears to be sufficient opportunity to develop agricultural markets for compost in the areas surrounding Erath County. In other areas of Texas and in California, compost producers specialize in agricultural application and market volumes in excess of 100,000 cubic yards per year. Development of potential markets is key to sustaining centralized composting; however, it may require considerable time, effort, and expense.

According to CDM, the candidate pilot facility would have annual production capacity of 19,350 cubic yards, enough to process the manure generated by 9,600 cows. Table 2 presents projected costs and revenues of a pilot composting facility. Capital and operating costs are those as calculated by CDM. BRA and TIAER expect dairy producers may provide a minimum annual contribution of $10.00 per cow. Based on marketing analysis, assumed revenue is $6.00 dollars per cubic yard based on current practices. Figures presented as "per cow" facilitates interpretation of costs and revenues at the farm level. For example, an individual dairy producer participating in the composting program may have 1000 cows, thus their annual contribution would be $10,000. Capital costs are assumed financed over a 20-year period at an interest of 5 percent. Total capital costs are estimated at $1,523,225.

Based on the preceding analysis, it is unlikely that revenues will support a pilot facility in the short term. There is a deficit or gap between total costs and what markets and dairy producers will support. In the long term, it is likely the facility will become sustainable if markets are aggressively developed. A promotional and education campaign targeted at existing and potential consumers will increase sales volume and revenues.

Table 2. Projected Costs, Revenues, and Deficit for a Facility.

	Facility	Per Cubic Yard	Per Cow
Costs			
Annualized Capital Costs	$183,413	$9.48	$19.11
Operations	$180,428	$9.32	$18.79
Total Costs	$363,841	$18.80	$37.90
Revenue			
Dairy Operator Contributions	$96,000	$4.96	$10.00
Sales of Compost	$116,100	$6.00	$12.09
Total Revenue	$212,100	$10.96	$22.09
Gap	**$151,741**	**$7.84**	**$15.81**

Market Clearing Strategies

Preceding information demonstrates two fundamental aspects of this study. Primarily, existing markets will not absorb the available supply of composted dairy manure in Erath County. Secondarily, revenues from the sale of the product will not support construction and operation of pilot composting facility until markets for the product develop. With this in consideration, TIAER explored various options that if implemented may assure an adequate income stream for a pilot facility. All options assume dairies would contribute a minimum annual tipping fee of $10.00 per cow. Alternatives addressed include the following:

Increased contributions by dairy producers: This option requires dairy operators to increase annual contributions by $15.81 per cow for a total contribution of $25.81 per cow. For average sized dairy in the county (400 cows), this would mean an additional expense of $6324 per year. Unlike other industries, dairy producers operate in a market where they have no control over product prices and increased costs cannot be readily passed along to consumers of dairy products. TIAER estimates that a typical 400-cow diary in Erath County has a net return of about $80,000 a year. Thus, a tipping fee of $15.81 would result in 7.9% reduction in annual income for dairy operators participating in the compost program.[1]

Establish a Milk Stewardship Program: This option would provide funds by shifting environmental costs to milk consumers. Purchasers of unprocessed milk would pay a milk premium to dairy producers who participate in a composting program. The increase in retail milk prices necessary to finance the total dairy operator contribution is approximately one and a half cents per gallon.

Direct state or federal appropriations: The BRA, Erath County, TIAER and other interested parties would request that public monies be allocated to fund the capital costs of a pilot facility. Without annualized capital costs, the facility would generate an estimated profit of $31,672 or $3.30 per cow.

Using government subsidy programs to offset operating costs in the short term: One of the most promising sources of funding identified by the Project Research Team is the Environmental Quality Incentives Program (EQIP). The program provides cost shares and incentive payments of up to $10,000 per person per year and $50,000 for the length of the contract. The possibility exists that dairy farmers could be reimbursed for transportation costs associated with the delivery of solid waste to a composting facility. In addition, farmers who purchase compost from the facility for agricultural applications might receive incentive payments. The use of EQIP may diminish short-term tipping fees paid by dairy producers. It could prove to be an adequate interim subsidy program, but cannot be depended on in the long-term.

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[1] Pagano, A., Holt, J., Schwart, R.B., Kristin, J. and Jones, H.A. National Pilot Project Livestock and the Environment: Profiles of Representative Erath County Dairies: Project Task 1.3a. Texas Institute for Applied Environmental Research. Tarleton State University (1995).

SUMMARY AND CONCLUSIONS

Large-scale removal of dairy manure from Erath County will help improve regional water quality. The objective of this study was to determine the feasibility of processing dairy manure into a marketable commodity. Ideally, sales revenue from the product would generate revenues adequate to sustain a processing facility. Compost is the product currently marketed that offers the maximum potential for cost recovery.

Existing markets for this product are robust, particularly in large urban areas. This is confirmed by the fact that there are numerous, well-established and efficient producers in the major market areas. However, as a result there is no supply shortage to any category of user or re-seller in these areas. lack of industry standards or product regulations contribute to the production and sale of low quality composts. This suppresses market prices for the product and makes cost recovery more difficult. High cost of transportation to existing markets is a compounding factor. In short, there is a disparity or "gap" between the value of the product and the risks and costs associated with production. The majority of private sector compost producers interviewed by the Project Research Team conclude that centralized composting is currently not profitable. As a result, private sector composting in the county is currently limited, and is not expected to expand rapidly in the near future. There is little economic incentive for the private sector to market processed animal wastes from the county on a scale that would remove significantly large volumes of dairy manure from the watershed.

Overall, it appears that revenue from direct sales of processed manure and waste disposal fees voluntarily paid by producers will not provide adequate revenue to support a large centralized composting facility. The Project Research Team has addressed the foregoing concerns by proposing that public funds be requested for the construction and implementation of an animal waste market research and development facility. The majority of current research focuses on the technical production aspects of processed waste, rather than market development. The proposed research center can stimulate product demand, develop new markets, and facilitate the expansion of private sector activity in the area.

If implemented, a compost producer will be selected on a contractual basis by TIAER and the BRA to serve as facility operator. The BRA will serve as a technical advisor during the start up phase of the facility. In addition, the BRA and a group of regional diary producers will serve as an advisory council for the facility owner and operator. The central can play a key role in ensuring the long-term sustainability of a market-based solution to the environmental issue surrounding livestock production and water quality. The information developed and the cooperation between public and private interests will serve as a model that can be transferred to other regions of the country with similar water quality concerns.

ANIMAL FEEDING OPERATIONS AND EMERGING EPA ISSUES

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CLEAN WATER - SUCCESS AND REMAINING CHALLENGES

- Twenty-five years ago, sewage treatment facilities served only 85 million people. Today, the number of people served by adequate sewage treatment has more than doubled to 173 million.
- Twenty-five years ago, wetland losses were estimated at 460,000 acres per year but today, wetland losses have been reduced significantly.
- Since 1982, soil erosion from cropland has been reduced by more than one-third, saving over a billion tons each year and substantially reducing sediments, nutrients and other pollutants to waters.
- Today, industrial pollution controls established since 1972 prevent billions of pounds of pollutants from being discharged each year.

Despite significant progress in reducing water pollution, series water quality problems persist throughout the country. Recent state reports of water quality conditions indicate that

- 36% of monitored rivers and streams are impaired and another 8% are threatened;
- 39% of assessed lakes are impaired and another 10% are threatened; and
- 38% of assessed estuaries are impaired and another 4% are threatened.

Much of our progress in reducing water pollution has been the result of improving controls over discharges of sewage and industrial wastes. We need to continue to address these significant pollution sources, but today, the major challenge the nation faces is to better manage polluted runoff from urban areas, construction sites, abandoned mines, forest harvesting operations, and agriculture (see table below).

Table 1. Five Leading Sources of Water Quality Impairment Related to Human Activities (1996 305(b) Reports).

Rank	Rivers	Lakes	Estuaries
1	Agriculture	Agriculture	Industrial Discharges
2	Municipal Sewage Treatment Plants	Unspecified Nonpoint Sources	Urban Runoff/Storm Sewers
3	Hydrologic Modification	Atmospheric Deposition	Municipal Point Sources
4	Habitat Modification	Urban Runoff/Storm Sewers	Upstream Sources
5	Urban Runoff/Storm Sewers	Municipal Point Sources	Agriculture

Twenty-two states reported on the impacts of specific types of agriculture. Nonirrigated crop production leads the list of agriculture activities, affecting 35% of impaired river miles, or about 25,000 river miles in these 22 states.

Water pollution clearly degrades environmental quality, but it also diminishes recreational and economic opportunities and poses clear threats to public health.

- In the Gulf of Mexico, a hypoxia or "dead" zone (an area with low levels of oxygen), threatens the livelihood of fishermen. The area has excess amounts of nutrients from the Mississippi River watershed.

- In some Maryland and Virginia tributaries to the Chesapeake Bay and in the Neuse River in North Carolina, the microorganism Pfiesteria has killed fish and posed a risk to people. Other harmful algal blooms and biotoxins have also affected the health of people, in addition to harming fish, shellfish, and other wildlife. Pfiesteria and harmful algal blooms have been associated with excessive nutrients in water.

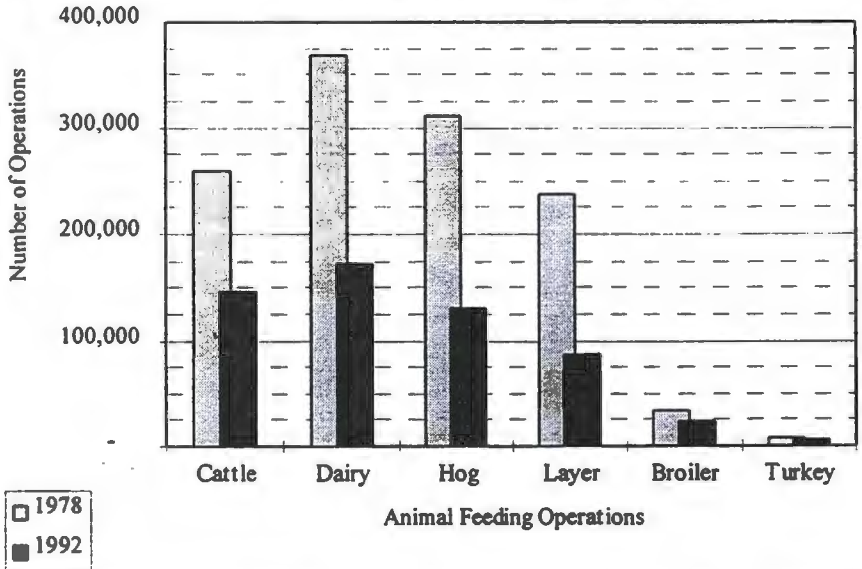
- Of the nation's 382 million acres of croplands, over 70 million acres suffer erosion rates that threaten long-term productivity., Poor land management and agriculture practices directly affect surface waters throughout the country.

- Polluted runoff from urban and agricultural areas adds sediment into water that carry it downstream and deposit it into harbors or reservoirs. Federal and non-federal dredging in coastal areas and the disposal of dredged materials costs about $1 billion per year.

ANIMAL FEEDING OPERATIONS

Approximately 450,000 Animal Feeding Operations (AFOs) operate in the United States, ranging from small livestock production facilities with few animals, to large geographically concentrated facilities that can generate animal wastes equivalent in magnitude to the volume of waste produced by a medium-sized city.

The nature of the animal feeding industry has changed dramatically over the past two decades. Advances in technologies for raising and feeding animals, decreases in transportation costs, and organizational changers in agricultural businesses and corporations have transformed the industry. USDA data show a shift from smaller to much larger operations. In North Carolina, for example the number of hog farms decreased by 62 percent between 1982 and 1992 while the average number of hogs per hog farm increased by 587 percent.



Increase in Animal Units per Operation (1978-1992)	
Cattle:	56%
Dairy:	93%
Hog:	134%
Layer:	176%
Broiler:	148%
Turkey:	129%

Figure 1. Industry Consolidation of Cattle, Dairy Hog, Broiler, Layer, and Turkey Animal Feeding Operations (Note: Numbers in box show percent increase in the average number of animal units per AFO, not just the change in the number of operations. Data source: Animal Agriculture: Information on Waste Management and Water Issues, General Accounting Office, 1995).

AFOs can impair water quality in a number of ways. If not collected and treated properly, animal manure can pollute surface and/or ground water with excess nutrients, such as nitrogen and phosphorus. Animal manure is commonly spread on agricultural land for its nutrient and organic value for both crops and the soil. If the manure is not spread in accordance with a nutrient management plan (which applies nutrients at the rates which crops can use them), nitrogen and phosphorus will leave farms and enter waterbodies, causing depletion of dissolved oxygen and eutrophication.

Studies have shown that AFOs, and particularly when several of these facilities are concentrated in a single watershed, can increase nutrient pollution to a river or stream. For example, a study of Herrings Marsh Run in the costal plain of North Carolina showed that nitrate levels in stream and ground water was highest in areas with the greatest concentration of swine and poultry production (P.G. Hunt *et al.*, 1995. Impact of animal waste water quality in an eastern plain watershed. Animal Waste and the Land-Water Interface, Kenneth Steele, Ed., Lewis Publishers, Boca Raton, FL, 589 pp.).

AFOs can also cause catastrophic effects locally. In June 1995, animal waste contained in an eight-acre lagoon in North Carolina burst through its dike, spilling approximately 22 million gallons of animal waste into the New River. The spill was twice the size of the Exxon Valdez oil spill, and reportedly killed fish along a 19-mile downstream area. It was the worst of six reported spills in the State during the summer of 1995 (EPA Office of Inspector General, March 1997, Animal Waste Disposal Issues, Audit Report No. E1XWF7-13-0085-7100142).

Most water quality problems and risks stemming from AFOs are addressed through voluntary programs that offer technical assistance, cost-share financing, and other incentives. EPA has developed a number of programs to support AFOs and to address the potential environmental and public health impacts from these facilities. Under section 319 of the Clean Water Act (CWA), EPA provides just over $100 million in grants to states each year to help implement nonpoint source programs and fund nonpoint source projects (this funding could double in FY99); the State Revolving Loan Funds created by each state under authority in the CWA can provide loans for projects that address pollution from nonpoint sources, including AFOs; and in Kansas City, EPA maintains a national agriculture assistance center that is currently working with USDA and the Land Grant Universities to develop an AFO focus.

Large AFOs and those causing significant water quality problems are regulated by EPA. Under Section 502 of the CWA, concentrated animal feeding operations (CAFOs) are identified as point sources and must obtain National Pollutant Discharge Elimination System (NPDES) permits. Of the estimated 6,600 CAFOs in the nation, less than a quarter have NPDES permits.

In addition, many states have regulatory programs that address water pollution from AFOs.

Joint USDA/EPA National AFO Strategy

After 25 years of progress, the Nation's clean water program is at a crossroads. The Clean Water Action Plan announced by the President in February outlines a blueprint for the future clean water program including over 100 key actions organized around four key tools to achieve clean water goals. A major key action directed USDA and EPA to develop a unified national strategy for controlling pollution from AFOs.

In May, Administrator Browner and Secretary Glickman laid out their vision for the Joint AFO Strategy. USDA and EPA can achieve a "marriage" of the knowledge, resources and programs of the federal government to livestock producers ensure effective waste management and protect water quality and public health. The Joint Strategy is about putting in place the tools and resources to ensure that producers understand what is expected and have the information to implement management practices that foster their historical stewardship role.

For the vast majority of the 450,000 AFOs nationwide, EPA expects to rely heavily on the voluntary actions by producers to effectively manage animal wastes and protect water quality. EPA and USDA need to ensure the Joint Strategy facilitates effective delivered by appropriate technical and financial assistance. CWA permits from EPA and the states are best tailored to address the largest operations and other, smaller operations designated as CAFOs because of impacts to water quality. EPA welcomes input from USDA to ensure that current and future regulatory programs are effectively targeted and to help AFOs ensure they are in compliance.

An interagency workgroup has met several times to draft the Joint AFO Strategy. AS of this printing, the draft Strategy had not yet been released for public comment. The final Joint AFO Strategy is due in November.

National Poultry and Egg Environmental Dialogue

Industry led efforts such as the Pork Environmental Dialogue and the current National Poultry and Egg Environmental Dialogue led by the National Broiler Council, are also critical to our collective success. Such approaches have the opportunity to develop actions that can complement existing federal and state programs for more comprehensive environmental protection. These dialogues also have the opportunity to provide input into the development and implementation of new regulatory and voluntary programs/activities, such as the revision of effluent guidelines (to be revised by Dec. 2001), expansion of NPDES permits to cover land application, and targeting of AFOs for inspections and possible designation as AFOs (therefore needing an NPDES permit) in priority watersheds.

The National Poultry and Egg Environmental Dialogue includes representatives from the broiler, turkey and egg industry, and stakeholder participation from the Farm Bureau, and state and federal agriculture, environmental and conservation agencies. EPA Administrator Carol Browner designated Regional Administrator Mike McCabe (EPA Region 3 -- Mid-Atlantic Region) as the national lead to work with the poultry industry to address nutrient and environmental impacts; as the National lead, Regional Administrator McCabe represents EPA in the Poultry dialogue effort.

Dialogue meetings have been held across the country; the following nine workgroups were established:

1. Financing, Technical Assistance & Cost Sharing
2. Manure/By-Product Management
3. Location and Siting
4. Alternative Uses
5. Education, Training & Communications
6. Wet Processing
7. Incident Response
8. Compliance Assurance
9. Research/Innovative Technologies

A preliminary draft report of issues and recommendations for these workgroups has been developed. Another meeting is expected in the September/October time frame,but as of this printing has not been announced. All meeting are open to the public.

CONCLUSION

Farmers were among the first stewards of our Nation's natural resources and farmers consistently recognize the value of protecting water quality and the environment. By working with the farm community and others, USDA and EPA are confident we can jointly develop a sound, common sense approach to reducing the environmental and public health threats posed by AFOs.

UPGRADING THE VALUE OF MORTALITY RESIDUES

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Chief among the problems facing the poultry industry today are those of waste management and associated environmental issues. Today the poultry industry is larger, more concentrated, and more technically advanced than it was one or two decades ago. The demand for poultry products by the consumer continues to increase and a variety of low-cost highly nutritious products abound in the market place.

The concentration of the poultry industry has results in the production of large volumes of by-products including: manure, farm mortalities, hatchery, and processing wastes that require daily attention. The poultry industry has responded well in objectively evaluating economically and environmentally sound management principles in dealing with by-product utilization as opposed to disposal. Many of the so-called wastes, if managed and processed appropriately, have the potential for increasing the economic profitability of the poultry operation.

Non-point source pollution has become a major environmental problem in many areas of the United States, especially near intensive confined livestock and poultry operations where wastes are being applied frequently to land at very high rates. Increases in human population and changing human diets have demanded rapid increases in livestock and poultry production, and most of these increases are taking place in areas containing many intensive confined production enterprises. In order for livestock and poultry expansion to be compatible with an increasing human population and not adversely affect the environment, new and innovative waste management systems must be developed and adopted by industry and grower alike.

Every turkey and broiler production facility is faced with the reality of dead carcass disposal. For a flock of 30,000 turkeys averaging 0.5% weekly mortality (9% total mortality), approximately 13.9 tons of carcasses will have to be disposed of during an eighteen week growing cycle (Blake *et al.*, 1990). For a flock of 50,000 broilers grown to 49 days of age and averaging 0.1% daily mortality (4.9% total mortality), approximately 2.4 tons of carcasses will require disposal in an environmentally safe manner (Blake *et al.*, 1990). These losses represent a tremendous amount of organic matter. A fresh broiler carcass contains approximately 34.2% dry matter, of which 51.8% is protein, 41.0% is fat, and 6.3% is ash (Malone *et al.*, 1987).

Disposal of poultry carcasses has been identified as one of the major problems facing the poultry producer. As the poultry industry expands, so also will the amount of waste generated on the farm. If poultry carcasses resulting in death by natural occurrences at such high levels of production are not disposed of by environmentally acceptable methods, future industry expansion will be limited or regulatory constraints will be imposed. Therefore, the poultry industry must aggressively pursue efforts to protect the environment in order to maintain a good public image.

ON-FARM DISPOSAL

Burial

Burial is an original method if disposal and is usually the most convenient. Open-bottom burial pits are presently the most commonly used method for the disposal of poultry carcasses. Disposal pits are presently the most commonly used method for the disposal of poultry carcasses. Disposal pits have been used with varying degrees of success by the poultry grower and can be fabricated from concrete block, monolithic concrete, or treated wood. Pre-cast, open-bottom septic tanks can be delivered to the site. These offer the best way of developing a concrete disposal pit at relatively low cost. The cover is made of reinforced concrete with a drop chute of polyvinyl chloride pipe at the center that is capped off with a tightly fitted cover.

However, increased production capacity per farm, high mortality rates, and increased market weights may attribute to slow decomposition rates and failure with this type of system. Ground water quality where open-bottom pits are located is of concern. Residue remaining in pits after years of use is also recognized as an emerging reason for considering alternative methods of disposal.

In Arkansas, legislation was enacted to prohibit the use of burial pits as a method for the disposal of poultry carcasses beginning July 1, 1994. In Alabama, the State Veterinarian mandated that no new burial pits could be established for the disposal of poultry carcasses after July 1, 1996. In essence, only burial pits in existence prior to July 1, 1996 can be utilized for carcass disposal. Other states are considering the passage of regulations to further limit the use of burial as a method for poultry carcass disposal.

Digestor

Dead bird digestors are a totally enclosed system utilizing a pre-cast septic tank or large capacity (1000 gal) plastic tank designed to contain poultry carcasses and to promote microbial breakdown of the organic material in addition to eliminating harmful bacteria that are present in the carcasses. Typically, a commercially available bacterial culture with enzymes is added to the dead bird digestor to facilitate organic decomposition. In a long-term study (15 months) of six units, Macklin *et al.*, (1997 and 1998) concluded that high levels of enteric bacteria exist in the dead bird digestors and that potentially pathogenic bacteria were continuously isolated from samples of the decomposing material throughout the course of the trial. Three units were infiltrated by ground water and were filled to capacity. Because of the potential threat that exists due to the presence of pathogenic microorganisms, the Alabama State Veterinarian currently prohibits the use of dead bird digestors in Alabama.

Incineration

Incineration is recognized as one of the biologically safest methods of disposal. Wastes can be disposed of a rapidly as they accumulate, and the resultant residue is easily disposed of and does not attract scavengers or insects. Incineration eliminates the threat of disease and resulting residue will not cause water quality problems. The most acceptable method of incineration is one in which complete combustion is accomplished. Commercial units are available with oil or gas burners and are usually equipped with automatic timers. Smoke discharge stacks for such equipment may also be fitted with after-burning devices that complete gas combustion and recycle fumes to reduce odors. In some states, a permit may be required to install and operate an incinerator.

Although incineration represents the safest biological disposal method, it tends to be low, expensive, and nuisance complaints are likely as pollution is generated (Murphy and Handwerker, 1988). After initially purchasing an incinerator, the average poultry grower will spend approximately \$3.50 to incinerate 100 lbs of carcasses above installation, based on a propane cost of \$0.61/gallon (Donald and Blake, 1992). Also, certain maintenance costs are incurred with incinerators, such as grate replacement every two to three years or in some instances the entire unit may require either refurbishment or replacement every five to seven years.

Composting

Composting is a controlled, natural process in which beneficial microorganisms (bacteria and fungi) reduce the transform organic wastes into a useful end-product called compost. Initial work conducted by Murphy (1988) indicated that composting poultry carcasses provides an economical and biologically safe means of converting carcasses resulting from daily mortality into an odorless, humus-like material useful as a soil amendment.

On-farm composting of poultry carcasses requires two types of composting bins: a primary or first-stage composting bin and a secondary composting bin (Murphy and Handwerker, 1988; Donald and Blake, 1990). Daily, carcasses are sequentially layered into the primary bin with used or caked litter and water at a ratio of 1:2:0.5 by weight, respectively (Blake *et al.*, 1991). A 1-ft layer of litter is first placed on the concrete floor of the bin, then a single layer of carcasses is placed into the bin and water is added to maintain a moist, but not saturated condition. Finally, the layer of carcasses, and water are layered into the primary bin. Once full, final cover of manure is placed over the carcasses.

Temperatures of the compost increase rapidly as bacterial action progresses, rising to 130 F plus within 5 to 10 days. The increase in temperature has two important effects: 1) it hastens decomposition; and 2) it kills microorganisms, weed seeds, and fly larvae. Temperature begins to decrease in the primary bin 14 to 21 days later. At this point, material is moved to the secondary bin, aerated in the process, and allowed to proceed through a second temperature rise. After the second heating cycle, composted material can be safely stored until needed for land application.

For composting to be a viable method for the disposal of poultry carcasses, it is paramount that the compost process completely inactivates pathogenic (avian and human) microorganisms prior to land application. Studies by Murphy (1990) and Conner *et al*. (1991 a,b,d) indicated that two-stage composting effectively inactivates poultry-associated bacterial pathogens. When properly managed, composting is a biosecure, relatively inexpensive, and environmentally sound method for the disposal of poultry carcasses. Its use is becoming more widespread as an alternative method for the disposal of poultry carcasses.

OFF-FARM UTILIZATION

Rendering is one of the best means for converting carcasses from on-farm mortalities into a valued biologically safe protein by-product meal. Unfortunately, the spread of pathogenic microorganisms during routine pickup and transportation to a rendering facility presents a substantial threat. Removing poultry carcasses from the farm is most acceptable for the environment, and a valuable feed ingredient results. There are several methods that have been promoted for the safe storage of poultry carcasses prior to transportation to a rendering facility. It is without a doubt that an effective system for the on-farm preservation of carcasses will reduce biosecurity risks and costs associated with daily pick-up or delivery to a rendering facility. In addition, such a system would facilitate the conversion of the mortalities into a valuable feed ingredient. Some of the methods described are being employed commercially today, while others are still in an experimental stage.

Central Pickup

One of the major concerns with this method is the possibility of disease transmission. Sound biosecurity at disposal sites is essential to prevent disease transmission. Daily transportation costs make this method prohibitively expensive.

Refrigeration

Freezing carcasses for short-term storage prior to transportation to a rendering facility is effective. Energy efficient freezer units are commercially available for placement on the poultry farm enabling carcass storage during a typical grow-out cycle. Costs associated with the on-farm refrigeration of broiler carcasses have been estimated to be approximately $0.60/day/house (Blake *et al.*, 1998b). One problem encountered in this study was the inability of the refrigeration unit to respond to heavy loading during periods of high environmental temperature. heavy loading of the refrigeration unit during a period of high environmental temperature (>75 F) with greater than 80 lbs daily resulted in the inability of the carcasses to eliminate their heat load in the lower layers and to thoroughly freeze prior to the addition of more carcasses. Refrigeration has potential for storage of carcasses prior to transportation to a rendering facility, but costs of operation and transportation require careful attention.

Acid/Base Preservation

This method employs mineral or organic acids as a preservative until the mixture is transported to a rendering facility.

Malone *et al.* (1988) placed punctured carcasses in a 3% solution of sulfuric acid and found that nutrients are readily preserved and pathogenic microorganisms were effectively inactivated. Processing and feeding of the resulting by-product meal indicated no detrimental effects when compared with conventional by-product meal (Lomax *et al.*, 1991). Because of concern for safety when mineral acids are transported and used on the farm, acid preservation has not been readily adopted. Organic acids such as acetic, propionic, and formic show promise, but may be prohibitively expensive.

Phosphoric acid has also been tested as a preservative for long-term storage of poultry carcasses (Middleton and Ferket, 1998). In their study, the preservation of poultry carcasses with phosphoric acid to pH <3.0 when stored will produce a biologically secure mortality silage, without putrefactive by-products of protein degradation, that is suitable as a raw material for recycling into a valued feed ingredient. Neither *Salmonella* spp. nor fecal coliform bacteria survived the acidification process.

Fully feathered broiler carcasses can be preserved in a 2 molar concentration of sodium hydroxide at a solution:carcass ratio of 1:1 (Carey *et al.*, 1997). The stabilized carcasses have been shown to retain nutritional value and inhibit the growth of *Salmonella* spp. when held within a pH range of 13.1 to 14.0. Trials lasting up to six months indicate that the preserved carcasses exhibited no putrefaction, microbial growth,m or odor development. Initial economic evaluations indicate that this method of managing on-farm broiler mortality merits further consideration.

Lactic Acid Fermentation

Controlled natural fermentation has been successfully used as a preservation method for foods and feeds for millennia (Ayres *et al.*, 1980; Banwart, 1981). Initial studies conducted by Dobbins (1988) described methods for preserving poultry carcasses by lactic acid fermentation. Carcasses can be stored for a period of time prior to transportation by employing lactic acid fermentation which stabilizes carcass deterioration but minimizes pathogen threat. Successful fermentation is enabled by the combination of prescribed amounts of farm carcasses with a fermentable carbohydrate source (i.e., sucrose, molasses, whey, and ground corn). In order for effective fermentation to occur, carcasses must be ground. Bacteria that produce lactic acid ferment the carbohydrate source, resulting in the production of volatile fatty acids and a subsequent decline in pH to below 4.5, which preserves the nutrients in the broiler carcasses. Similar results have been obtained by Murphy and Silbert (1990), Parsons and Ferket (1990), and Conner *et al* (1991c).

Pathogenic microorganisms associated with the carcasses are effectively inactivated during the fermentation process (Dobbins, 1988; Murphy and Silbert, 1990; Conner *et al.*, 1991c). Presumably, fermented material can be stored and will remain in a stable state for several months. Therefore, fermentation could be initiated and continue on-farm until carcass amounts are sufficient to warrant the cost of transportation. Unlike routine pickup of "fresh" carcasses, the convenience of fermented carcasses will reduce transportation costs and when coupled with rendering, the fermented carcasses can result in an excellent feed ingredient.

The feasibility and economics of on-farm endogenous microbial fermentation for stabilizing poultry carcasses have been demonstrated under commercial conditions for broiler and broiler breeder mortality (Blake *et al.*, 1992 and 1998a). Net disposal costs averaged $.045/lb and fermentation represents an economical, feasible, and environmentally safe method for the on-farm storage of carcasses prior to transportation to a rendering facility.

Yeast Fermentation

The Bertullo process for fermentation of mortality utilizing a proteolytic yeast was described by Malone *et al.* (1990). Similar to lactic acid fermentation, the carcasses require grinding, the addition of a fermentable carbohydrate and a yeast starter culture (*Hansenula montevideo*). The starter yeast culture is added only upon initiation and start-up in a continuous-type fermentation process. Carcasses are added repeatedly to a tank under constant agitation (aerobic process) which is maintained at 80-85 F. Within the first 48 hours, pH is reduced to 4.4. No *Escherichia coli, Salmonella typhimurium*, Newcastle disease or infectious bursal disease viruses were recovered 12 hours post inoculation. Both *Bacillus subtillis* and *Staphylococcus aureus* survived 48 hours post inoculation. Actual feeding value of this product has not been demonstrated.

EXTRUSION AS A RENDERING ALTERNATIVE

Extrusion is not a new idea and is commonly employed as a high-temperature, short-time treatment. Extrusion cooks, sterilizes, dehydrates, and stabilizes by-products into a high-quality, highly digestible feed ingredient. Extrusion technology utilizes the principle of friction as a means of creating heat, shear, and pressure. The material to be extruded is fed into a barrel and forced by means of a screw against a series of baffle-like restrictions, causing the material to back flow against itself. Due to the forces of friction and pressure within the barrel, product is cooked to a preselected temperature of 250 to 340 F in less than 30 seconds. Upon exiting the extruder, a rapid drop in pressure allows for the evaporation of 12 to 15% of the moisture.

Prior to the extrusion, carcasses are ground and blended with other ingredients (i.e., in a complete diet) or a single ingredient (i.e., soybean meal, corn, or wheat). Feathers, whole carcasses, processing plant wastes, and hatchery wastes have each been extruded into acceptable feed ingredients (Tadtiyanant *et al.*, 1989, 1991; Blake *et al.*, 1990). Poultry feeding trials indicate that extrusion of poultry carcasses is a viable alternative to conventional rendering.

Microbiological studies have also been conducted to determine the ability of bacteria, molds, and viruses to survive the extrusion process (Blake *et al.*, 1990). In all cases, the extrusion process effectively inactivated these microorganisms and the extruded products would not pose a potential disease transmission problem.

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ESTABLISHING NEW OPERATIONS-MEETING ENVIRONMENTAL AND SOCIAL EXPECTATIONS

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The state of Kentucky has experienced a significant growth of the poultry industry over the last ten years. During this period of time four broiler complexes, two large egg complexes, and a primary broiler breeder hatchery and research farm have been built. In addition, contract broiler houses for two broiler complexes in adjoining states have been built within Kentucky. This expansion of the poultry industry into Kentucky has created numerous opportunities for understanding the social and environmental concerns with new complexes.

WHY KENTUCKY?

The poultry industry moved to Kentucky for various reasons. The main reason was Kentucky had the resources necessary for a successful poultry operation. Kentucky either had or was willing to invest in the necessary infrastructure to provide the water, waste treatment, electricity and road system for a poultry operation. Corn and soybean meal was available in sufficient quantity and quality to meet the needs of the poultry industry. Kentucky has a large number of farms (over 90,000), with the average size of 150 acres. The number and size of the farms provides the necessary base for contract growers. In addition there was a strong interest by Kentucky farmers to find alternatives to tobacco and other traditional farm crops. Kentucky had higher unemployment than many states. Kentucky developed a tax incentive program that was linked to job creation and retention. The large number of jobs associated with a poultry operation fit well with this type of incentive program. Most importantly,Kentucky was interested in attracting the poultry industry to the state.

Local Interest

In the late 1980's and early 1990's, a poultry complex was a very attractive industry for many rural communities. During this time period rural communities were experiencing high unemployment, declines in population, an aging of their population and a shrinking tax base. There was great interest in recruiting industries into these areas that could reduce or reverse many of these concerns. The poultry industry was viewed as one of these industries and was aggressively recruited by some local and state officials. The benefits that communities envisioned from a new poultry complex were:

- Creation of new jobs and employment opportunities
- Increase in local tax base
- Alternative opportunities for farmers
- Increasing the value of locally grown corn
- Economic impact of new construction
- Improvements in their infrastructure

ECONOMIC IMPACT

The location of a broiler complex into an area will affect the economy through the creation of new jobs, capital investment and stimulation of the construction industry. The economic impact of a new broiler complex on a community was studied in an Environmental Impact State prepared by the USDA (1). The direct construction costs for a potable water treatment plant, poultry processing plant, feed mill, hatchery and associated poultry houses were $17.6 million. During the construction phase 700 jobs would be creased in the construction area. A work force of approximately 1200 people would be needed to operate the processing facilities. In Table 1 the total direct effects and indirect effects for the first three years of this type of project are presented (1). The estimated economic impact of the broiler complex during the first three years of construction and operation is approximately $830 million dollars.

The tremendous economic impact that a new complex has on a community can change the community. This economic change can lead to social changes and impacts.

Table 1. Direct, Indirect, and Induced Economic Impacts of a Broiler Complex.

Economic Impact	Industry Output	Employee Compensation
Direct Effects Year 1	$157,609,868	$ 22,664,600
Indirect and Induced Effects Year 1	$ 74,657,756	$ 16,318,700
Direct Effects Year 2	$163,983,735	$ 25,512,600
Indirect and Induced Effects Year 2	$ 92,600,658	$ 17,846,400
Direct Effects Year 3	$136,008,846	$ 23,805,200
Indirect and Induced Effects Year 3	$ 82,670,107	$ 15,557,700
Total Direct, Indirect and Induced Effects Years 1-3	$707,530,970	$121,705,200

COMMUNITY CONCERNS AND REACTION: SOCIAL

Due to the size and scope of a poultry complex, when one moves to an area there are anticipated changes that will occur in the community. How well one deals with these changes will impact the acceptance of the new complex by the community. These changes can be divided into the following areas population and workforce, land use and property value, community resources, quality of life and community dynamics.

Population

Changes in population will occur due to the number of employment opportunities that will be created. If the area has a history of high unemployment or underemployment then these employment opportunities will help retain the population. If the local labor pool can not provide the necessary work force then a movement of labor into the area can be anticipated. Careful analysis of the labor market is necessary.

Competing industries for this workforce must be taken into consideration. If a competing industry feels that their labor force will be adversely affected then there may be hidden resistance from that group. If a migration of labor into the area is anticipated than the community must plan for this increase in population. This includes the need for additional housing and services.

As the community feels the economic impact of the new complex, significant changes in the work force can be expected. New employment opportunities will develop, which could pull employees from the poultry complex work force. What was once an adequate supple of labor can become a storage due the favorable impact the operation had on the local economy. Retention of the work force must be a priority.

One of the significant changes in population that we have seen is a reversal of the brain drain that had been occurring in many of our communities. The limit number of employment opportunities for educated individuals in rural communities has traditionally resulted in an outward migration of these individuals from rural communities. While many times the number of jobs that are created by a new complex is emphasized, the fact that there are many managerial and supervisory positions in a poultry complex is sometimes forgotten. These managerial and supervisory positions allow successful and educated people to return to the community. Their leadership extends outside the company to the community, civic groups, religious organization and schools.

Land Use and Property Value

One of the biggest concerns that a community has is the impact that a new poultry complex will have on property values and land use. The neighboring property owners are very concern by the aesthetics of the facilities, air quality, and noise. The greatest fear that a property owner has is the lost of the use and enjoyment of their property and the potential lost of resale value. the new complex must fit into the land use plan of the community, and must meet all zoning and planning requirements. The concerns of neighboring landowners must be addressed through discussions and factual information. The use of buffer zones and windscreens can address many of the aesthetic concerns.

The large number of poultry houses that are necessary to support a boiler complex can be a source of concern for a community. Guidelines for the siting and operation of these poultry houses must be established. These guidelines must address the location of poultry houses near residences, schools, churches and businesses. If there is a need for a variation from these guidelines, an agreement with adjacent property owners should be obtained. The least resistance occurs when the potential poultry farmer is a long term resident of the community, there are less than four houses on one site and poultry houses are viewed as an alternative for helping family farms. The greatest resistance occurs when more than six houses are being built on one site. There also is resistance if the farmer is new to the area or there is an absentee landowner involved.

Community Resources

A poultry complex can have both a positive and a negative impact on community resources. Proper planning and cooperation between the poultry company and the community can improve the roads, the water supply and waste treatment facilities of a community through incentive programs at the state and federal levels. These improvements in the infrastructure will benefit the community and may even serve to attract additional businesses to the area. The increase economic activity in an area will increase the tax base and increase the revenues available for community. These resources may be used to address community needs that will occur if the area experiences a growth in population. A community must anticipate change and cooperate with the poultry company to prevent future problems.

Quality of Life and Community Dynamics

The quality of life and the dynamics of the community will change from the economic impact of the poultry complex. How they will change is up to the community. There will be resistance to change; there must be some reassurance that the impact of the new complex will improve the quality of life. The company and community leaders must address concerns such as traffic congestion and noise. The location of the facilities and the traffic pattern to farms must be taken in consideration when choosing a site. The community leaders must develop a plan for maintaining the quality of life in the community even in the face of rapid growth. The time for planning is at the beginning of the project and not after the growth has occurred.

With in a community there are many groups and group dynamics. A project of the scope of a new poultry complex can impact the community dynamics. Different individuals and groups will view the project through their own personal experiences and biases. Some individuals may view the potential of others to change their economic situation as a threat to their own stature within the community. These individuals can be very detrimental to the success of these types of projects. Others may have different plans for the future of the community and feel that the poultry complex will hinder their plans. As an example, if a segment of the community view tourism as a viable future growth area they then may view the poultry industry as being inconsistent will this vision. This can create resistance, even if the group is a small minority and the majority in the community want the poultry complex. The lack of viability of the vision will not lessen the resistance or conflict.

COMMUNITY CONCERNS AND REACTION: ENVIRONMENTAL

The environmental concerns associated with a poultry complex can be divided into those that are associated with the processing plant and those associated with the poultry farms. The primary concern with the processing plant is the wastewater treatment facilities and particularly the discharge of treated water. The quality of the discharge water must be thoroughly explained to the community. In addition, the permit application procedure for the wastewater treatment facilities must be explained to the community. The second biggest concern with the processing plant is odor. This includes odors from the plant and the waste treatment plant. The only way to over come this concern is to take community leaders to existing facilities and then have personal testimony from these visitors. The third concern is air pollution particularly concerning dust from the feed mill and feathers from the live haul area. The community must be assured that there will not be a problem. The one area that does not seem to be a great concern to the community is the offal, once the rendering process is explained there is acceptance for this process. However, if a rendering plant is part of the poultry complex then the operation of that facility becomes increasingly important.

The poultry farms can generate concerns in two ways, first as local concerns about specific farms and second as general concerns about poultry production and the impact of large number of houses in a general area. The concerns about poultry houses in general are more difficult to address than those concerning specific farms. Guidelines for the operation and siting of poultry houses must be developed and communicated to the community. Most of the general concerns with poultry production deal with litter and manure disposal, dead bird disposal and the impact on water quality. These concerns are also associated with specific farms; however, in addition there are concerns that are more related to odor, aesthetics, flies and truck traffic. Adjoining property owners need to be assured that the operation of the poultry farm will not adversely impact their property.

SUCCESSFUL COMPLEXES

When a poultry complex enters a new area there are certain things that can be done to improve their ability to be successful through observation of numerous poultry companies moving into new areas the following list of activities increases the chance for success.

- Only go to areas that want you. This may seem obvious; it is essential that the community leaders and the community understand the type of operation that is being discussed. The community also needs to know why you selected this area.

- Understand the history and group dynamics of the community. Each community has its own history and group dynamics and you must understand these dynamics and relationships. You must identify the community leaders and build a relationship with them. Do not place yourself between politicians and their constituents.

- There must be one strong company spokesman. This spokesperson needs to be able to address the questions about the company and the poultry industry. It is best if this person is a long-term employee who can discuss the philosophy and operations of the company. This will give increase credibility to this person over a new employee or a recently hired local person.

- The company must be visible in the community. The company should open an office in highly visible location as soon as possible. Do not open the office on the future site of the operations. The neighboring property owners need a adjustment period. If you open the office on that location there is a feeling of finality that will increase resistance and eliminate the necessary adjustment period.

- Information is vital. A new community wants information and will obtain it either from your company or from other less reliable sources. The community has questions and concerns and you must be prepared to address them. Do not enter a community until your plans are firm and can discuss them.

- A visit is worth a thousand rumors. As part of your public relation campaign it is essential that you provide opportunities for community leaders to visit your existing operations. This will answer many of their concerns and help project a positive image of your operation.

- Become involved in the community. Encourage your employees to become involved in civic organizations, schools, religious organizations and youth activities. Create a speaker's bureau to supple speakers to these organizations. Funds for public and civic activities need to be part of any new operation's budget. Establish a policy on donations and be prepared to make decisions at the local level.

- Be prepared to interact with the media. Identify employees who will be spokespersons for the project. provide media training for the spokespersons and instruct all other employees to refer questions to these trained employees. Build a relationship with the media by providing news releases and providing factual information.

- Develop a set of guidelines for the siting and operation of contract poultry farms. The size and location of contract farms can be a source controversy. Local communities are more agreeable if they feel the farm will be operated by a local farmer, that there are no more than six houses, and that there is an adequate plan to dispose of litter and dead animals.

- The employment policy and purchasing policy of the company needs to be conveyed to the community. The community must understand the type and quantity of jobs that will be created. The economic impact that these employment opportunities will provide to the community must be delineated. Community farmers need to understand how feed ingredients will be purchased. A creation of a new local market for feed ingredients will impact the farm economy and this must be convey to the farming community.

SUMMARY

There are many social economic and environmental issues that are involved in the location of a poultry complex into a new area. For a new complex to be successful there must be adequate communication between the company and the community to address these concerns. Failure to communicate honesty and with integrity can lead to community resistance and legal actions.

REFERENCES

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ESTABLISHING NEW OPERATIONS
MEETING ENVIRONMENTAL AND SOCIAL EXPECTATIONS

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Thanks for the opportunity to be part of the National Poultry Waste Management Symposium. It's an honor to be part of such a knowledgeable and well-known group of the industry. I will try to keep my comments brief and to the point. Hopefully, you will feel free to ask questions at the end if time permits.

I thought it might be good to give you background as to where I am coming from. I have been part of the egg industry for the past 33 or 34 years. My background is not one of academia, but purely from the experience side - one who has been involved in all aspects of the egg industry. In these 33 years I have cleaned chicken houses, debeaked, vaccinated, gathered eggs, serviced chickens, moved pullets and old hens, se t eggs, pulled hatched, sexed chicks, delivered chicks, owned and ran egg laying units, traveled intermittently and visited all parts of the world's egg industry, and marketed breeding stock, chicks, hatching eggs and commercial eggs.

In 1993, after starting AgriGeneral Company in the late 70's, I decided to leave the egg industry. I decided to come back in December of 1996 after being absent from the egg industry some three years. The three years I was absent from the industry made me feel a little like Rip Van Winkle when I returned. I could not believe the changes. From my background I should have had the experience to breeze through a challenge in an industry that I had known for so long.

Wrong - I understood the industry and egg production, but I did not understand the dynamics of the changing industry. The misconception of **Establishing New Operations - Meeting Environmental and Social Expectations.** The last two years have been ones that have added to my continuing eggucation.

Let me digress a little. The operation that my partners and I had turned over to another of our partners and his son was an operation which had had start up problems beginning in 1980. All these opportunities had been fixed. We had a smoothly running 5-million hen operation.

The new owners decided to increase their production barn from 5 million to 15-16 million layers. This would be done by adding four farms about twice the size that we had at Croton. They set about doing the engineering, quietly purchasing the land, and getting ready to establish a new operation 50 miles from the original facility. The area selected was poorer farm land, had high unemployment and was critically in need of good grain markets. The new facilities would have a feed mill (buying grain from 150,000-200,000 acres of land), provide more than 400 jobs, pay more than one million in property taxes and be an important part of the community. They got their permits, fire codes were enacted against them. The facility was built, and the first year of operation fly control was not where it should be. The son decided he had enough. A new president was brought in. The new president had a reputation that caused the different regulatory agencies of the government to come in. By this time, the CCCO (opposition group) had formed and really had a foundation against large farms to sell from. When I returned, we had investigations by or violations of:

1. Ohio Department of Health
2. Federal Department of Labor
3. EOC
4. OSHA
5. NLRB
6. DOT
7. USDA
8. Ohio EPA
9. Federal EPA
10. USDA

I have probably missed a few.

In addition we had:

1. Daily articles in newspapers (4-5 about the company/management).
2. Television stories weekly.
3. Numerous lawsuits by employees, opposition groups, and concerned citizens.

All the above culminated with a nationwide story on Dateline. This is what was there on my return or soon after. I don't say this for sympathy; just to appraise you what can and will happen if you don't take the correct steps. I have learned a lot from this experience. Things that will be helpful if/when I do it again.

We are not only surviving, but also we are doing well and earning back our reputation. We could have avoided some the things that happened. We aggravated too many employees, too many neighbors and too many regulatory groups. Simply, I think, by not keeping people informed in all areas. There are and will be opposition groups you can do nothing about. Try to understand them but be aware they are there.

1. **Assess the Area** - Positive and negative.

2. **Get permits exactly the way you want them.**

3. **Understand your opposition.** Address their concerns, realizing you probably can't do much about prejudice. Explain things to them.

4. **Outline the economics to the community.**

5. **Be prepared to be legally challenged.**

6. **Do the right thing in operations.**

7. **Be accessible to the press.**

8. **Be accessible to the community.**

9. **Be proactive with regulatory agencies.** Do more than necessary.

10. **Be active in community affairs.**

11. **Admit mistakes.**

12. **Deal with complaints immediately**

13. **Don't take the mistakes by the press personally.**

14. **Be clear with instructions to employees.** Articulate very carefully - they are your spokesmen.

15. **Know what your facility does or doesn't do to the environment.**

16. **Open doors and tours to all willing visitors.**

Establishing new operations and meeting environmental and social expectations is very difficult in today's environment. We do soil sampling, water sampling, stream sampling, manure sampling, fly monitoring, beetle monitoring, air monitoring and manure monitoring. There are many NIMBYS (not in my backyard). Everyone wants 5 acres and a horse barn. The changes in animal agriculture in the last 3 years brought on by social pressure are very difficult.

There are organized opposition groups. However many make comments without even seeing the facilities. Tours and videos are very effective. You can't do it the way you used to. By the way, we have a 12-15 minute video on our farm we give to groups if anyone has interest. You can't do it the old way, you must do it right, do more than necessary, and be proud of what we the American Farmers have accomplished and will continue too. We have accepted the challenge and have provided the highest quality and cheapest food supply in the world.

CO-UTILIZATION OF AGRICULTURAL, COMMERCIAL AND MUNICIPAL RESOURCES TO PRODUCE COMPOST

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The production and sale of compost is one technology available to farms where nutrient management dictates farm nutrient export. The conversion of poultry manure or litter into a value added marketable product is a desirable means of environmental stewardship. Compost is a product that is gaining market demand but, the economics of production in many circumstances is marginal. Composters must find additional sources of income to improve cash flow and net profit.

The method of choice for improved composter income is to become a for fee processor of waste produced by others. Collection of tipping fees for taking in materials from other farmers, industrial and commercial businesses and local governments provides cash for compost operations. The materials received reduce the purchase of compost ingredients as well as increase the quantity and in some cases the quality of the compost produced. Income is improved on both ends of the compost operation.

A wide variety of materials may be available. They can bring moisture, nutrients, carbon and bulk into the composting process. Materials may include:

- greens and wood from landscapers and tree trimmers
- wood from recyclers such as chipped pallets (not demolition debris & treated wood)
- gypsum board
- wood from modular home, furniture and other product manufacture
- food residuals from processors, grocery stores and restaurants
- DAF solids and other residues from poultry, seafood and meat processing
- residues from rendering
- damaged paper and cardboard from recyclers

end of roll paper and cardboard tubes from printers
municipal biosolids (sewage sludge)
municipal grass and leaves
manure from dairy, livestock, poultry farms
manure from specialty animal operations (fairs, race tracks, zoos, etc.)
manure from urban horse owners
egg residues from hatcheries
catastrophic poultry mortality

Each type of material has an effect on the operation of the compost facility. The compost process must be adjusted so that the material is blended into a mix resulting in the desirable porosity, moisture and C:N ratio. The physical handling of the material and method of incorporation into the compost mix needs to be well developed. In cases where material inflow is sporadic composting may have to be in batch mode to be able to identify which piles or windrows contained which materials and had what finished properties.

Handling wet materials requires special attention. Liquids can be sprayed onto windrows while the windrow is being turned or mixed. Liquids can be poured into basins or furrows formed by dry materials and later mixed when most of the liquid is absorbed in the mass. Liquids can be injected into windrows or piles. If the liquid has an odor potential, choose a method to get it mixed and covered rapidly.

Select material combinations to improve pile or windrow physical structure. Blocky wood chips are excellent for improving porosity. One composter used two to three inch pieces of wood to give structure to a mixture of small wood chips and sediment from a clam processing plant. Unfortunately, that combination was very difficult to mix with the compost windrow turner. He found that adding seed obtained from a mustard manufacturer was just the right lubricant to allow efficient operation of the turning machine.

It is important to experiment with trial mixes of materials to determine suitability and to develop a management plan for handling logistics before accepting more materials. The experiment will define how much can be handled and give some indication of time and cost factors that will help in establishing whether the material will be profitable to accept.

An important activity for a composter is to develop relationships with anyone who can assist with the finding and processing of materials imported to the farm. A composter should get to know the right people and the recognized sources of information. These may include:

local and state recycling program managers
environmental regulators
cooperative extension, colleges and universities with compost expertise
compost producers through associations and the Internet
waste haulers
compost and recycling magazines

Every contact should be considered a source of future assistance or business and should be used to develop knowledge of materials availability. The information gained should include:

what kinds and quantities of products are available
what is the present mode of disposal and at what cost
who is responsible for those products
is it better working with the generator or the contract hauler
are the materials source separated or mixed
are bulk materials pre-ground or would on-farm grinding be required
can the materials be processed without causing notice by neighbors

The composter should understand the position of the waste generator in order to obtain and retain the business. Businesses and governments with waste materials want to move materials as cheaply as possible. If a composter is accepting waste for a $10 fee and an alternate appears at $5, the $10 composter may be quickly out of product. But, waste generators also need a reliable place to send these materials. If a food processor has an equipment failure and needs to move several trailer loads of waste between two and four in the morning and the $5 vendor is unreachable whi. One composter used two to three inch pieces of wood to give structure to a mixture of small wood chips and sediment from a clam processing plant. Unfortunately, that combination was very difficult to mix with the compost windrow turner. He found that adding seed obtained from a mustard manufacturer was just the right lubricant to allow efficient operation of the turning machine.

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Waste generators want to have the least amount of noise about where their waste goes. The last thing a company manager wants to read in the paper is how his firm has been dumping large amounts of smelly stuff on someone's farm. A responsibility carried by the composter is to manage the materials in a sound manner and to stay in business by being recognized for doing good things for the environment.

A contract specifying materials to be accepted, fee structures and other terms is good if one can be obtained. Governments usually work with annual contracts to be bid but, businesses usually work by loose verbal agreements. As noted earlier, businesses are always looking for a better deal and may not want to be tied to a long term agreement. In a contract, make sure to stipulate the quantity and quality of the product that will be accepted and provide for return or additional payment for disposal of unacceptable material. Too often trash is hidden in loads by employees and passed on by haulers. The farmer must inspect for quality control.

The contract should also include ways to quit the contract. One farmer contracted for waste sweet potato peelings and tuna fish residuals to use as hog feed. He had not idea of the condition and quality of material that would be delivered. Within two weeks he had piles of whole dead fish in a quarter acre sea of caustic potato glop. But he was being paid to take the stuff with a contract he had no way to terminate without fear of a lawsuit. It took regulatory agency action to stop the hauling company from delivering material and the farmers was ordered to clean up the mess.

Before venturing into accepting off-farm materials for composting, a farmer should check with applicable local zoning regulations to determine what activities are considered agricultural and what activities are considered commercial. Most zoning agencies rule that on-farm composting of farm and off-farm materials (with the exception of human sewage) for use on the farm property is an agricultural activity. But, sale of the compost may change the designation from agricultural to commercial. The change from agricultural to commercial activities may require adherence to different regulations, pose different real estate and income tax conditions and require zoning variance.

The farmer should be familiar with local and state environmental regulations that might affect the composting operation. What environmental permits are needed? What incoming materials and quantities trigger permit adjustment? Is a certified operator required? Does the compost need to be registered with some agency before sale? Is the site open for inspection and by whom and what for? What site development for water and air pollution control is necessary?

Also, the neighborhood needs to be considered. Are there folks who would complain? Are there activists needing a cause? Are the roads suitable for the added truck traffic? How close are the residences? Can the dust, noise and odor be controlled and confirmed to the farm boundary? Maintenance of good neighbor relations is important before, during and after the establishment of a compost operation.

Most of all, the operator/manager of a compost facility must set and meet goals to make good compost, offer good service and operate a profitable business. In order to achieve these goals the composter needs to be able to recognize:

what needs to be done
why it needs to be done
when it needs to be done
how it needs to be done

and then do it.

In summary, off-farm materials taken in for a fee can provide an economic advantage to agricultural composters. To be successful the composter needs to be knowledgeable of the materials and how to handle them. Accepting off-farm materials and the marketing of compost requires an ability to sell as well as maintain the quality of service, environmental integrity and compost product.

HANDLING MEDIA INQUIRIES

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The public relations or corporate communication department provides counsel with contact number 24 hours a day. This procedure is distributed to all managers, security, safety and reception personnel.

When a reporter or news editor calls, be courteous and take the following information:

- Caller's name
- Name of publication or broadcast station
- Telephone number
- Information request
- Specific questions
- Reporter's deadline.

Reporters almost never arrive at your property unannounced. However, should this happen, the following guidelines apply in a non-crisis situation:

- Be courteous.
- Find out their name, publication/station and reason for coming to your facility.
- Have the reporter and news crew wait in a designated place: the reception area or guardhouse. Assign someone to keep them company, but not to give an interview.
- Contact the designated company media spokesperson and see if an interview can be arranged. If an interview is possible immediately, escort the reporter and crew to the meeting place (a conference room is best) and wait with the reporter for the designated spokesperson. If an interview is not possible at this time, tell the reporter it will be arranged later by the spokesperson. Take information on how and when to reach them by telephone.
- If the reporter asks questions while you are with them other than general facts about the company (who is manager, how many people are employed, hours of

operation, products manufactured, how long in the community, and such), tell him/her they will have to ask the spokesperson.

- Never allow a reporter in an unsafe area for visitors or to wander unaccompanied.

If a crisis situation exists, implement emergency communication procedures that are specific to each facility:

- Designated crisis management team with spokesperson on site on each shift. Employees have been previously trained on the importance of a spokesperson in representing the company and best providing as complete information as possible for media needs.
- Designated media waiting area with access to telephone, electrical outlets, and rest rooms.
- Frequent news briefings, if only to say an investigation is going on. Express concern and regret that the crisis occurred. Emphasize company's concern for employee safety and product integrity. Cite safety procedures, training and record. Cite product integrity record. Do not answer questions bout economic impact. It is too soon to know the full impact and, out of context, it can incorrectly appear that all the company cares about is money and not people.
- At the same time, keep employees on site and, as appropriate, throughout the company updated through faxed bulletin board releases and conference calls to human resources departments.
- Do not release names or extent of injuries, just the rescue and medical care that is being provided. If there have been fatalities, acknowledge that, but do not release names until their families have been notified. Emphasize what is being done to contain the situation and prevent further problems.
- Follow up after the crisis with updated stories and what the company is doing to assure this does not reoccur in the future.

Dealing With the Media
DO's and DON'Ts

Your best chance of getting your side of the story into a news report is to understand the reporter's job and what the reporter may do to accomplish that job. You then can use that understanding to convey the poultry industry's point of view.

Here are some specific tips to follow when dealing with the media:

DO prepare for the interview. Ask the reporter his or her name and affiliation, the nature of the story, specific questions the reporter wants answered and the story deadline. If possible, try to determine how much the reporter already knows about the subject. Based on that information, prepare several points and/or quotable statements to use in the interview.

DO remember that nothing is "off the record." If you don't want to see it in print, don't say it.

DO take control of an interview. Say what you want to say, not what the reporter wants you to say.

DO keep your responses simple. Use short speeches, short clauses and short words whenever possible.

DO stop talking when you've answered a question. Too much information, not too little, often gets you in trouble.

DO fashion responses that simplify, clarify and emphasize your position.

DO be confident, credible, convincing and enthusiastic. Do not be overbearing, though.

DO tactfully cut off a question that is too long or is covering up a speech by a reporter. Quickly summarize the question being asked and respond.

DO state the company or association policy regarding a specific issue.

DO always correct the reporter if a question misstates a fact or is based on an erroneous premise.

DO use the reporter's first name during an interview.

DO keep eye contact with the reporter.

DO supply accurate information.

DO remember a reporter's deadline. When the deadline is near, call to inquire if there are any additional facts you can provide or any information to cross-check.

DO send a letter or note to a reporter commending the fair coverage or the good job covering a complicated subject.

DO keep a record of press contacts.

* * * * * *

DON'T feel you must submit to an interview immediately. If a reporter calls, ask if you can call back - and use the intervening time to prepare for the interview.

DON'T say anything you wouldn't want to see in print.

DON'T use too many numbers or statistics.

DON'T try to answer a question if you don't know the answer. Instead, offer to get an answer quickly - then to it.

DON'T break a promise to call a reporter back. If you've promised to call back and don't, you've seriously impaired your relationship with that reporter - and your opportunity to present your side of the story.

DON'T feel you have to answer every question directly. If you don't want to answer a question directly, use the opportunity to make one of the points you do want to cover.

DON'T say "No Comment" if you don't want to respond to a question. Such a response will cause the reporter to suspect you are hiding something.

DON'T give personal opinions unless they are very general in nature.

DON'T answer hypothetical or "what if" questions.

DON'T comment on information provided by others.

DON'T start to answer a question if you're not sure of the answer.

DON'T try to mislead a reporter. Good reporters do their homework before they interview you - and if you mislead them, they'll know it.

National Turkey Federation

NUTRIENT MANAGEMENT PLANNING: PHOSPHORUS OR NITROGEN-BASED?

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Nutrient management planning is an integral part of modern production agriculture but is hardly a new concept. The key steps in the development of profitable and environmentally sound nutrient management plans - setting realistic yield goals, using soil testing and agronomic research to identify crop nutrient requirements, applying fertilizer nutrients and manures in a timely and efficient manner, and monitoring the success of nutrient management decisions, (Figure 1; Sims and Gartley, 1996) - have been well-established and widely accepted agricultural practices for decades. Despite this, we now face in many U.S. states and European countries political and legal pressures to institute mandatory nutrient management planning. For example, in 1998 the State of Maryland passed the Water Quality Improvement Act mandating that any agricultural operation with a gross income > $2500 or ≥ eight animal units must "..have and implement a nitrogen (N) and phosphorus (P) based nutrient management plan" Simpson, 1998). Individuals using only chemical fertilizers must implement a plan by December 31, 2002; those using sludge or animal manure by July 1, 2005. What has caused this movement away from the use of voluntary practices to manage nutrients? Why are nutrient management plans now being based on N and P, instead of N? And, most importantly, what are the implications of mandatory N and P based plans and how can agriculture adapt to this new direction in nutrient management planning?

VOLUNTARY OR MANDATORY NUTRIENT MANAGEMENT PLANS?

The major driving force causing state and national governments to consider the need for mandatory nutrient management plans has been the industrialization and specialization of

1. Identify the nutrient requirements of the plants to be grown at the desired level of plant performance or "realistic yield".

2. Use soil testing to quantify the nutrient supplying capacity of your soils. This represents the plant nutrients available from past fertilization, native soil minerals and soil organic matter.

3. Determine which plant nutrients are <u>not</u> present at optimum levels for plant growth. Then select the most profitable and environmentally sound nutrient rates needed.

4. Quantify the plant nutrients available "on-site" - those provided by animal manures, composts, irrigation waters, and legumes. Are they adequate to meet plant nutrient needs? If not what options are available to obtain the needed nutrients?

5. Select the most efficient nutrient sources or combinations of sources. Consider plant nutrient uptake patterns and how the timing and methods of application required for different nutrient sources can best maximize profitability and minimize potential nutrient losses to the environment.

6. Develop an approach to monitor the success of the nutrient management program. Use soil and plant testing, yield or plant performance data, and good record-keeping practices to construct a "nutrient budget". If large excesses of any nutrients exist, consult with advisory agencies on the best means to improve the efficiency of your operation.

Figure 1. Key components of a nutrient management plan (from Sims and Gartley, 1996).

agriculture and particularly animal agriculture. During the past 30 years there has been a national re-structuring of the agricultural systems used to feed and produce poultry and livestock. Geographic intensification of poultry, swine, dairy, and beef operations resulted in economies of production that increased the profitability of these industries and maintained low prices for the consumers of animal products. However, the intensification of animal agriculture also set the stage for the long-term nutrient management problems we face today in many countries, including the U.S. The fundamental reason for these regional or national nutrient management problems is the same, whether we are discussing poultry production on the Delmarva peninsula and in the Southeastern U.S., swine production in North Carolina and Iowa, or the highly intensive, mixed (dairy-beef-swine-poultry) animal agriculture of the Netherlands, - nutrient surpluses that accumulate in soils or are lost to air and water by erosion, runoff, leaching, and volatilization. The term "nutrient surplus" refers to the fact that annual nutrient inputs (feed, fertilizer) to intensive animal operations at any scale (farm, state, region, country) usually exceed annual outputs in animal products and harvested crops. As intensification of animal production increases, so does the magnitude of the annual nutrient surplus that must be dealt with by individual farmers or the industry as a whole.

The presence of these nutrient surpluses on farms reflects a fundamental breakdown in the global N and P cycles. Nutrients are obtained from air (N) or ore deposits (P), processed into chemical fertilizers and transported to grain producing regions, such as the midwestern U.S. The nutrients in the grains are then transported to areas of concentrated animal production as feed and then transformed into animal products and animal wastes. Since there is at present no economically viable alternative to land application of animal wastes and the costs of transporting these nutrients back to the site of grain production is prohibitive, the nutrients in animal manures, composts, wastewaters, and animal mortality remain and accumulate in the geographic vicinity of animal production, fragmenting the global N and P cycles. Further, because the management of animal wastes is inherently less efficient than with chemical fertilizers, the likelihood of nutrient losses to air and water is usually greater when these materials are the primary source of nutrients to crops.

In contrast, very extensive operations (low animal density or no animals) should have little or no surplus of nutrients because the primary nutrient inputs to these farms are purchased fertilizers, which represent an expense to the farmer. In these settings the nutrient management principles shown in Figure 1 are relatively easy to follow and minimal environmental impacts on air and water quality should occur.

Exceptions to this generalization are farms and horticultural operations producing high cash value crops where the cost of fertilizer is a small percentage of the overall cost of production (e.g. vegetables, ornamental plants). In these systems there is less economic incentive to implement the best management practices (BMPs) needed to minimize nutrient losses and accumulations in soils. Environmental protection, either voluntary or in response to regulations, must be the driving force behind more intensive nutrient management plans.

The movement toward mandatory nutrient management planning reflects an emerging national consensus that the nutrient surpluses and logistical difficulties associated with animal waste management enhance the likelihood of nonpoint source pollution of air and water. Further, it is now argued that, in the long-term, the breakdown of the N and P cycles in areas of intensive animal production is inconsistent with the principles of sustainable agriculture because this represents a waste of finite natural resources. The U.S. Environmental Protection Agency, the USDA Natural Resources Conservation Service, and many state governments, acting in response to public and legislative concerns about nonpoint source pollution of air, soil, and water perceive the existence of a national mandate to protect the environment through improved nutrient management planning. What this will entail and how the costs will be allocated remains to be determined. It seems inevitable, however, that formal nutrient management plans will be developed, voluntarily or involuntarily, on farms and that these plans will be based on both N and P.

NUTRIENT MANAGEMENT PLANS: NITROGEN OR PHOSPHORUS BASED?

One of the major points of debate with regard to nutrient management today is the perceived shift away from N-based plans to those based on N and P. This perception, however, is only partially correct. It is true that for organic wastes (animal manures, municipal sewage sludges, wastewaters) land application programs have traditionally been based on approaches designed to provide the amount of plant available N needed for an economically optimum crop yield and to reduce the likelihood of nitrate contamination of ground waters. Whether voluntary or regulatory, these N-based approaches have recognized, but not seriously addressed, the fact that application of organic wastes based on N will consistently apply more P than is needed by crops, thus causing a buildup of P in soils to values well beyond what is required for optimum yields. It is important to note, however, that the accumulation of P to "very high" or "excessive" levels and the application of any source of P to soils such as these has never been regarded as a sensible agronomic practice by either land grant universities or private soil testing laboratories, for both economic and environmental reasons. Rather, it has been viewed as a seemingly unavoidable consequence of the agricultural use of animal manures and other organic wastes. Economically, the P is not needed because crop yields will not be increase; hence the costs of purchasing, handling, and applying manure or fertilizer P is unprofitable.

From an environmental perspective it has long been known that P can have deleterious effects on surface water quality (i.e. eutrophication; Foy and Withers, 1996). However, it was generally assumed that P losses could be minimized to acceptable levels by controlling soil erosion since P is strongly adsorbed by most soils. The movement of significant quantities of soluble P to surface waters by runoff or through leaching and shallow ground water flow was thought to be of little importance. Unfortunately, research conducted in the past 10-15 years has increasingly shown that controlling soil erosion alone cannot prevent the loss of environmentally significant quantities of P from some agricultural soils (Sharpley *et al.*, 1994). Specifically, research has shown that soluble P in soils and P loss in surface runoff increases with soil test P (Pote *et al.*, 1996; Sibbesen and Sharpley, 1997) and that soils can become "saturated" with P to the point that P leaching and losses in lateral ground water flow or tile and ditch drainage can occur (Breeuswma *et al.*, 1995; De Smet *et al.*, 1996; Sims *et al.*, 1998). Additionally, in some agricultural settings, e.g. pastureland, surface applications of manures can result in the release and direct transport of soluble manure P to surface waters with little or no interaction with the soil.

Issues such as these are highly problematic because they point to the need to restrict P applications to soils with P values that are at or near the agronomic optimum. This will create formidable economic challenges for those involved in intensive animal agriculture that have annual surpluses of manure P and an inadequate land base, a common scenario in the U.S. In essence, animal agriculture is being asked (or required) to absorb the economic impact of developing and implementing alternatives to the land application of animal manures. Other nutrient users will be affected as well, such as the municipalities and industries that rely upon land application for biosolids and face similar problems with P-based nutrient management plans and the agricultural and horticultural industries where the value of the crop and/or traditional fertilization practices often result in over-application of P. Clearly these problems are complex; however, the unavoidable question faced today is how to develop sustainable nutrient management plans that are based on N and P.

ADAPTING TO NITROGEN AND PHOSPHORUS BASED NUTRIENT MANAGEMENT

The move to N and P based nutrient management plans is the first step in recognizing that water quality cannot be protected by N management alone. It means we must also devise best management practices that prevent the accumulation of P in soils to excessive values and the transport of P to surface waters, by all pathways, not just soil erosion. Reducing the unnecessary use of purchased chemical fertilizers is an obvious and relatively easy first step in this direction. However, what strategies are available to animal agriculture and municipalities, where the use/disposal of manures and biosolids is a requirement, not an option?

- Develop a N and P based nutrient management plan: The principles involved in developing a N and P based nutrient management plan for animal wastes (or municipal biosolids) are conceptually straightforward but practically impossible in many agricultural settings today. First, the N and P requirements of the crop to be grown are identified based on a realistic yield goal. Next, an application rate of manure is selected that does not over-apply either N or P. Identifying the correct application rate to provide the amount of available N required is a well-developed process that basically requires knowledge of the expected mineralization of organic N and recovery of inorganic N in the particular manure for a given soil and cropping system, information that is readily available in most states (Sims, 1995). Finally, timely and efficient application of the manure is made taking into consideration crop N uptake patterns and the potential pathways of N loss that must be avoided. Phosphorus application rates are normally based on soil test P values, with most manures regarded as being approximately equivalent to fertilizer P in terms of plant availability. However, because the soils in most areas with intensive animal agriculture are often well above the critical soil test P value recommended for optimum yields, the P-based manure application rate is essentially zero, thus land application is a moot point. This requires farmers to not only identify alternatives to land application for their manures, but to purchase chemical fertilizers to meet the N needs of their crops.

  Today, for many farmers, this approach is economically impossible. Alternative to land application are not developed and the costs of purchasing fertilizer N to replace manure N already present on the farm will be a significant economic burden. Additionally, the current state of knowledge on P transport suggests that P-based management is not necessary in all situations where soil test P values are excessive, at least not in the near term. The use of risk assessment tools, such as the P Index, to identify areas on farms with the greatest likelihood of impacting surface waters based on hydrology, soil P, and management practices, is now being regarded as a more effective approach to identify areas where P-based management should be required (Lemunyon and Gilbert, 1993; Sims, 1996). At the same time it must be recognized that simply because the risk of P transport is low now, the buildup of soil P to grossly excessive values is unlikely to be a sustainable practice in the long term.

Given the conflicting realities of nutrient management planning today - the pressures to prevent nonpoint source pollution by N and P *vs.* the practical and economic constraints faced by farmers in responding to this challenge -most state and federal governments are opting for a five to ten year transition period to allow those confronted by this task to resolve these problems. The following actions are needed during this transition period to allow future generations of farmers to profitably implement N and P based nutrient management plans:

- <u>Develop alternative to land application</u>: There is a pressing need for serious efforts to develop alternatives to land application of animal wastes. The most prominent suggestions to date have been to use manures as bioenergy sources or as components of value-added products that can be economically re-distributed to areas with nutrient deficits (composts, pelletized fertilizers). While with proper economic incentives, these may be promising options for dry manures (e.g. poultry), they are unlikely to be useful for industries that rely on liquid treatment systems (swine, dairy, beef). National or regional efforts are required to identify the best technologies available and promote new research in these areas, to carefully assess other environmental impacts that might occur (e.g. air quality problems from burning manures), and to foster private investment in large-scale solutions such as these.

- <u>Improve the efficiency of land application programs</u>: While long-term solutions are debated, there is a near-term need to implement the practices identified by researchers in the past decade to improve nutrient management when manures are land applied. It is beyond the scope of this paper to describe all of these, but examples are: greater use of soil and plant N tests such as the pre-sidedress soil nitrate test, the leaf chlorophyll meter, and the stalk nitrate test; the adoption of "environmental soil P tests" by soil testing laboratories to aid, along with the P Index, in identifying soils that are "saturated" with P and located in hydrologically sensitive areas (Sims, 1998); the modification of animal diets using phytase enzymes and high available P corn, which can reduce P excretions by poultry and swine by 30-50%; and the use of municipal wastewater technologies for animal wastes, such as the amending poultry litters with alum to stabilize P in a form that is less susceptible to runoff and leaching (Moore, 1998).

- Remediate soils that are environmentally "excessive" in P: Finally, even if the large scale solutions are successful and we see more widespread implementation of new, research-based BMPs, many soils and sediments are sufficiently enriched with P that it may be decades before they decrease to values where minimal environmental impact can be anticipated. We need to consider the value of site-specific remediation of high risks soils - those that are saturated with P and located in hydrologically sensitive areas. The use of constructed wetlands and enhanced buffer strips, where the soils are amended with by-products such as water treatment residuals, iron oxides, or fly ash both to immobilize P and increase P sorption capacity, has received limited investigation and needs further work in the future.

CONCLUSIONS

Nutrient management plans based on Both N and P will become the norm in the future, primarily driven by concerns about the impacts of these nutrients on water quality. Phosphorus based management plans will be extremely difficult and expensive for animal agriculture to implement in the near term because of the lack of profitable alternatives to land application of animal manures. A transition period of five to ten years will likely occur, during which research and policy efforts should focus on field and watershed scale solutions that allow farmers to develop and implement economically feasible N and P based plans. Well-designed plans should still allow for the use of manures as soil amendments. However, during this transition period we must also provide farmers, and the animal industry, with other options (bioenergy, value-added products) to efficiently and profitably use the nutrient surpluses commonly associated with intensive animal agriculture.

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HEALTH ASPECTS OF FEEDING BROILER POULTRY LITTER TO BEEF CATTLE

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Broiler poultry litter has been used as an alternative feed source for beef cattle for over 43 years. Its use as a marketable feedstuff has been regulated for over 24 years (14). One of the earliest feeding trials reported in the scientific literature was published in 1955 (32). Since 1955 numerous reports have been published, and most of these continue to focus on the basic premise that broiler poultry litter can serve as an alternative feed source for ruminants. The reason that litter is used as a feed ingredient is because it is a low cost source of dietary nutrients. The savings in feed and fertilizer costs to the beef cattle producer can be substantial (33). Therefore, economics and particularly, reduction in feed costs to the producer is the incentive to feed litter.

The major opposition to the feeding of litter is the concern that litter is not safe to animals fed litter and the perceived risks to humans who consume the products of the animals. Broiler poultry manure is perceived to be filthy, putrid, decomposed and disease ridden because it originates from the digestive tracts of poultry. By criteria that are used to judge acceptance of foods, poultry litter certainly would be judged unacceptable. Most conventional animal feeds also would be judged to be repugnant to humans. However, raw oysters which are filter feeders and raw mushrooms grown on manure compost are consumed by the public without much thought given to their sources. It has been an accepted practice for many years to feed by-products to animals especially ruminants.

During the 1960's and 70's the practice of feeding broiler poultry litter became more wide spread. Apprehension about the practice became evident when a committee formed by the USDA, with an advisor from the FDA, recommended the need for research to address the safety status of litter as a feed ingredient (25). In 1967 the FDA issued a policy statement which indicated that the FDA did not sanction the feeding of poultry litter and other animal manure-derived products to animals (17). The feeding practice deviated from conventional feeding practices, and was perceived to be a potential health risk to animals fed litter and to humans who consumed the products of the animals (36). The FDA indicated that data were not available concerning the health risks of feeding litter, and therefore it was prudent to advise against the practice. FDA issued a list of potential health risks (Table 1) relative to the feeding of broiler litter and other animal wastes (21).

Table 1. Potential Hazards from Feeding Animal Wastes.

Pathogenic organisms	Antibiotics and drugs
Microbial toxins	Hormones
Mycotoxins	Coccidiostats
Parasites	Pesticides
Viruses	Heavy metals
Arsenicals	Trace elements

An organized effort was initiated in 1976 by researchers from several state Agriculture Experiment Stations (AES) and the USDA/ARS to investigate potential health risks associated with the feeding of animal wastes. In 1978 an AES regional project was initiated entitled "Animal Health and Food Safety Aspects of Feeding Animal Waste." During the six-year project, 38 researchers from 13 states conducted research to address the issue (25). Participants of the project met annually with representatives of the FDA to review their work and to develop strategies for future studies.

In 1977 the FDA requested information and data on the practice of feeding animal wastes (6), and in 1980 the FDA published a response to the inquiry (35). The FDA response was the revocation of the 1967 policy which opposed the feeding of animal waste on the legal basis that it was adulterated under section 402(a)(1), (a)(2)(c), and/or (a)(3) of the Federal Food, Drug and Cosmetic Act. The revocation statement indicated that the feeding of animal waste is primarily a local practice. Therefore, legal jurisdiction over marketing of litter as a feed ingredient comes under the purview of the state departments of agriculture which also have authority over the marketing of conventional feeds. The FDA revocation did not constitute a positive endorsement of the use of animal waste as a feed. In the future if animal wastes move in interstate commerce and the feeding practice presents risks to the health of animals or humans, risks that are not controlled by state agencies, the FDA will take an active role in the regulation of animal waste used as a feed ingredient.

The nutritional, economical and environmental benefits of feeding poultry litter and other animal wastes are generally recognized (4), but the issue of safety is not totally resolved. Absolute safety cannot be achieved with poultry litter, with food we consume, or with any commodity. If every known analysis were conducted on litter and no apparent health hazards were detected, it still could not be claimed that litter has been shown to be absolutely safe. Several strategies can be used to build confidence in the safety of litter destined to be used as a feed ingredient. The long term safety record of feeding litter for over 43 years is a major accomplishment, but more evidence of safety is required. To do this, each of the potential risk factors issued by the FDA in 1967 (Table 1) will be addressed relative to the risks that each presents to the practice of feeding poultry litter to ruminants. An assessment of the risks is based on numerous publications and personal communications with veterinarians, national associations, and with directors of state departments of agriculture in the leading broiler poultry producing states.

HEALTH RISKS

Pathogenic Microorganisms: Of all the perceived health risks of feeding litter, pathogenic bacteria pose the greatest threat because recontamination of litter with pathogens can occur from several sources. Several studies have been conducted which demonstrate that enteric bacteria such as *Salmonella*, *E. coli* and *E. coli 0157:H7* do not persist long in poultry litter (18, 20, 21, 22, 24, 25). Even when poultry litter is inoculated with over a million *E. coli*, the bacterial count is reduced by over 4-log cycles in 48 hours (22). Litter must be processed before it is used as a feedstuff. Studies have shown that when litter was inoculated with a million/gram each of *E. coli*, *Salmonella* and *Listeria monocytogenes*, these bacteria were killed when the litter was dry stacked for 14 days (23, 24). Two mechanisms occurring in stacked litter limit the growth of non-sporeforming, mesophilic bacteria. Litter stored in dry stacks achieves internal temperatures of 54.4C (130F) in as little as one day. Higher temperatures (>60C) are reached if the litter has 25% or more of moisture (34). Although higher temperatures are more effective in killing pathogenic bacteria, temperatures over 60C tend to complex litter nitrogen and make the nitrogen unavailable as a dietary nitrogen source (24). A temperature of 44.4C (120F) is adequate to eliminate non-sporeforming, mesophilic bacteria from dry stacked litter because killing is a function of temperature and time (24).

Litter should be stacked for at least 20 days and a 20-day "cook" at 44.4C is adequate to eliminate mesophilic bacteria.

The process is analogous to a crock pot which cooks at a low temperature for a long time. Beef should be cooked to an internal temperature of 71.1C (160F) to ensure that *E. coli 0157:H7* is killed. However, because litter is stacked for several days, a lower temperature is sufficient to kill *E. coli* in litter. In addition to the heat generated by litter, ammonia, resulting from the natural transformation of protein, uric acid and urea to ammoniacal nitrogen, is toxic to bacteria in litter. The combined effects of heat, ammonia, high pH (8.4) and low contents of moisture and available carbohydrates make litter a very unlikely habitat for the growth of pathogenic bacteria. These conditions limit the persistence of pathogenic bacteria in litter and contribute to the microbial safety of litter. The Association of American Feed Control Officials (AAFCO) guidelines (1) specify that litter for feeding shall not contain *Salmonella* and *E. coli*.

Microbial Toxins: The microbial toxin of most concern in litter intended to be fed to cattle is the botulinal toxin produced by *Clostridium botulinum* types C and D. Botulism outbreaks have been reported in cattle fed litter in Europe (26, 31), but none have been reported in the United States. Many of the outbreaks were associated with litter that was processed by ensiling rather than by dry stacking. Furthermore, dead poultry were found in poultry litter ensilage on several farms where botulism had occurred. Poultry litter alone will not ensile because moisture and carbohydrate contents are not adequate to support the growth of lactic acid-producing bacteria. Litter can be combined with whole corn plant green forage, with litter making up no more than 30% of the total dry matter of the mixture, to produce a good quality ensilage (19). A pH of 4.5 or less is required to preserve litter ensilage and to create acidity sufficient to prevent growth of *C. botulinum* (21, 25). Poultry litter is highly buffered, and to overcome the buffer capacity, litter must be mixed with other feed ingredients containing carbohydrates and moisture to promote fermentation to achieve a pH of 4.5 or less. Dead poultry in litter provides a niche of nearly neutral pH and adequate moisture where *C. botulinum* can grow and produce toxin. In the United States beef feeding programs generally do not involve the use of ensilage, therefore ensiling of litter for beef cattle is not widely practiced. Dairy cow feeding programs commonly use ensilage, but it is widely accepted that dairy cows must not be fed litter because there is no opportunity to withdraw litter from the diet of dairy cattle before marketing the milk.

Mycotoxins: Mold growth on litter is very limited because molds do not tolerate the ammonia associated with litter (2). Ammonia levels associated with dry stacked litter are sufficient to detoxify aflatoxin. Researchers have demonstrated that it is possible to deep stack aflatoxin-contaminated corn grain with poultry litter to substantially reduce the aflatoxin level of the corn grain (16). Molds are predominantly aerobic requiring oxygen for growth, and processing litter by dry stacking before feeding discourages mold growth and mycotoxin production.

Zooparasites: The zooparasites of poultry (Table 2) present no threats of transmission from poultry via poultry litter to beef cattle (5). Intestinal parasites of poultry are specific to poultry and do not infest ruminants. The feeding of waste across species such as the feeding of poultry litter to beef cattle is a natural barrier to prevent spread of parasite infestation to cattle. There has been concern in the past that poultry and cattle can contract coccidiosis, and the feeding of litter might present a health risk to cattle. The avian coccidia which cause coccidiosis are species specific and do not infest across animal species (5). Poultry zooparasites are not likely to survive in built-up litter in the poultry house and also during the dry stacking of litter (5). During both of these events, microorganisms degrade a wide variety of substrates, produce heat and many chemical end-products, such as ammonia, that are toxic to many life forms including zooparasites.

Table 2. Zooparasites of Poultry.

1. Protozoa
   a) Coccidia
   b) Histomonads

2. Helminths
   a) Nematodes (roundworms)
   b) Cestodes (tapeworms)
   c) Trematodes (flukes & flatworms)
   d) Acanthocephala (thorny-headed worms)

Viruses: Viruses are more infectious than bacteria, but unlike bacteria, they require a living host to propagate. Therefore, they will not propagate in litter. Viruses are highly host specific, and infectious poultry viruses are not known to infect ruminant animals (5). If waste were fed to the same animal species such as poultry waste to poultry, there would be concern about the transmission of viral agents through the feeding of wastes. Although viral agents might vary in their tolerance to environmental conditions, studies with five model bacterial viruses inoculated at a rate of 0.1 to 10 billion viruses per gram of beef feedlot waste fermented with cracked corn, showed a 90% destruction of viral propagules in less than 18 hours (15). Most of the viral populations were reduced by 90% in less than 5 hours. If the tolerance of these bacterial viruses is typical of poultry viruses, the ensiling process should be adequate to eliminate viruses from ensiled poultry litter. Heat and ammonia generated during the dry stack processing of litter should be adequate to eliminate most types of viruses from litter.

Arsenicals: Currently only 3-nitro-4-hydroxyphenylarsonic acid is used as a dietary arsenic supplement for poultry. Its use is limited to broiler poultry rations to improve feed efficiency. Studies conducted prior to 1985 revealed arsenic levels in poultry litter ranging from 1 to 76 ppm (21, 25). Arsenic levels in poultry litter have decreased because less of the 3-nitro compound is used compared to the other arsenic-containing compounds that were used in previous years (5). Because arsenic is a mineral element, it cannot be destroyed by processing the litter or even burning the litter to ash. Therefore, dry stacking or ensiling poultry litter will not destroy arsenic.

The tissues of ruminants predisposed to arsenic accumulation are the liver and kidney with little or no build-up in muscle tissues. Arsenic fed at 25.9 to 274.1 g/kg dry matter of feed to sheep increased the arsenic content in liver, kidney and blood of the sheep as the arsenic content of the diet was increased (3). Arsenic in muscle tissue of the sheep was unaffected, and levels in all tissues were depleted within 6 days after arsenic was withdrawn from the sheep diet (3). Lactating dairy cows fed diets containing 3.2 or 4.8 mg arsenic per kg body weight continuously for 28 days showed increased arsenic levels in milk the first 14 days of the study, and then the level plateaued. After a 5-day withdrawal period of arsenic from the diet, the arsenic level of the milk decreased to the pre-experiment level (3). The AAFCO guidelines (1) require a 15-day or more withdrawal period of poultry litter from beef cattle diets prior to slaughter of the animals. The 15-day withdrawal period should be adequate to eliminate any arsenic residues in beef cattle fed poultry litter.

Antibiotics and Drugs: The feeding of poultry litter to beef cattle which contains antibiotics and drugs not sanctioned for use in beef cattle is in violation of animal drug laws. The major issue is whether the drugs or their metabolites excreted by poultry are still potent, and whether they retain their potency in built-up poultry litter in the poultry house and also during the processing of litter for feed. The issue of drug residues in animals fed wastes has not been resolved because the research presents formidable tasks which public supported laboratories have neither the resources nor funds to undertake. This area of research might best be accomplished by animal drug manufacturers or their allied laboratories.

To avoid the risk of illegal drug residues in tissues of beef cattle fed poultry litter, feed only litter that is certified to be free of illegal drugs or use poultry litter from poultry growers who do not use the drugs. Another approach is to determine the clearance time for the drug or its metabolites from tissues of the animals fed the drug containing wastes. A study has reported that many drugs do not create a residue problem in tissues of beef cattle following a 5-day litter withdrawal period (37). It is unlikely that antibiotics would persist long in poultry litter. Built-up litter in the poultry house has a myriad of microbes that are capable of degrading a variety of complex chemical compounds such as keratin, hemicellulose, cellulose and lignin. Antibiotics in litter also are likely to be attacked by microbes. If antibiotics are administered to broilers, the use will be restricted to the starter or early grower poultry production phases and none will be used during the finisher phase.

Most antimicrobials approved for use in poultry also are approved for beef cattle including enrofloxacin which is a fluroquinolone antibiotic only recently approved for use in beef cattle (8). Less than 1% of chicken and turkey flocks in the United States are treated yearly with the approved fluroquinolones (7). The use of antibiotics in poultry does not present a health risk to beef cattle fed poultry litter. The recommended 15-day withdrawal period for exclusion of litter from diet of cattle destined for market provides an additional safety measure.

<u>Hormones</u>: There has been only one reported incidence of health problems attributed to the feeding of poultry litter from poultry fed a diet supplemented with estrogen. One incidence of abortion was reported due to feeding litter from roaster poultry fed a ration containing 150 to 250 ppm of diensterol diacetate (13). The hormone has not been permitted in poultry rations for many years. Currently there are no hormones added to poultry rations.

<u>Coccidiostats</u>: The ionophore coccidiostats commonly used inpoultry production to control coccidia also are used to improve feed efficiency of beef cattle. One animal health product manufacturer markets Monensin for poultry and Rumensin for beef cattle, and another markets Avatec for poultry and Bovatec for cattle. Because these animal health products are approved for use in both poultry and beef cattle, any carry over of these coccidiostats to poultry litter poses no apparent risk to beef cattle fed the litter.

Nicarbazin is a coccidiostat that is approved for use in broilers but not in cattle. Poultry industry sources indicate that less than 3% of all broilers receive nicarbazin. Some growers use nicarbazin as an occasional alternative strategy to control coccidia. Nicarbazin is used only occasionally because it reduces feed efficiency. One study indicated that when litter containing 70 to 73 ppm of nicarbazin was fed to beef cattle for up to 198 days, there were no apparent differences in the nicarbazin levels of tissues of cattle fed litter compared to cattle not fed litter (37). Although there does not appear to be a problem with the feeding of litter containing nicarbazin, however, because the drug is not approved for cattle, it would be prudent to not feed litter which contains the drug.

Pesticides: The only insecticide permitted in poultry feed is Larvadex which is limited to laying hens and not broiler chickens (5). Other approved insecticides are used but their use is not permitted when birds occupy the house, and a time restraint is imposed before birds can occupy the facility again. Pesticides include insecticides, rodenticides and herbicides, and the use of these compounds are strictly regulated to not create illegal residues in poultry. As an additional safety measure the poultry industry analyzes fatty tissue of a few birds in a flock for pesticide residues before the flock is marketed. If there are no pesticide residues in the poultry, then it is unlikely that there will be pesticide residues in the poultry litter. Additional information on pesticide residues in cattle fed poultry litter was published by Fontenot *et al.* (11) and McCaskey and Anthony (21).

Heavy Metals: The term heavy metals generally refers to mineral elements such as lead, mercury, chromium and cadmium which are toxic to metabolic processes at relatively low levels. These mineral elements are not added to animal feeds but they might be detected in feeds at very low levels which represent natural background levels in the environment. There should not be a problem with heavy metals in poultry litter if there was not a problem with the poultry feed or with the material used as bedding in the poultry house. Arsenic, which was discussed earlier, is added to broiler poultry rations, however arsenic and most of the drugs have a mandatory withdrawal time before the birds are marketed. Also, AAFCO guidelines require a 15-day withdrawal time for exclusion of poultry litter from diets of cattle before slaughter (1).

Copper is added to broiler poultry diets up to two pounds of copper sulfate (39.8% Cu) per ton of feed (5). The rate most commonly used is one pound per ton of feed. At the two pound rate, the copper content of poultry feed would be 398 ppm. Copper analysis of 46 samples of broiler litter from broiler operations feeding dietary copper revealed an average copper level of 254.7 ppm (37). Litter samples collected from operations not feeding dietary copper had an average copper level of 50 ppm with a range of 37.3 to 99.4 ppm. Copper is added to poultry feed to retard mold growth and to improve poultry feed efficiency. The only documented evidence of harmful effects of feeding animal waste to animals is copper toxicity in sheep fed broiler litter with high copper levels (9). Sheep fed a diet containing broiler litter for 254 days resulted in death of 55% of the ewes fed the 25% litter diet and 64% death of ewes fed the 50% litter diet (10). Liver copper levels at death or slaughter were higher for ewes fed the litter diets. The litter contained 195 ppm of copper and rations containing 0, 25 and 50% litter had 17.8, 57.1 and 109.1 ppm of copper, respectively.

Beef cattle are considerably more tolerant to dietary copper than sheep. Beef cattle fed broiler litter with 259 ppm of copper for 121 days in trial 1 and fed litter with 228.6 ppm copper for 198 days in trial 2 showed no evidence of copper toxicity (37). The liver is predisposed to copper accumulation and this was evident whether the cattle were fed or not fed broiler litter. There was no significant difference in the liver copper level of cattle fed the litter diet or the control diet in trial 1 but there was a difference in trial 2. However, there was no difference in muscle tissue copper level of cattle fed either the litter or control diets.

The National Research Council on nutrient requirements for beef cattle (28) designates 115 ppm of copper as the maximum tolerable dietary level for beef cattle. Some state departments of agriculture require processed litter and litter formulations marketed as feed to not exceed 100 ppm of copper. The AAFCO (1) guidelines, which have been adopted by the state departments of agriculture and apply to all feed ingredients, require poultry litter and all types of processed animal waste products marketed as feed which contain 25 ppm or more of copper to bear the following label "Warning: Contains high levels of copper: Do not feed to sheep." As an added precaution that applies to copper and all the safety issues, it is strongly advised that poultry litter or any type of animal excreta, processed or otherwise, not be fed to animals if it is not possible to have a practical withdrawal period of the excreta from the diets of the animals before the animals or their products are marketed for human consumption.

<u>Trace Elements</u>: The mineral elements of most concern relative to the safety of feeding broiler poultry litter to beef cattle are arsenic and copper (4). These elements are usually added to broiler poultry diets and thus will be deposited in the litter bedding. Health issues concerning arsenic and copper in litter have already been discussed. Selenium is a trace mineral and it too, may be added to broiler poultry diets. Like arsenic and copper, selenium cannot be destroyed in the litter. The NRC recommendation for dietary selenium for broiler poultry is 0.15 ppm (29), however diets may be supplemented with 0.30 ppm (5). The NRC dietary selenium

recommendation for beef cattle is 0.1 ppm with a maximum tolerable level of 2 ppm (30).

There is very little data on the selenium content of broiler poultry litter. One study reported 0.31 ppm as the mean selenium content of 17 broiler litter samples and a range of 0 to 0.86 ppm (14). Another study reported 1.09 ppm of selenium for one litter sample (38), and the NRC reported 0.79 ppm (28). These levels of selenium in poultry litter do not appear to present a health risk to beef cattle fed litter because cattle can tolerate up to 2 ppm of selenium in their diets. Some feed ingredients such as brewers grains, corn gluten meal, hydrolyzed poultry feathermeal and yeast have selenium levels comparable to or higher than the reported levels in poultry litter (28).

<u>Prion Diseases</u>: Questions have been raised about the potential risk of prion diseases being contracted by cattle fed litter. This concern originates from the permitted feeding of rendered ruminant by-products to poultry. The feeding of these by-products to poultry, which might find their way into poultry litter either as spilled feed or after passage through the bird's digestive tract, has been questioned relative to the risk of beef cattle contracting prions from poultry litter.

Based on information from several sources, the risk of beef cattle contracting prions from poultry litter resulting from poultry fed ruminant by-products is extremely remote. The low risk is based on the low usage of ruminant by-product feed used in poultry diets, the carbonaceous nature of prions that are not likely to escape alteration by microbes in built-up poultry litter, and the fact that no "Mad Cow Disease" associated with cattle has ever been reported in the United States. Over 7,000 cattle, mostly "downer" cattle, have been examined and none have shown evidence of the disease (12). If the disease has not been reported in cattle in the United States, then it is not likely that poultry litter fed to beef cattle would present a risk of the disease. Most poultry operations use their own poultry processing by-products in poultry feed, unless the price differential favors the feeding of ruminant by-products. A large portion of the ruminant by-product market is for pet food and only blood meal is permitted to be used as a feed supplement for ruminants. Personal communications indicate that only limited use is made of ruminant by-products for poultry feed.

CONCLUDING REMARKS

Broiler litter has been used as an alternative feed source for beef cattle for over 40 years (4). The California Department of Agriculture in 1974 was the first state to regulate the marketing of poultry litter as a feedstuff (14). In October, 1977, the Association of American Feed Control Officials (AAFCO) drafted guidelines for marketing of poultry litter and other animal excreta by-products (27), and these guidelines currently serve as the regulatory model for state governments that license the marketing of litter as a feedstuff. When the AAFCO guidelines are followed, health risks of feeding litter are minimized, however it is not possible to achieve absolute safety. The feeding of litter has been practiced for over 40 years in the United States, and there have been no documented incidences of health hazards to animals fed processed litter except to sheep. This record of achievement is cited as the major testament to the safety of feeding poultry litter to beef cattle.

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POULTRY LITTER TREATMENT-PLT®

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Poultry Litter Treatment-PLT® is a dry granular liter additive used extensively by the poultry industry for poultry house ammonia control, litter acidification, on-farm HACCP programs for pathogen reduction, and in the prevention of many bacterial or stress related poultry conditions. PLT® meets Food Chemical Codex Standards that ensure product safety and purity and PLT® is manufactured under ISO 9002 standards that ensure consistent quality. PLT® has been used by the poultry industry since 1989 as a method of cutting production costs and increasing revenues. Hundreds of millions of birds have been grown on PLT® treated litter. Research has been conducted at dozens of independent universities and poultry production companies to document the current usage of PLT® in the poultry industry.

PLT® is a unique blend of sodium bisulfate and other ingredients that have three mechanisms of action. Sodium bisulfate is considered a non-hazardous and non-toxic substance classified as a GRAS and food grade substance. PLT® eliminates ammonia by converting litter ammonium to ammonium sulfate, lowers litter pH to acidify litter, and provides potent ionic effects that enhance acidification. These actions lead to a host of benefits in poultry production and represent the first non-hazardous and non-toxic litter treatment used as part of an overall Total Litter Management Program (Terzich, 1997).

POULTRY HOUSE AMMONIA AND LITTER pH

The volatilization of ammonia has been attributed to microbial decomposition of nitrogenous compounds (Carlile, 1984), principally uric acid in poultry house litter. Litter pH plays a decisive role in NH_3 volatilization. Once formed, the free ammonia will be in one of two forms: as the uncharged NH_3

species or the ammonium ion (NH4), depending on the pH of the litter. Ammonia concentration increases with increasing pH (Carr *et al.*, 1990). Ammonia release is small when litter pH is below 7.0, but substantial when litter pH is above 8.0. Uric acid decomposition is most favored in alkaline pH conditions. Uricase, the enzyme that catalyzes uric acid breakdown, has maximum activity at a pH of 9 with uric acid disappearance decreasing nearly linearly for more acid or alkaline pH values. One principal ureolytic bacterium, *Bacillus pasteurii*, can not grow at neutral pH, but thrives in litter above 8.5 (Burnett and Dondero, 1969; Ivos *et al.*, 1966).

Several chemicals have been used to control or reduce ammonia release from poultry litter. They act by either inhibiting microbial growth, and hence uric acid decomposition, or by neutralizing ammonia by combining with the released ammonia (Carlile, 1984). Phosphoric acid liquid treatment of poultry litter lowered litter pH and decreased ammonia levels compared to control, but caused concerns with phosphorus run-off (Reece *et al.*, 1980). Other chemical litter treatments are considered hazardous substances or have been documented to cause toxicity in poultry (Julian and Brown, 1997). PLT® is a dry acid used in poultry litter to control ammonia, lower litter pH, and alter litter ionic balance to provide an environment in which pathogenic bacteria are controlled.

To determine the effects of PLT® on ammonia control, two hundred 40′ x 500′ poultry houses were studied in the mid-Atlantic region during the winter of 1996, one hundred had the litter treated with PLT® at rate of 2.5 kg/10m2 by topdressing the litter the day before chick placement, the other hundred houses were controls with non-treated litter. The farms were paired and conditions in the matched control and treated houses were the same. Ammonia levels were measured (Matheson toxic gas detector Model 8014KA; Precision gas detector tubes #105SC, 5-260 ppm; Fisher Scientific Co., Pittsburgh, PA) at floor level before PLT® treatment, immediately after treatment, and on a weekly basis for the flock duration. Litter pH levels were determined (PH TESTR® 1 Model #35624-00 by Oakton; Fisher Scientific Co.) by collecting 60 ml of litter and mixing with an equal amount of distilled water. All samples were collected in six different locations in the house and the data represents averages of those readings.

Fuel usage was measured daily during the test period and the control houses averaged 43% greater usage than treated houses due to longer fan times and venting of heat. In this study, PLT® treated litter houses had significantly lower ammonia (Table 1) and litter pH (Table 2) than untreated litter control houses.

Table 1. PLT® Treated Litter in 100 Houses vs. 10 Untreated Control Houses. Data represents Average of 100 Houses in each group.

	Ammonia Levels in ppm as Affected by PLT®3								
	Before	After	1 Wk	2	3 Wks	4 Wks	5 Wks	6 Wks	7 Wks
PLT®	127	0	0	5	8	15	19	20	18
Control	119	119	125	125	138	114	128	98	97

Table 2. Litter pH as Affected by PLT®.

	Before	After	1 Wk	2 Wks	3 Wks	4 Wks	5 Wks	6 Wks	7 Wks
PLT®	8.5	1.7	2.1	3.4	4.5	5.0	5.5	5.9	6.4
Control	8.9	8.9	8.7	9.1	8.5	9.3	8.6	8.1	8.9

The detrimental effects of ammonia in poultry production have been known for years. Numerous laboratory and field studies have shown how ammonia affects bird health and performance. High ammonia levels damage the bird's respiratory system and allow viruses and bacteria to cause infection leading to declining flock health and performance (Nagaraja *et al.*, 1983). *E. coli* bacteria are significantly increased in the lungs, air sacs, and livers of birds exposed to ammonia following aerosol exposure to *E. coli*. Because of ammonia damaged tracheal cilia, clearance rate of *E. coli* from the bird is decreased compared to birds not exposed to ammonia (Nagaraja *et al.*, 1984). Body weight, feed conversion, and condemnation rates of ammonia exposed birds are poorer as ammonia levels rise (Quarles and Caveny, 1974) and resistance to respiratory diseases is decreased (Anderson *et al.*, 1964).

BIRD PERFORMANCE

Birds from another field study were processed and bird performance was evaluated between PLT® litter treated houses and the control non-treated litter houses (Table 3).

Table 3. Bird Performance as Affected by PLT®.

	# Birds	% Mort.	Age-Days	Avg. Weight (lbs.)	Adjusted Feed Conversion
PLT®	2,345,759	3.48	45.7	5.08	1.94
Control	2,478,957	4.29	46.3	4.79	2.09

ASCITES

A study was conducted at the facilities of Colorado Quality Research, Inc. to determine the effects of PLT® on atmospheric ammonia and death in broilers due to ascites (Terzich *et al.*, 1998). Data were collected from 2640 chicks raised in containment conditions that resembled commercial settings.

The ascites death rate (5.9%) in broiler chicks on PLT® treated litter was significantly lower than that (31.5%) in broiler chicks raised on untreated litter. Likewise, atmospheric ammonia levels in pens that had been treated with PLT® were significantly lower than those in pens that received no treatment (Table 4).

Table 4. Comparison of Atmospheric Ammonia Levels (ppm) in Pens With Non-treated Litter and PLT® Treated Litter.

	Interval*					
Treatment	-1	0	7	14	22	48
Control	96.3	94.5	72	114.5	114.8	52.5
PLT®	87.5	5.1	14	20.4	22	19

*Intervals are in days post-treatment. Day 0 is the day of litter treatment and is also the day before chick placement. All readings between control pens and treated pens are significantly different except day -1.

LITTER PATHOGENS

The pH of poultry house litter has an effect on litter bacteria populations. As the litter pH decreases from an average litter pH of 8.0-9.0 down to 4.0, the bacteria load decreases (Hardin *et al.*, 1989).

A study was conducted in the laboratory in 12 polyethylene containers, 12" x 12" x 12" with sterilized poultry litter (*wood-shavings) and in 12, 11′ x 12′ colony houses. The litter was treated with PLT® at a rate of 3 lbs/100 sq. ft. by topdressing once. The litter was dragged over the surface of a 2" x 2" swab before and after PLT® application and at 3, 6, 24, 48, 72, and 168 hours after PLT® application. The litter was seeded with 2 x 109 colony forming units of *Salmonella enteritidis* prior to PLT® treatment. The litter drag swabs were cultured on MacConkey and XLD agar. All potential colonies were verified by biochemical assays and typed by anti-serum agglutination. Verified Salmonella colonies were quantified as no growth, 1-10, and > 10 colonies.

In this trial, PLT® treated litter had significantly lower pH than control, non-treated litter and PLT® treated litter had significantly lower Salmonella counts (Table 5).

Table 5. The Effect of PLT® Treated Litter on *Salmonella enteritidis* (SE) Growth.

Hrs After Treatment	PLT® Litter SE Count	PLT® Treated Litter pH	Control Litter SE Count	Control Litter pH
0	++[a]	8.0	++	7.9
3	NG[b]	2.1	++	7.8
6	NG	2.3	++	7.5
24	NG	2.4	++	7.9
48	NG	2.3	++	8.1
72	NG	2.5	+	7.8
168	NG	2.8	+	7.9

[a]+ = 1-10 colonies, ++ = > 10 colonies. [b]NG = No Growth.

These findings have implications for bird health and performance and food safety. Mallinson *et al.* have shown that litter Salmonella has been linked to poor bird feed conversion, and increased condemnations with decreased weight gains. They have linked on-farm HACCP based pathogen control program success with reduction of Salmonella and other pathogens and manipulation of litter characteristics as part of these programs.

Salmonella bacteria were responsible for 27.4% of all reported foodborne illness in the US in 1997. However, Campylobacter bacteria were discovered in 49.4% of foodborne illness incidents in 1997 (Reported in Meat and Poultry, July 1998 from FoodNet: An Active Surveillance System for Bacterial Foodborne Disease in the United States, April, 1998).

In a recent USDA study (Table 6), the effects of PLT® on Campylobacter were studied. Eighty Campylobacter inoculated chicks were placed in each of several pans. After a 7 week grow-out period the inoculated seeder birds were removed and the litter from 2 pens was treated with PLT®. One pen had litter treated with the normal application rate (2.5 kg/10 m^3) another had a higher rate (4 kg/10 m^3), and a third pen has no treatment. Newly hatched uninoculated chicks were placed in the pens and grown for 6 weeks. Cecal and whole carcass rinses (WCR) were taken at weeks 1.5, 5, and 6. All positive control birds in the new uninoculated chicks were colonized with Campylobacter by 1.5 weeks. All PLT® groups remained Campylobacter free for the duration of the study.

Table 6. Effects of PLT® Treated Litter on Carcass Campylobacter.

	Before Treatment		Week 1.5		Week 5		Week 6	
	Fecal	Cecal	Cecal	WCR	Cecal	WCR	Cecal	WCR
Pos. Control								
Log cfu Campy/g	5.66	7.05	>6.0	2.09	+	+	3.46	1.42
% Campy Positive	100	100	100	100	100	100	75	50
PLT® (2.5 kg)								
Log cfu Campy/g	3.84	7.0	-	-	-	-	-	-
% Campy Positive	100	100	0	0	0	0	0	0
PLT® (4 kg.)								
Log cfu Campy/g	5.09	7.13	-	-	-	-	-	-
% Campy Positive	100	100	0	0	0	0	0	0

LITTER BEETLES

The darkling beetle, *Alphitobius diaperinus*, also referred to as the lesser mealworm, litter beetle, black bug, and black poultry bug, is found abundantly in poultry house litter and manure worldwide. They originated in Africa, but have become well adapted pests in poultry houses feeding on dead birds, poultry feed, and manure. Untreated poultry litter is a perfect environment for beetle reproduction (Jones *et al.*, 1994).

Beetles threaten profitable poultry production in three ways: 1) they burrow into and damage poultry house insulation, destroying up to 30% of the total insulation resulting in substantially higher fuel usage; 2) consumption of beetles and larvae by birds may result in decreased weight gain and feed efficiency; 3) beetles are well know transmitters of many costly poultry diseases (De Los Casas *et al.*, 1972; Despins *et al.*, 1994; Eidson *et al.*, 1966).

The purpose of this trial was to determine the effect of litter acidification with PLT® on beetle populations in poultry houses and the effect of litter acidification of effective life of insecticides. Twelve commercial broiler houses were used for this study. PLT® was applied at 2.5 kg/10 sq. m in two houses, two houses had litter untreated as controls, and two houses each had litter treated with an organophosphate insecticide, pyrethroid insecticide, PLT® with organophosphate, and PLT® with pyrethroid. Beetle counts were done at several locations in each house on a weekly basis for the flock duration of seven weeks by using 1.5 inch diameter plastic tubes with corrugated cardboard inserts. The results (Table 7) showed that litter acidification is critical to insecticide efficacy with lower litter pH resulting in greatly increased life compared to higher, commonly found, litter pH and PLT® helps lower beetle populations.

Table 7. The Effect of SBS and Insecticides on Beetle Populations (data represents average counts/tube from two replicates/treatment).

Treatment	Wk 1	Wk 2	Wk 3	Wk 4	Wk 5	Wk 6	Wk 7
Control	5	25	35	38	58	73	128
PLT®	7	5	8	12	14	16	48
Organophosphate	3	5	6	15	12	23	35
PLT® + Organophosphate	3	3	4	8	7	10	9
Pyrethroid	2	5	7	12	18	28	45
PLT® + Pyrethroid	2	3	3	7	12	15	14

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REDUCING AMMONIA VOLATILIZATION AND DECREASING PHOSPHORUS RUNOFF FROM POULTRY LITTER WITH ALUM

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THEORY

Ammonia (NH_3) is produced in animal manures, by the breakdown of urea. Since NH_3 is uncharged, it can be given off as a gas. The gaseous emission of NH_3 can be inhibited if the NH_3 is converted to NH_4^+ (ammonium); which can be accomplished by lowering litter pH. Aluminum sulfate ($Al_2(SO_4)_3 \cdot 14H_2O$), commonly referred to as alum, is an acid that produces six moles of hydrogen ions (H^+) when it dissolves, in one of the following ways;

$$Al_2(SO_4)_3 \cdot 14H_2O + 6H_2O \longrightarrow 2Al(OH)_3 + 6H^+ + 3SO_4^{2-} + 14H_2O \quad \text{Equation 1}$$

$$Al_2(SO_4)_3 \cdot 14H_2O + 2H_3PO_4 \longrightarrow 2AlPO_4 + 6H^+ + 3SO_4^{2-} + 14H_2O \quad \text{Equation 2}$$

The hydrogen ions produced by this reaction will react with NH_3 to form NH_4^+, which will react with sulfate ions to form six moles of ammonium sulfate, as follows;

$$6NH_3 + 6H^+ \longrightarrow 6NH_4^+ \quad \text{Equation 3}$$

$$6NH_4^+ + 3SO_4^{2-} \longrightarrow 3(NH_4)_2SO_4 \quad \text{Equation 4}$$

Ammonium sulfate is a water soluble fertilizer. As a result of these reactions the amount of NH_3 emitted from litter will be reduced, which will increase the fertilizer N value of the litter. Alum additions should also result in less soluble phosphorus, as shown in equation 2. Another possible mechanism of soluble phosphate reduction is adsorption of phosphorus to aluminum hydroxide, as follows;

$$Al(OH)_3 + H_3PO_4 \longrightarrow Al(OH)_3\text{-}H_3PO_4 \quad \text{Equation 5}$$

With time this amorphous aluminum phosphate compound would probably be transformed into a crystalline mineral, such as variscite ($AlPO_4 \cdot 2H_2O$) or wavellite ($Al_3(PO_4)_2(OH)_3 \cdot 5H_2O$).

LABORATORY AND SMALL PLOT STUDIES ON PHOSPHORUS

The goal of research on adding alum to poultry litter was initially to precipitate soluble phosphorus and thus reduce phosphorus runoff. Edwards and Daniel (1993) had shown that most of the phosphorus in runoff from pastures fertilized with poultry litter was in the soluble form. Based on this finding, we hypothesized that aluminum, calcium or iron amendments would reduce soluble phosphorus and decrease runoff. A laboratory study was conducted where 100 different treatments (various Al, Ca, and Fe compounds) were added to poultry litter. Many of these compounds reduced soluble P levels from 2,000 mg P/kg to approximately 1 mg P/kg (Moore and Miller, 1994).

The results obtained by Moore and Miller (1994) were promising, but did not provide direct evidence that these amendments would reduce phosphorus runoff from lands fertilized with poultry litter. Hence, a small plot experiment was conducted using rainfall simulators (Shreve *et al.*, 1995). The results from this study indicated that alum applications to poultry litter could reduce phosphorus concentrations in runoff water by 87% (Shreve *et al.*, 1995).

We also found tall fescue yields were significantly higher when plots were fertilized with alum-treated litter, compared to normal litter or litter treated with ferrous sulfate. Analysis of the plant tissue indicated that the plants fertilized with alum-treated litter had higher N contents than the other treatments, indicating N availability to the fescue had been increased with the addition of alum (Shreve *et al.*, 1995). The most obvious mechanism of increased N availability to plants fertilized with poultry litter is a reduction in ammonia volatilization.

LABORATORY STUDIES ON AMMONIA VOLATILIZATION

For over 30 years researchers have known that high levels of atmospheric NH_3 negatively affects poultry performance (Anderson *et al.*, 1964). High NH_3 levels cause decreased weight gains, reduced feed efficiency, damage to the respiratory tract, increased susceptibility to diseases like Newcastle, and can cause blindness (Carlile, 1984). As a result of these problems, Carlile (1984) suggested that atmospheric NH_3 not exceed 25 ppm in poultry houses.

Ammonia volatilization experiments were conducted in the laboratory to assess the efficacy of different chemicals to reduce ammonia emissions (Moore *et al.*, 1995, 1996). These studies showed that many of the chemicals currently used by poultry producers, such as ethylene glycol, calcium-iron silicates, sodium bisulfate, and extracts from yucca plants had no significant effect on ammonia volatilization from litter over a 42 day period when applied at the manufacturers recommended rate (Moore *et al.*, 1995, 1996). Iron compounds, such as ferric chloride and ferrous sulfate did result in a significant reduction in NH_3 loss, however, the most effective treatments were alum and phosphoric acid (Moore *et al.*, 1996). Phosphoric acid has been used for about 20 years in the Delmarva area to reduce ammonia volatilization from litter. Although it is efficacious and cost-effective, it results in high levels of soluble and total phosphorus in litter, which would increase phosphorus runoff (Moore *et al.*, 1996).

FIELD TRIALS WITH ALUM

As a result of the above mentioned research, the U.S. EPA provided support of our work to demonstrate the effectiveness of alum in reducing phosphorus runoff from agricultural fields (Moore *et al.*, 1997a). The objectives of this project were to determine the effects of alum applications to poultry litter in commercial broiler houses on (1) litter pH, (2) NH_3 volatilization and atmospheric NH_3 levels, (3) poultry performance, (4) energy use, and (5) phosphorus runoff from fields fertilized with litter.

Alum was applied at a rate of two tons/house, which is equivalent to 0.2 lbs/bird. This amount was based on an application rate corresponding to 10% alum by weight of the litter (20,000 broilers produce about 20 tons of moist litter per growout).

Alum additions reduced litter pH significantly, particularly for the first 3-4 weeks (Moore *et al.*, 1997a). This reduction in pH resulted in significant reductions in NH_3 volatilization rates and atmospheric NH_3. Moore *et al.* (1997b) found that NH_3 volatilization rates were reduced by 97% for the first four weeks of the growout and 75% for the full six weeks. This reduction in NH_3 volatilization also reduced atmospheric NH_3 levels in the houses treated with alum, compared to the controls, even thought the ventilation rates were much higher in the control houses during the winter months (Moore *et al.*, 1997a). These results were confirmed by Brewer (1998), who showed that NH_3 fluxes during the first 3 weeks of a growout were reduced by near 100% with the full rate of alum and by 52% with the half rate.

Poultry performance was improved markedly with alum use. Birds grown on alum-treated litter were significantly heavier than controls (3.80 versus 3.65 pounds). Feed conversion was also better when alum was used (1.98 versus 2.04) and mortality tended to be lower (3.9 versus 4.3%). As a result of these improvements in performance and reduced energy costs, an economic analysis showed that the benefit/cost ratio of this practice was 1.96 indicating that it is very cost-effective (Moore *et al.*, 1997a).

Both soluble and total phosphorus in runoff water were monitored from paired 1-acre watersheds for three years. Litter application rates were 2.5, 4.0, and 4.0 tons/acre for years 1, 2, and 3, respectively. Alum applications reduced soluble phosphorus concentrations in runoff water by 75% over the 3 year period (1.60 mg P/L for alum-treated litter and 6.29 mg P/L for normal litter). Total phosphorus followed the same trends (Moore *et al.*, 1997a).

Aluminum concentrations in runoff were not significantly different between alum-treated and normal litter (Moore *et al.*, 1997a). This was supported by small plot studies conducted by Moore *et al.*, (1998a) who showed that aluminum runoff from tall fescue plots fertilized with alum-treated litter was not significantly different from runoff from normal litter.

LONG-TERM STUDIES ON ALUM

One obvious gap in research is on the effects of long-term applications of poultry litter to land. Therefore, we initiated long-term studies on 52 tall fescue plots in 1995. There are a total of 13 treatments in this study; an unfertilized control, four rates of normal poultry litter, four rates of alum-treated litter and four rates of ammonium nitrate. The four rates of litter are 1, 2, 3, and 4 tons/acre (2.24, 4.49, 6.73, 8.98 Mg/ha). Ammonium nitrate is being applied at rates roughly equivalent to the amount of nitrogen supplied by alum-treated litter (65, 130, 195 and 265 kg N/ha). The fertilizers will be applied once each year (in the spring) for 20 years. The objectives are to determine the effects of normal litter, alum-treated litter and ammonium nitrate on soil chemical characteristics, yields and nutrient uptake by tall fescue, and runoff water quality.

Large differences in soil test phosphorus have been observed after only three years of annual applications. Water soluble phosphorus levels have increased dramatically in the plots fertilized with normal litter, particularly at the higher rates, whereas soluble phosphorus in plots fertilized with alum-treated litter is not different from that in the unfertilized control plots (Self-Davis *et al.*, 1998). Studies have shown that water soluble phosphorus in soils is a very good predictor of phosphorus concentrations in runoff water (Pote *et al.*, 1996).

One of the reasons alum was chosen for phosphorus control was because aluminum phosphates are stable under a wide range of soil physical and chemical conditions. Iron phosphate minerals are affected by redox reactions and can be reduced under wet conditions, releasing soluble phosphorus. Likewise, calcium phosphate minerals are not stable under acid conditions (Moore *et al.*, 1998d). Aluminum phosphates are not affected by redox reactions and are stable over a very wide range of pH conditions (Lindsay, 1979; Moore *et al.*, 1998d). The aluminum phosphate mineral that forms when alum is added to poultry litter will likely be stable for geological time periods.

Another important parameter that has been affected is soil pH. Acidity produced via nitrification of NH_3 from ammonium nitrate fertilizer has resulted in lower soil pHs on plots fertilized with ammonium nitrate, particularly at the higher rates (Moore *et al.*, 1998b). On the contrary, soil pH has increased with both normal litter and alum-treated litter. This is due to the fact that poultry litter (even alum-treated litter) contains more lime (calcium carbonate) than potential acidity from nitrification (Moore *et al.*, 1998b). Soil pH is considered one of the most important parameters affecting soil chemistry. One effect of reduction in pH noted in the plots fertilized with ammonium nitrate was an increase in exchangeable aluminum, with the high rate of ammonium nitrate causing exchangeable aluminum concentrations to be 5 times higher than that observed with both normal and alum-treated litter (Moore *et al.*, 1998b). This increase in exchangeable aluminum is expected to continue with time, as the pH of the soils fertilized with ammonium nitrate decreases. Eventually, we expect that the fescue yields and aluminum uptake will be negatively impacted by this acidity, although this has not been documented to date. Runoff studies conducted on these plots have shown that alum-treated litter does not increase aluminum runoff, as mentioned earlier (Moore *et al.*, 1998a).

Research has also shown that alum applications to poultry litter reduce estrogen and heavy metal concentrations in runoff water. Nichols *et al.* (1997) found ß17-estradiol concentrations in runoff water were significantly lower from alum-treated litter than from normal litter. Moore *et al.* (1998) found heavy metal (arsenic, copper, iron and zinc) concentrations in runoff to be significantly reduced by alum. At present, it is unclear whether or not estrogen loading to the aquatic environment is cause for concern.

CONCLUSIONS

1. Alum reduces NH_3 volatilization by lowering litter pH.
2. Alum was found to be more effective than most compounds in reducing NH_3 volatilization.
3. Alum additions to litter precipitated soluble phosphorus and reduced phosphorus runoff.
4. Alum reduced ammonia volatilization by 97% for the first four weeks in commercial houses.
5. Broilers grown with alum were heavier, had better feed conversion and lower mortality.
6. Alum applications resulted in less energy use due to reduced ventilation requirements.
7. The benefit/cost ratio for alum use was 1.96, indicating it is very cost-effective.
8. Alum reduced phosphorus runoff by 75% from small watersheds.
9. Soil aluminum, aluminum runoff and aluminum uptake by plants were not affected by alum.
10. Ammonium nitrate fertilizer acidified the soil, resulting in higher exchangeable aluminum.
11. Normal litter increased water soluble phosphorus in soils; alum-treated litter did not.
12. Aluminum phosphates are far more stable in acid soils than calcium phosphates.
13. Alum applications reduced heavy metal and estrogen runoff.

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SULFUR AND ACID TREATMENT

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High concentration of ammonia in broiler houses have been blamed for many respiratory problems. Damage to the respiratory tract may not always be directly detected, but irritation due to long term exposure, even at low levels, may lead to increased incidence of infection from microorganisms (Elrich, 1963). Anderson *et al.* (1964) has shown that ammonia concentrations as low as 20 ppm have exhibited histopathological damage to the respiratory tract of chickens and turkeys when exposed for six weeks. Quarles and Kling (1974) have also found that levels of 25 ppm caused severe cases of airsacculitis. In their study, average bird weights and feed efficiency were also reduced. The amount of airborne bacteria were also found to increase with increased ammonia after eight weeks. Problems associated with excessive ammonia levels have not been limited to the respiratory tract. Eye disorders have also occurred due to elevated ammonia levels. Valentine (1964) reported that 60 ppm ammonia would cause keratoconjunctivitis.

There have been attempts to reduce broiler house ammonia levels by various litter treatments. Earlier methods were the application of superphosphate to trap N, but this method had only limited success. By the end of a 17 day brooding period, the ammonia levels and the litter pH had reached the same levels as the control (Reece *et al.*, 1979). The main reason for failure of this treatment was the application rate used. In their study they applied only approximately 1.29 mol_c/m_2 of monocalcium phosphate, while the ammonia deposition rate is about 32 mol_c/m_2 (assuming half of deposited N is ammonia). Thus, the rate used by Reece *et al.* (1979) would be insufficient when considering the reaction of $NH_3 + H_3PO_4 \rightarrow NH_4H_2PO_4$. They also used phosphoric acid at a rate of 4.25 mol H_3PO_4/m^2. This material was more effective than the superphosphate since it was applied at a higher molar rate. The application of H_3PO_4 has a two fold effect, lowering pH and trapping NH_3 as $NH_4H_2PO_4$. But again the treatment was at less than optimum rate.

A method using litter aid (95%, ferrous sulfate) at a rate of 1.46 kg/m^2 had some initial effect on ammonia levels but was gone by 7 weeks (Huff, 1983). The use of ferrous sulfate is dependent upon the oxidation of ferrous to ferric or iron oxide (FeOOH) as shown by the following reaction: $FeSO_4{}^*7H_2O + 1/4O_2 \rightarrow FeOOH + 2H^+ + 5.5H_2O + SO_4{}^{2-}$. The rate applied in this study was approximately 10 $mol_c\ m^{-2}$ which is higher than any previous study, but still less than needed. This study showed the acidifying nature of ferrous sulfate but this oxidation process may become limited and even reverse when litter moisture becomes excessive and conditions become anaerobic.

Formaldehyde has also been shown to reduce ammonia gas levels, Seltzer *et al.* (1969) found in laboratory experiments that paraformaldehyde flakes successfully reduced ammonia to very low levels. This technique was applied in the broiler house by Veloso *et al.* (1974), but there was no affect on pH and any effect on ammonia levels was not reported. However, microbial populations were reduced for the first 8 weeks.

Recently, alum application to broiler house floors has been investigated to determine pH and ammonia reduction during a grow out period (Moore and Miller, 1994). Alum was effective in lowering litter pH and reducing NH_3 levels. Moore and Miller (1994) also found that P solubility was reduced in litter.

Many previous studies used rates that were as much as 10-100 times too low to compensate for the buffering capacity of the litter or compacted material after clean out. The use of acid materials such as H_2SO_4, CHl, and H_3PO_4 plus an acid forming material such as elemental sulfur have received little or no attention in previous research. Phosphoric acid would also be an excellent acidifier since it has a normality of 44.6 in its concentrated form. However, the phosphorus concentration in litter may make the disposal of litter treated with H_3PO_4 or polyphosphates less desirable when disposal may be limited by the phosphorus content. However, the litter would be improved as a fertilizer source due to increased nitrogen and phosphorus.

MATERIALS AND METHODS

Initial attempts to adjust broiler house floors to a lower pH used HCl, elemental S and alum ($AlSO_4{}^*6H_2O$. These materials were applied at meq rates to lower the broiler house floor pH to 5.5 to a depth of 2.54 cm using titration data similar to that found in figure 1. Materials were applied to 1 m^2 areas with four replications randomized within one house. At another location five houses were treated with HCl.

More recently, H_2SO_4, was used to lower pHs because it does not have the problem of fumes as does HCl in its concentrated form and is a stronger acid with a normality of about 36. The acid was added to water in a 270 gallon plastic tank with a 6 ft boom of PVC pipe with holes approximately one inch apart that was attached on the bottom of the tank. The boom was gravity fed and evenly distributed the acid on the broiler house floor. Tractor speed was adjusted to 88 ft/min and flow rate was approximately 33 gal/min. This gravity feed system eliminated any spray mist that might corrode equipment.

Figure 1 would represent about 32 gallons of concentrated sulfuric acid for a 16,000 sq ft house. Amounts were also determined based on bulk density of the broiler house floor since it may differ from loose litter to a packed floor after clean out.

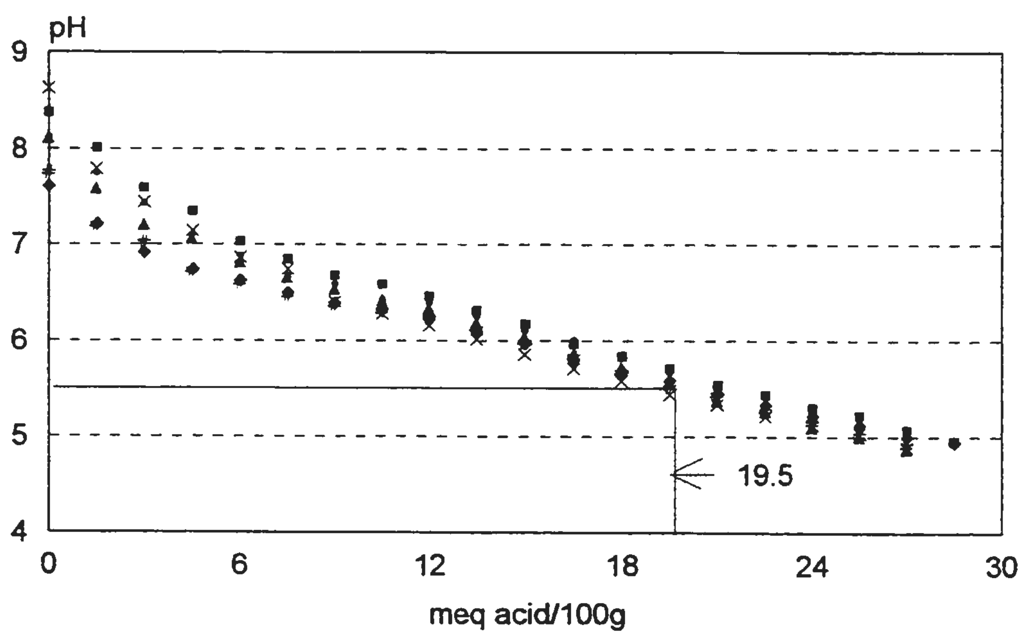


Figure 1. Titration of broiler house floor after clean out using H_2SO_4. Target pH was 5.5 for a 2.54 cm depth.

RESULTS AND DISCUSSION

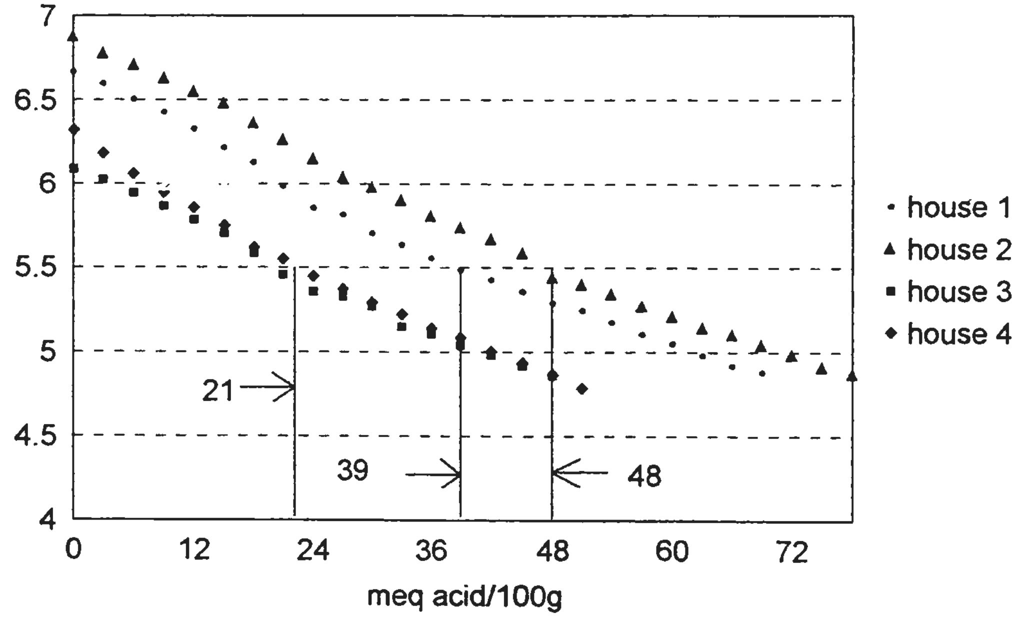
Since all previous studies were directed at the amelioration of the litter or underlying soil with out determining buffer capacities, a preliminary study in cooperation with a producer was initiated. Results have shown that HCl applied at a rate of 4 mol_c m^{-2} was successful in lowering soil pH and maintained lower litter pH for an extended period of time. This rate of acid application lowered the soil pH from an initial pH of 7.0 to 5.0 for a depth of 2.54 cm. Mortalities from the average of five houses went from 100 per day per house to less than 100 per batch. The approximate cost of treatment for five houses was $750 with a net increased profit of $5000 for one batch (personal communication, Dennis Maze, Blount County, Alabama).

The use of elemental S was unsuccessful in lowering pH. The likely cause for the failure of S to lower pH, which is routinely done in agricultural practices, may have been due to the excessive ammonia levels that inhibit thiobacillus bacteria population. Thus, preventing the oxidation of S that is required for acid production. Microbial processes for the generation of H^+ must have favorable conditions.

The application in these preliminary studies found that alum was not effective in lowering pH. Although other studies have found alum, when incorporated, was very effective in lowering pH (Moore, 1998). The suspected reason for the lack of alum reaction to lower pH may be due to occlusion of $Al_2(SO_4)_3 {}^*14H_2O$ by gibbsite ($Al(OH)_3$) when the outer surface of the alum started to dissolve gibbsite would precipitate on the surface thus trapping the unreacted alum.

Sulfuric acid was effective in lowering pH when applied at rates reflected by titration data that is required to reach a pH of 5.5. Prior to application strong ammonia odors were very noticeable, but immediately upon application ammonia odors were no longer apparent. Broad recommendation rates for acids simply based on sq ft may prove to be unwise. For example, figure 2 shows houses on the same farm may have varied acid requirements to achieve a pH of 5.5. Houses 3 and 4 require about 35 gallons of sulfuric acid while house 2 requires 80 gallons. A single acid rate based on sq ft would either excessively acidify or not be adequate for pH reduction.

The use of sulfuric acid was effective in achieving the desired pH, but there are several drawbacks to its use. Sulfuric acid is considered a hazardous material and transportation of the material must meet strict guidelines. The material may not be suited for the producer's own application because of the dangers associated with its handling. Specific application equipment must be used because of the acid's highly corrosive nature (avoid nonstrainless steel metals). Transferring the acid requires special pumps that may not be available to the producer and accidental spillage may cause severe injury.



Another aspect of poultry litter treated with sulfuric acid is that the P content may become more available. If the litter is used as a P source for fertilization or used in feed rations, then this would be a desirable treatment. From an environmental standpoint the more available P in the litter may cause problems in runoff. Phosphorus availabilities were not investigated with the sulfuric acid treated litter.

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OVERVIEW OF IN-HOUSE LITTER TREATMENTS

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Three basic types of litter treatments are chemical, microbial and enzyme-base products. For years, ammonia control was the primary purpose for using a litter treatment. In recent years, the reasons for using these treatments and the potential benefits derived have greatly expanded. Although the different types of litter treatments vary in efficacy of ammonia control, each type has unique characteristics that one needs to consider in selecting a product.

What is the best litter treatment? This is a frequently asked question for which there is no general answer. The difficulties in addressing this question are numerous. There has never been a comprehensive study that has evaluated all products under the vast range of management scenarios in the poultry industry. Total fecal accumulation, litter moisture, brooding program, bird type, ambient temperature and level/type of disease challenge are among a few of the variables potentially influencing product selection, efficacy and potential return on investment.

Most important in selecting a litter treatment is identifying the goals of the application. Litter treatments may be cost-effective and justified under one or more of the following situations; high fuel prices, extreme cold weather, short layout periods, persistent disease challenges, or severe vaccination reactions. Also, a desire to; reduce ammonia-related stress to achieve greater productivity and genetic potential from modern broilers, prolong the reuse of litter due to high bedding prices or limited availability, increase bird density, reduce ammonia-related carcass quality problems, or address marginal management or housing situations, may be objectives. Some litter treatments may be used to enhance the composition of the litter as a fertilizer or as part of best management practice to reduce food-borne pathogens. Ammonia reducing litter treatments offer a potentially better in-house environment for both the birds and growers. They may also play an increasing role in reducing ammonia and odor emissions from poultry facilities. The litter treatment that offers the best return on investment will depend on the user's ability to select the product that best meets the overall goals of his application.

Proper preparation, application and management of the house and litter are essential to maximize the effectiveness of any litter treatment. In the future, the use of litter treatments will likely increase since these products provide another management tool to address production or environmental quality problems associated with broiler production.

SOIL PHOSPHORUS LEVELS: CONCERNS AND RECOMMENDATIONS

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PHOSPHORUS - NECESSARY FOR PLANT AND ANIMAL GROWTH

Phosphorus (P) is a naturally occurring element in the environment found in all living organisms as well as in water and soils. It is an essential component for many physiological processes related to proper energy utilization in both plants and animals. Phosphorus can be added to the environment by man's activities as point source discharges or as non-point source runoff. Typical sources include industrial and municipal wastewater discharges and runoff from agricultural lands or urban areas. This publication addresses the concerns arising from land application of animal manures.

Plants derive P needs from soil. Livestock, in turn, derive part of their P needs from plant materials. However, much of the naturally occurring P in grains is in an indigestible form. Therefore, inorganic P sources are added to poultry and swine feeds to ensure adequate nutrition and to prevent rickets. As a result, much of the dietary P passes through livestock and poultry and is excreted in animal manure.

Utilizing animal manure as a fertilizer on crop and grazing land can recycle nutrients.

Plants uptake P from soil mostly in the orthophosphate form. Native soil P levels are often low enough to limit crop production. Both inorganic P fertilizers (treated rock phosphate) and organic P sources (animal manures) are equally adept at supplying the orthophosphate ion and correcting P deficiencies in soil. Most of the P in animal manure is in an organic form and must be converted to plant-available forms via soil biological activity, a process known as mineralization. The net effect of this characteristic is that P derived from animal manure may act more like a slow-release fertilizer than commercial inorganic fertilizers, which are more soluble and readily available to plants.

UNDERSTANDING SOIL TEST NUMBERS

The University of Arkansas' P fertilizer recommendations for crops are based on soil testing procedures. Soil samples are analyzed to determine the current levels of P available to the crop. Research-based recommendations are then made on the amount of additional P needed to achieve crop production goals.

When discussing P, it is important to make the distinction between elemental phosphorus (P) and the more historic phosphorus equivalent (P_2O_5). Soil test results are usually reported as elemental P. Animal manure analysis results are usually reported as the amount of phosphorus equivalent or P_2O_5, because commercial fertilizers are formulated with P_2O_5 (2.29 pounds of P_2O_5 is the equivalent of 1 pound of P).

Soil test phosphorus (STP) is not an indication of total P in the soil but how much is available for plant use. If STP numbers are to be compared, the laboratory test method for extracting P and how the number is reported (parts per million or pounds per acre) must be know. Different testing labs use different methods for extracting P, producing different test results that are difficult to compare even for the same sample. The University of Arkansas Soil Testing Laboratory uses the Mehlich III method, and the results are reported in pounds per acre of elemental P. Other soil testing labs may report their results in parts per million (ppm) without making the conversion to pounds per acre (lbs/A). This conversion from ppm to lbs/A involves assuming that a 6-inch deep layer of soil (furrow slice) covering one acre weighs 2,000,000 pounds. To convert soil test results from ppm to lbs/A, multiply the value in ppm by 2. For example, a soil test P value of 150 ppm is correlated to 300 lbs/A.

THE PHOSPHORUS CONCERN

Commercial fertilizers are commonly applied to croplands in a mixture of nitrogen, phosphorus and potassium (N, P_2O_5, and K_2O) that is balanced to meet the nutrient needs of the desired crop. However, nutrients in livestock manure are not balanced with respect to crop requirements. Table 1 reveals that N and P_2O_5 are found in about equal amounts in broiler litter. However, Table 2 indicates that typical forage crops require about 2½ to 4 times as much N as P_2O_5. Growers with confined livestock and poultry operations have tons of P-enriched feed brought onto the farm. Much of the P passes through the animals and is excreted in manure.

Table 1. Average Nutrient Values for Manure Samples Collected by Arkansas Producers[a].

	N	P_2O_5	P	N/P_2O_5	
Broiler litter	56	54	23.6	1.04	lbs/ton
Dairy manure	6	4	1.75	1.50	lbs/1000 gal
Swine manure	14	13	5.68	1.08	lbs/1000 gal

[a]These values are derived from manure samples collected by producers and sent to the University of Arkansas Agricultural Diagnostics Laboratory. The nitrogen values are the total nitrogen concentrations. The phosphorus values are the P_2O_5 and P concentrations as marked.

In turn, the manure is spread on fields to take advantage of the nutrient value and organic matter. Crops most readily respond to nitrogen, so growers have historically applied enough manure to meet crop nitrogen needs. This results in applying several times the needed amount of P (Tables 1 and 2).

Repeated application of manures based on nitrogen needs causes P to accumulate in the soil. In some cases, 10 years of repeated applications has caused very high STP levels, particularly on pasture-lands where crops have not been removed. In the past, this build-up has not been a cause for concern. Phosphorus is a naturally occurring nutrient and, even at high levels, is not detrimental to crop production. It is also relatively stable once attached to soil particles. Phosphorus was once thought to have significant movement off fields only if soil was moved by erosion.

Table 2. Nutrients Removed Per Ton of Forage Dry Matter[b] (Average of Arkansas Forage Tests from 1984-1996).

	N	P_2O_5	P	K_2O	N/P_2O_5
Alfalfa	58[c]	14	6	56	4.14
Bahiagrass	31	8	3	34	3.88
Bermudagrass	40	12	5	44	3.33
Clover	43[c]	12	5	44	3.58
Fescue	36	14	6	50	2.57
Legume/grass	39[c]	12	5	43	3.25
Ryegrass	39	16	7	54	2.44
Sudangrass	37	14	6	47	2.64
Wheat	36	13	6	40	2.77

[b]Pounds removed per ton of forage production.
[c]N from N fixation, not N fertilizer.

For land with high STP levels, it is now know that appreciable amounts of soluble P can exist in the runoff water from these areas and can significantly impact water quality in nearby streams and lakes. Looking at the top one inch of the soil profile, recent research has shown that the concentration of P in runoff increases as STP increases (Figure 1).

Phosphorus is not toxic and would not be a problem except P is the nutrient that limits biological activity in most of our clear water lakes and streams. Nitrogen and potash generally occur naturally in the environment in sufficient quantities to support algae and plant growth in water bodies. Insufficient P in most inland water bodies keeps the clear water lakes and streams from being congested with algae and aquatic vegetative growth. Levels of P exceeding critical values for algae growth can lead to the acceleration of eutrophication, the natural aging process of a lake that is characterized by excessive biological activity.

Consequences of accelerated eutrophication include degradation of recreational benefits and drinking water quality, which in turn can increase treatment costs. Advanced eutrophication can also reduce aquatic wildlife populations and species diversity by lowering dissolved oxygen and increasing the biological oxygen demand (BOD). Eutrophication from excessive P has not generally been considered a public health issue like other contaminants derived from agricultural runoff, such as nitrates or pathogenic bacteria. However, there are toxic algae that can flourish with increase in available nutrients, which is causing researchers to focus more attention on the isolated events that have occurred in other states.

HOW MUCH SOIL TEST PHOSPHORUS IS NEEDED?

Arkansas scientists agree that there is no agronomic reason or need for STP levels to be greater than about 80 to 10 pounds (P by Mehlich III extraction) per acre. typical forage crops will annually remove from 8 to 16 pounds of P_2O_5 per ton of production. As an example, bermudagrass removes about 12 pounds per ton or 72 pounds of P_2O_5 annually for a 6 ton per acre crop. (Divide P_2O_5 by 2.29 to determine elemental P; 72 lbs P_2O_5 = about 31 lbs P).

It must also be emphasized that P contained in plant material is recycled to the soil unless it is removed, either by crop or forage harvesting, or by soil erosion and runoff. On grazing land, most P is recycled to the soil in manure. Only a small portion of the P uptake in the animal is retained and removed from the land with the animal.

The environmental concern of letting P accumulate to very high levels in the soil is the long period of time required to reduce STP to levels normally recommended for agronomic production. High levels of P can require as many as 15 to 20 years of continuous crop harvesting for removal, with no additional P from any source during that time.

HOW MUCH SOIL TEST PHOSPHORUS IS TOO MUCH?

A rigid, maximum STP level has not been set by soil scientists or the Natural Resources Conservation Service. However, one suggested limit that has been debated is 300 pounds P per acre (by the Mehlich III extraction testing method). This number has been suggested as an upper limit simply because it is much more than the available P needed for crop production (about three times more than needed), and it is hopefully low enough to avoid eutrophic runoff. The environmental impact of an STP level of 300 lbs/A has not been established at this time. The variables and unknowns in the movement (transport) of P once it is in runoff water make its environmental impact difficult to assess. It should also be noted that the concentration of dissolved P in runoff water changes with rainfall intensity and duration, and the research has been under very specific rainfall and runoff conditions.

Soil test phosphorus is clearly a good indicator of when an appreciable concentration of dissolved P may be in runoff water. it does not, however, offer any indication of the amount (rate) of runoff water that may be generated for a given set of conditions. The total amount of P leaving a field is a function of the runoff P concentration and the runoff volume. The real issue is not the P concentration in runoff from the edge of any one field but the total P load transported to the stream or lake from an entire watershed. The maximum amount of P that can be assimilated in a watershed without causing eutrophication depends on a number of factors including STP levels. Distance from significant streams or water bodies, slope, soil type, buffer strips and crop or forage cover are potential factors, as are the characteristics of the streams and lakes themselves. However, soil testing, if properly used, may be the most significant tool for assessing the potential for high P concentrations in runoff water.

Some watersheds with a high percentage of cropland and pastureland receiving animal manure may require restricted P applications to avoid excess P loading of streams and lakes fed by the watershed. Maximum STP levels may be appropriate for these watersheds. Watersheds with a low population density of livestock and poultry farms may be able to tolerate higher STP levels on fields without harmful effects to water quality. However, to effectively manage P in every watershed, the factors affecting the movement of P from application sites to streams and lakes must be considered.

RECOMMENDATIONS AND CONCERNS

- An Stp of 300 lbs/A is a good indicator that P build-up in the soil is a valid environmental concern for that particular field. Growers with management alternatives for manure or litter should reduce or totally avoid animal manure or P applications from any source on high P fields. Current scientific evidence is limited on how much P can be tolerated for all fields in all situations. However, it is known that high P fields can require as much as 15 to 20 years of continuous crop harvesting, with no added P during that time, to reduce high STP levels. Therefore, it is to the landowner's advantage not to let STP build to high levels if he has alternatives for management.

- A STP of 300 lbs/A should not be considered an absolute maximum number for P applications at this time except in specific watersheds that have been determined to have excess P loads harmful to water quality and the environment.

- Growers should be encouraged to make commercial fertilizer applications formulated with N and K_2O to meet the forage needs of fields where animal manure is no longer applied. It must be recognized that decreased fertility will result in a loss of forage cover and increased erosion, which could create a greater P problem in runoff than continued manure applications. Research has shown that when erosion is kept to a minimum, dissolved P is predominant in runoff water, but as erosion increases the percentage of particulate P in the runoff increases (Figure 2).

- When applying commercial fertilizer on fields with STP at 100 or more pounds per acre, do not use fertilizer with P in the formulation. It should be N (ammonium nitrate or urea) or N-0-K_2O, which is nitrogen and potash with no phosphorus.

- When making N-based early season applications with manure, late season commercial fertilizer applications should be N or N-0-K_2O with no P in the formulation.

- All livestock and poultry producers with confined animal operations should have a nutrient management plan prepared for their farm. The application rates should consider P. Low fertility fields with low P could have N-based applications for a limited time, but all fields with repeated animal manure applications will ultimately require applications that consider P.

- Proper soil sampling techniques are critical to the accurate characterization of STP in pastureland. Samples should be collected from 12 to 15 locations within a field in a zigzag pattern across the field. These samples should be mixed together and a composite sample taken from the mixture. This provides the most representative sample possible. Also, care should be taken to collect a sample approximately 6 inches in depth. Producers are encouraged to contact their local county extension office for sampling instructions prior to sampling.

- In Arkansas dry manure or litter is not regulated, and growers have more options for handling excess nutrients on their farms. Dry manure has a higher nutrient density and can be hauled greater distances than liquid manures with fewer economic hardships. Liquid manures in Arkansas are regulated, and growers have fewer options for handling excess nutrients. The permits specify the minimum required acreage and the land application areas for each farm.

- Most livestock and poultry producers spread litter based on the best management practices at the time they started in business, only to find now that they may have inadequate land for P-based application rates. As a result, restrictive P regulations could cause financial hardship for many producers and affect Arkansas' agricultural economy unless economically feasible alternatives to land application are developed. High-quality water is also important for the economy and the people of Arkansas, so additional research is needed to help producers find better ways to manage, utilize or market the valuable nutrients in excess manure.

- Carefully prepared nutrient management plans for all confined livestock and poultry operations, implementation of current technology with best management practices and limited P applications in certain critical watersheds should protect our water until new research and good science can further define more specific P recommendations.

- Additional solutions and management practices need to be developed and implemented. The areas of emphasis should include reducing the P concentrations in feeds while maintaining production, management practices to reduce the transport of P from the application areas to water bodies and the development of economical long distance transportation of manure to land areas in need of P.

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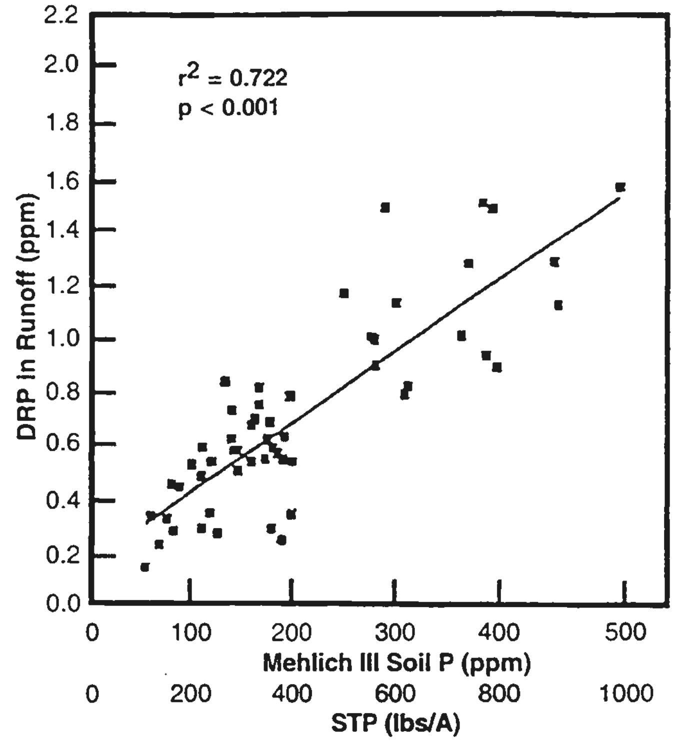

Figure 1. Relationship Between Mehlich III Extractable P in Captina Surface Soil and Dissolved Reactive P (DRP) in Runoff (based on STP levels in the top 1 inch of soil).

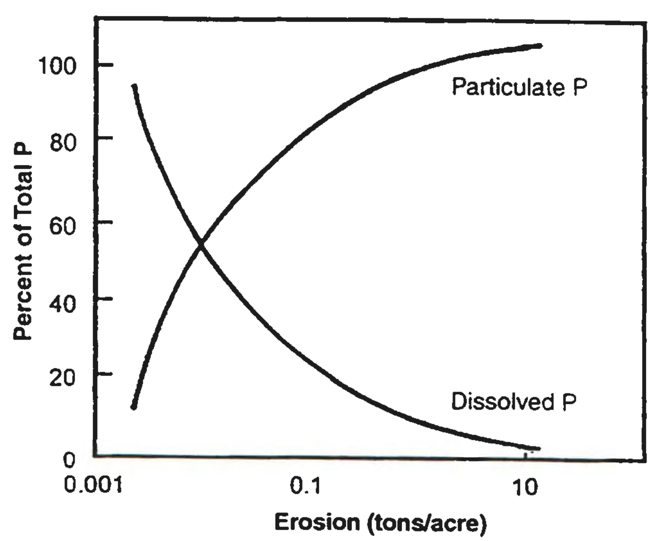

Figure 2. Percentage of Total P as Dissolved and Particulate P as a Function of Erosion in runoff from Watersheds at El Reno, Oklahoma.

HOLISTIC SOLUTIONS TO ENVIRONMENTAL PROBLEMS

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The environmental problems brought about by intensive poultry production are both undeniable and severe. I will not enumerate the various instances of pollution from concentrated poultry operations with which you are familiar. Rather, I would like to discuss the general environmental situation with respect to the poultry industry and offer a few comments about how the industry can face these problems.

When I was an undergraduate student I worked as a keypunch operator at Girard Bank in Philadelphia. I remember speculating at that time that, eventually, keypunch operators would be phased out in favor of computers. Just a few years later this happened. An entire occupation was eliminated, although the basic service provided not only remains, but does so in a much more efficient fashion. Even Girard Bank is an historical footnote, having been bought my Mellon Bank.

Likewise, while people will continue to eat food in the future, they don't have to buy it from you. And I suspect that what we eat and how it will be produced will change radically in the coming years.

The poultry industry exists within a changing society - a society undergoing fundamental shifts in its expectations of industry, in its values, and in its demand for rapid improvements to be made. We are entering an era, I believe, in which environmental responsibility will be an essential component of business survival; rather than simply being a public relations adjunct to corporate operations-as-usual, it will be a focal point of most businesses, particularly manufacturing enterprises such as poultry production.

There was a time, not too many years ago, when the public was largely disinterested in food production as long as the food was cheap, good-tasting, and plentiful. This is no longer the case. The poultry industry is now facing rising opposition from unions and those concerned with worker safety, from religious, environmental, humane, and health related organizations, from community activists, and many others. Simply put, the poultry industry cannot survive in this country in the face of this opposition unless it undergoes systemic change. The relationship between animal production and concentration and water quality has long been established, yet the poultry industry, in most cases, has been slow to act, or, in some cases, even acknowledge the depth of the problem. The first step is admit that there is a major problem

The relationship between intensive poultry production and society is not simply a question of economics or ecology. It is also a moral question, as well as a social-political one, involving issues of culture. To view the environmental consequences of industrial poultry production through the prism of economics alone is a mistake: the issue is far more complex. It is also a mistake to equate industrial poultry production with "agriculture." When it is increasingly being seen by the public and by regulators as, essentially, a manufacturing industry.

The primary concern of most people is their own well-being, and that of their families. They therefore become involved in issues which directly affect their daily lives, such as diminished property values resulting from a newly built factory farm, or nuisances such as odors, or from contaminated water. When things get bad enough, people organize or use existing organizations as vehicles for expressing discontent and for obtaining change (or compensation). Today we see community groups being formed for the singular goal of fighting factor farms. Environmental groups such as the Sierra Club is making animal agriculture a focal point. This is a significant change, because in the past, many environmental hesitated to directly confront animal producers. The increasing concentration in the industry, and public support, have combined to spur these organizations to give animal production top billing on their agenda.

On a broader level, the public is increasingly concerned about the treatment of farm animals (the Humane Society of the United States has five million members and has made intensive animal production a major issue), the safety of the food supply, the environmental impact of food production, and is shifting toward foods, and products generally, which are thought to be more responsibly produced. Hence the demand for ecolabeling, organic foods, and the Gardenburger. Simply put, consumers are demanding environmentally-friendly food, and increasingly willing to pay for it. From the Dairy Network partnership's Chesapeake Milk ("ecomilk"), to the growing demand for "Happy Eggs" the trend is clear. If you would like to view our future, The Netherlands is a place to start. Fresh range meat, eggs from uncaged birds, vegetable burgers at McDonald's are commonplace in Holland, in a country with a high level of education and environmental awareness.

On a societal scale there is growing recognition that the protection of the natural environment is essential to the preservation of our society. As economist Garrett Hardin has suggested: "Some day political conservatives will once again be defined as concerned about living within limits" (1993). This is not a new concept, for even Plato wrote about the overriding need for the common good to make possible a just society (Johnson, 1996), and the current manifestation of this philosophy can be seen in Kenneth Boulding's concept of the "coming spaceship earth" (1966), and in Hardin's "Cowboy Economics Versus Spaceship Ecology" (1993). There is growing global recognition that we are spending our capital (environment) in order to sustain what is, in essence, an unsustainable way of life. If you are interested in learning more about this, I would recommend your reading "Living High and Letting Die" by philosopher Peter Unger (1996). It is a profound book that will alter your thinking, and possibly disturb your sleep.

In 1995, the Club of Rome issued a report entitled "Taking Nature into Account." This report considers the question of "externalities." That is, the fact that the external costs of our economic system are not reflected on our national balance sheets, particular environmental degradation. In fact, pollution and its remediation are often measured in terms of its contribution to our gross domestic product (e.g., medical costs). This report is one of many that are precipitating the rise of a movement to cause industries such as yours to internalize the costs. Who, for example should pay for the cleanup of the Neuse River in North Carolina the degradation of the Chesapeake Bay, or the dead zone in the Gulf of Mexico? The trend is toward making those who cause the pollution (and their customers) to pay the bill rather than the taxpayer. In the case of the poultry industry, this will ultimately lead to higher prices if newer, less polluting, production methods are not found. If you doubt that this movement is significant, visit virtually any college of agriculture and you'll see students voting with their feet. Ask how many students are majoring in ecological economics or natural resource management. Then ask how many are majoring in poultry science or in other traditional agricultural fields. To some extent these changes are generational.

The best defense for any industry is to understand the nature of change in society, and to take anticipatory action. Environmental responsibility needs to be seen as crucial to a business's success. You need to read widely and deeply. This is not a luxury, but a necessity. Read Vegetarian Times and Wired. You need to understand the dramatic shifts occurring in the way that people think, and in the demographic changes in the United States and in the world. You cannot do this if you are constantly in meetings populated by middle-aged white guys. I was once on the Board of Directors of the American Feed Industry Association. There were about fifty members of the board...all were demographically similar. This call "group-think" as it should be avoided. You need to understand how industry critics think. You may be surprised - if you are honest you may find that they are right. If the people want free-range eggs, find a way to produce them. Exploit change, don't fight it. Producing environmentally sound products that the future population wants will be highly profitable.

The emerging issues facing the poultry industry are not difficult to ascertain. In the future, there will be zero tolerance for salmonella-laced eggs. Concern about phosphorus and ammonia emissions will continue to grow, and, most importantly, water quality and quantity will be an issue so important that wars will be fought in its name (The forthcoming Global Water Contract, Promulgated by the Group of Lisbon, will receive intense international debate and deserves your attention. It will delineate the coming global water crises and make recommendations for action.) In addition, the controversy over the healthfulness of poultry products, worker safety, and, especially, the issue of animal protection will rise in importance. Increasingly, you will face the standards and requirements of other industries such as the automobile and paper industries.

The technology of water quality monitoring makes it easy for anyone (yes, anyone) to accurately measure the water quality of streams and rivers flowing through your facilities. This new technology, coupled with the growing trend toward citizen-monitoring, means that your contribution to water quality if going to be obvious. Today, easily available to anyone who can pay the price (425) can obtain a water monitoring kit which will accurately measure chloroform bacteria, nitrates, phosphorus, and six other variables. Each kit has ten tests for each variable. Consider the implications.

What are you to do in an era of escalating regulation, increased liability. Media scrutiny, and public concern? How will you deal with the upcoming trend, via Europe, for example, for the abolition of battery cages? Can you find a better way?

I suggest that you put the trends together. If, increasingly the public will not accept the current level of environmental degradation from the poultry industry, if it is growing concerned about animal protection issues, the use of antibiotics, pesticide residue, odors, and so on, then there is a tremendous opportunity at hand. Can chicken be produced by entirely different methods which address these concerns? Can the poultry industry be sufficiently innovative to reinvent itself?

I am convinced that cosmetic changes and mere tinkering will not be sufficient in addressing these issues. Rather, the industry will need to develop entirely new approaches which will yield tremendous profits for successful innovators. The rest will ultimately go the way of the keypunch operator. If you don't make the switch, someone else will do it for you.

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OPTIMIZING ANIMAL PERFORMANCE AND MINIMIZING ENVIRONMENTAL LOAD WITH THE USE OF FEED ENZYMES

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Optimizing animal performance while minimizing the environmental load of animal production are two key goals the modern animal producer has to aim for in a global and consumer oriented food industry. Feed enzymes in animal nutrition are useful tools to achieve those goals. Enzymes help to optimize animal performance by improving nutrient utilization. Improvement in nutrient utilization leads to reduce nutrient output into the environment. In addition, enzymes allow increased use of local feed ingredients or by-products. Both reduction in nutrient output as well as the use of local feed ingredients help in reducing environmental load caused by animal production.

While enzymes for broilers fed diets containing wheat and barley have become an industry standard, new innovative applications are developing rapidly. Latest technologies have allowed the development of enzymes systems to enhance forage utilization in ruminants. Enzyme processing of by-products such as feathers or carcasses is becoming reality. In monogastric nutrition new applications are targeting at improving phytin-phosphorus utilization and nutrient utilization from soy or alternative raw ingredients such as rice bran, copra or palm kernel cake. In order to obtain maximal benefits from enzyme inclusion in animal feeds, it is necessary to ensure that the enzymes are chosen on the basis of the feed composition. It is critical that the enzyme is properly matched to the substrate. An enzyme cocktail containing more than one enzyme will often improve the response, assuming that cost considerations are not ignored.

Since enzymes are proteins, the structure of the enzyme is critical to its activity. Enzyme structure can be altered by pH, heat or certain organic solvents. Changes in the structure of the protein can decrease or negate enzyme activity. The temperatures in which feeds are exposed during the pelleting process can range from 60 to 90°C under normal conditions. These temperatures and pressures can therefore lead to the loss of feed-borne and added enzyme activity (Rexen, 1981). Recent studies reveal that enzyme activity begins to decrease as pelleting temperatures reach 80°C. These data suggests that cellulase, fungal amylase, and pentosanase can be pelleted at temperatures up to 80°C and bacterial amylase up to 90°C without any considerable loss of activity (Spring *et al.*, 1996). In cases where temperatures are excessive for enzyme stability, post-pelleting application is commonly used.

ENZYMES DESIGNED TO IMPROVE NUTRITIVE VALUE OF SOY

Legume seeds such as soy contain non-starch polysaccharides (NSP) in the form of oligosaccharides (e.g. alpha galactosides), hemicellulose and pectin, which have been shown to decrease nutrient utilization. Alpha galactosides are raffinose and stachyose-based oligosaccharides which accumulate as the seed matures. Endogenous enzymes in monogastrics are specific for alpha-linked carbohydrates such as starch but are not active against beta-linked carbohydrates or galactose-containing oligosaccharides. Degradation of these galactosides is accomplished by the gut microflora in the large intestine yielding volatile fatty acids and gas production. The net result is less energy and gastric disturbances in many species. Enzymatic degradation of these compounds can produce monosaccharides and result in better energy and protein utilization.

In poultry, improvements in amino acid digestibility and energy utilization have been noticed with an enzyme cocktail specifically designed for vegetable proteins (Table 1). This improvement in nutrient utilization has led to improved weight gain and feed conversion under experimental and field conditions (Tables 2 and 3). Table 2 shows the effect of the enzyme cocktail on broilers fed a wheat-soy based diet under experimental conditions. In a field trail, two flocks of broilers in separate barns (10,800 birds per barn) on a farm in Ontario were used to evaluate effects of the enzyme cocktail on bird performance and economics. A 5% improvement in energy and protein utilization of the soybean meal with enzyme was taken into consideration when formulating the diet. Performance in both barns was compromised by high *E. coli* challenge. As a result, mortality was higher than expected in both groups and condemnations were higher at slaughter. Despite the impact of disease, the flock given Vegpro was more profitable due to improved weight gain and feed efficiency. Enzymes for soy offer a new tool to the nutritionist to enhance diet density or to reformulate the diet factoring an enhanced nutritive value of soy into the diet formation.

Table 1. Effect of Allzyme Vegpro (Alltech, Inc.) on TME and True Amino Acid Digestibility (%) of Soybean Meal (48%)[1].

Amino Acid	Control	Allzyme Vegpro
TME (MJ/kg)	11.8	12.3
Lysine	82.1	86.0
Methionine	65.4	69.0
Cystine	41.6	57.9
Leucine	80.6	82.0
Threonine	72.7	78.5

[1]Charlton, 1996.

Table 2. Effect of Allzyme Vegpro on Broilers Fed a Wheat-Soy Diet Under Experimental Conditions[1].

Parameter	Control	Allzyme Vegpro
Weight gain 15 days (g)	549	555
Weight gain 29 days (g)	1463	1471
FCR 15 days (kg/kg)	1.62[a]	1.55[b]
FCR 29 days (kg/kg)	1.73[a]	1.69[b]

[a,b]Means in the same row with different superscripts differ significantly (P<0.05).
[1]Schuttle *et al.*, 1996.

Table 3. Effect of Allzyme Vegpro on Broilers Fed a Corn-Soy Diet Under Field Conditions[1].

Parameter	Control	Vegpro
Weight, kg	2.80	2.93
Conversion	2.20	2.13
Mortality, %	6.64	7.85
Condemned, %	1.6	2.3
Days to slaughter	49	49
Fed cost/tonne, Canadian $	296.50	294.58

[1]Bannermann, personal communication.

IMPROVEMENT OF PHYTIN-PHOSPHORUS UTILIZATION WITH PHYTASE

There has been considerable interest in recent years in examining ways to decrease the amount of phosphorus excreted by animals in order to minimize water pollution. Much of the phosphorus in feed ingredients obtained from plants is in the form of phytic acid, a compound not degraded by the endogenous enzymes found in monogastric animals. Consequently, approximately two-thirds of this phosphorus is considered unavailable for monogastric animals. Thus, it is often necessary to add inorganic phosphorus to monogastric diets in order to meet the animals requirement for this element. One of the methods to reduce the amount of phosphorus added to diets is to increase the availability of the phosphorus in the feed ingredients by the addition of microbial produced enzymes to the diet. Phytase should also help in reducing the negative effects of phytate on protein and mineral availability as well as lowering the buffering capacity of the diet due to reduced dicalcium phosphate addition.

Cantor *et al.* (1994) determined the effect of a commercial and two experimental phytase products on P utilization in broilers. He stated that supplementing the basal diet with different phytase products resulted in an increase of available phosphorus in the diet by 0.10, 0.10 and 0.12%, respectively. These improvements in phosphorus utilization correspond to the addition of approximately 5 kg of dicalcium phosphate per tonne of feed.

Table 4. Effects of Allzyme Phytase and Dietary Phosphorus Content on Egg Production, Bone Measurements and Fecal Phosphate Content[3].

	Control	Phytase	Control	Phytase
No hens	54,050	54,100	53,570	53,975
Initial age, week	38	38	28	28
Feed intake, lb/100/day	10.65	10.69	10.60	10.32
Avail. P intake, mg/hen/d	275	179	285	160
Livability, %	94.9	95.3	95.4	97.7
Eggs/hen housed	79.7	80.9	84.6	82.8
Shell quality[1]	N.D.[2]	N.D.	40.3	38.5
Tibia bone ash, %	56.2	55.8	56.7	57.2
Fecal phosphate, %	4.46	3.78	3.92	2.77

[1]Percent of eggs floating in a 1.080 specific gravity salt solution.
[2]N.D. Not determine.
[3]Zimmermann *et al.*, 1997.

Phytase has also ben tested in layers. Table 4 summarizes two field trials measuring the effects of phytase on egg production parameters and on P excretion. In both trials single houses were used with 108,000 bird capacity. Birds were commercial layer stock (SCWL) aged 28 weeks. There were approximately 54,000 hens per group. The basal ration was a commercial layer formula that was fed according to feed intake to supply specific levels of nutrients daily. Available P target (min.) in the control diet was 250 mg/hen/day. The test ration was the basal diet modified for an available phosphorus target (min.) of 170 mg/hen/day plus phytase (Allzyme Phytase) added to 1 kg/t. Performance was similar while fecal phosphate content was reduced by 15% and 29% in the groups receiving the phytase-supplemented diet (Table 4). These data indicate that 150 mg available P can be fed in a diet containing phytase without sacrificing performance.

ENZYMES FOR RUMINANTS

For many years, the use of enzyme in ruminants has been limited to processing feed or fiber prior to feeding animals. Pretreatment of forages by enzymes has been shown to improve forage digestibility and consequently animal performance. Exogenous enzyme supplementation of ruminants might have failed until recently because enzymes were broken down in the rumen. Biotechnology offers new possibilities to stabilize enzymes and maintain their activity over a longer period of time in the ruminal environment. A newly developed enzyme "Fibrozyme" which is targeted to increase fiber digestion has been tested at the University of Kentucky in an *in vitro* rumen simulating system.

Table 5. *In vitro* DM Disappearance, Hexose Utilization, and Net Volatile Fatty Acid (VFA) Production from a Hay Based Reference Ration by Batch Cultures Inoculated with Rumen Contents from Animals Fed a 100% Grass Hay[1].

Item[c]	None	Fibrozyme	SEM	% Difference
In vitro dry matter disappearance (%)				
12 h	26.1[a]	37.7[b]	3.3	+44.4
24 h	50.3	50.2	5.7	-.2
Estimated hexose utilization (mM)				
12 h	16.4	18.6	1.4	+13.4
24 h	24.65	26.1	1.1	+6.1
Net VFA production (mM)				
12 h	28.9	32.3	2.5	+11.8
24 h	43.7	46.0	2.2	+5.3

[a,b]Means differ ($P<.05$).
[c]Mean values (n=12).
[1]Dawson, personal communication.

At 12 h, *in vitro* dry matter (IVDM) disappearance was 44% greater in cultures receiving enzyme with a grass hay diet (Table 5). Estimated hexose utilization and net VFA production tended to be greater in response to enzyme addition after 12 h of incubation. The addition of enzyme to ruminant diets enhanced digestion of particulate material and carbohydrate metabolism in a fescue hay diet during the short incubation period (first 12 h after addition), but had little consistent long term effects on digestion when examined over a along period (18-24 h after addition). An increase in 12 h fiber digestion might increase rate of passage in the ruminant and therefore increase intake.

A series of field trials were conducted by a mid-Atlantic US cooperative to determine performance response with Fibrozyme. Fifteen herds varying in size from 60 to 500 cows were selected for the field trial. Forage and concentrate programs varied, but were largely based on corn silage, and a corn-based concentrate with some legume haylage. The enzyme was added either as a topdress at 15 g per cow daily or mixed into the concentrate in herds fed total mixed rations. In every case, trials were conducted on an "all on-all off" basis with 30 day test periods. All but two of the herds responded positively to the enzyme with a milk yield increase. Weighted average response based on 1752 cows was +0.9 liter of milk and +.115% butterfat.

Rumen stable enzymes give the nutritionist and producer a new tool to enhance forage digestibility. The efficient utilization of regional grown forages is essential for successful milk and beef production. Improvement in forage utilization can enhance performance and reduce the need for more expensive concentrated feeds.

CONCLUSIONS

Numerous studies over the past ten years have demonstrated improvements in feed utilization with enzyme supplementation. As enzyme technology is improving we are seeing benefits in areas not traditionally associated with digestive inefficiencies such as energy and protein utilization from soy and other feed ingredients. Future developments will likely focus on more the mo-tolerant enzyme preparations, greater enzyme activity and enzymes which function optimally at low gastric pH values. Additionally,as more is known of the chemical nature of our feed ingredients, better methods of degrading these compounds may be found.

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UTILIZING PLANT GENETICS TO REDUCE NUTRIENT LOADING IN THE ENVIRONMENT

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Nutritional approaches could be utilized to reduce nitrogen (N) and phosphorus (P) excretion, and yet still maintain optimum bird performance/carcass quality. Dietary protein in excess of the animal's needs may lead to the excess being excreted as N. Possible factors to address the reduction of N excretion involve: 1) reducing dietary protein levels; 2) utilizing crystalline amino acids; 3) formulating feeds on a digestible amino acid basis; 4) closely match the dietary protein/amino acid levels with the bird's requirement at various ages and 5) knowing the amino acid digestibility of plant and animal ingredients. "Biotechnology may offer solutions to corn's poor protein quality" (Ertl, 1995). Several strategies for manipulating protein quality in plants are discussed by Kleese (1996), these being: 1) altering the amino acid biosynthetic pathway, 2) overexpression of a gene coding for a protein with high levels of a desired amino acid, 3) manipulating several limiting amino acids together, or 4) reducing nonessential amino acids. He indicates the first two are based on reported literature but the latter two are speculative.

Phosphorus is an important mineral to animals, necessary for proper bone formation and maintenance of the bones, as well as metabolic functions. Methods which animal nutritionists may use to reduce P in animal waste are: 1) formulated feed on available P rather than total P; 2) using feed ingredients possessing high available P content; 3) knowing the P availability of plants; 4) better agreement between nutrient supply and the animal's requirements; 5) phase feeding; 6) separate sex-rearing; 7) enzymes and 8) plant genetics.

Genetic selection can improve the nutrient content of corn hybrids and soybean varieties that are used in animal feeds (Ertl, 1995). A major advantage of plant genetic improvements is they are permanent for that hybrid or variety (Kleese, 1995).

HIGH AVAILABLE PHOSPHORUS (LOW PHYTIC ACID) CORN

Cereal grains and protein meals of vegetable origin contain significant amounts of P, however 50 to 80% of this is stored in the phytic acid ("phytate") form which is predominately unavailable to the animal (Lloyd *et al.*, 1978; Scott, 1991; Coehlo, 1994). Phytic acid, represents more than 80% of the total P in the corn kernel with the germ containing 88% of the phytate P (O'Dell *et al.*, 1972). Poultry and swine lack the phytase enzyme necessary to utilize the phytic acid in grains.

There currently are two methods available to overcome the poor availability of P in grains. One method is the use of added inorganic phosphates and/or animal byproducts to meet the animal's needs (Cromwell and Coffey, 1991). This approach does not address the phytate P content of the diet. The second method utilizes added phytase enzymes to poultry diets which increases the availability of P in the diet (Nelson *et al.*, 1971).

A third approach is to lower the phytic acid content and increase the P availability in the corn, known as high available phosphorus (HAP) corn. A low phytic acid mutant lpal showed an altered relationship between total P and phytic acid (Ertl *et al.*, 1996). The release P due to the reduction of phytic acid is present as inorganic P (Gerbasi *et al.*, 1993; Raboy and Gerbasi, 1996). The result is that total phosphorus remains the same but instead of phytate P representing about 78 to 80% of the total P as is the case for normal corn, HAP corn contains approximately 35% of the total P bound in the phytate form. A preliminary chick trial supports the chemical analyses of the increased available P present in the HAP corn (Ertl *et al.*, 1998). Coinciding with this was a reduction in excreted P.

Further research with HAP corn examined broiler performance 0 to 49 days of age (Huff *et al.*, 1998) and the subsequent influence on P runoff of the manure from these birds (Moore *et al.*, 1998). Broilers of a commercial strain, reared on floor pens (6 pens/treatment), were randomly assigned to one of four treatments which examined feeding yellow dent corn (YDC) or HAP corn with or without phytase. Diets were fed from 0 to 49 days of age and then a second flock followed using the same dietary treatments. Results indicate that 25% of the dicalcium phosphate in the diet could be replaced with use of phytase or HAP corn, without affecting broiler performance or health. Including HAP corn with phytase further reduced the dicalcium phosphate addition to 50% of the YDC diet containing no phytase with no adverse effects on broiler performance or health. The litter from these pens was then spread (4 tons/acre) on fescue plots followed by simulated rainfall application (Moore *et al.*, 1998). Total P runoff from the control plots (no litter) was significantly lower compared to the plots containing poultry litter in the first runoff event. Although there were no significant differences in P runoff between the different litter treatments, feeding HAP corn or HAP corn plus phytase reduced P runoff by 22% and 26%, respectively. This reduction reflects the lower phytate P content of the HAP corn based diets because of less phytate P coming from the HAP corn.

Replacing the yellow dent corn with HAP corn markedly reduced the fecal P output (Kersey *et al.*, 1998). Adding phytase to the diets reduced the fecal P, only when dietary available P levels were no greater than that needed for maximum tibia ash in a 21 day chick study.

The added value of the HAP corn based on replacement of the dicalcium phosphate is approximately $0.05 to $0.10 (US$)/bushel over yellow dent corn. This added value does not incorporate the value of reducing the P levels in the manure and the cost associated with waste management. The environmental value may be a similar amount or more than the phosphate replacement value (Dr. T. Sauber, Optimum Quality Grains, L.L.C: personal communication).

OTHER POTENTIAL PLANT GENETIC CHANGES

Several approaches have been or are currently under examination. One area is the nutritional quality of soybeans may be improved through a reduction in seed phytic acid content (Raboy and Dickinson, 1993). For soybeans, about 70% of the total P in the seeds is present in the form of phytic acid (Raboy *et al.*, 1984). Through breeding efforts, two-thirds of the phytic acid could be reduced (Raboy *et al.*, 1985).

Another area to aid in the reduction of P excretion is incorporating phytase into the plant so it is expressed in the seed. Several approaches are being investigated. One is Phytaseed®, a transgenic canola meal containing the *Aspergillus niger* gene. Ledoux *et al.* (1998) compared the performance of male turkeys when fed either the Phytaseed® or phytase (Nutaphos®[1]) at different levels in the diets during the day 1 to 35 study. Results indicate that increasing the

[1]Nutaphos is a registered trademark of BASF Corporation.

phytase level (250, 500 and 2500 FTU) regardless of source (commercial phytase or Phytaseed) to the basal diet (0.30% available P; 0.90% calcium) increased weight gains, feed intake and improved feed efficiency. The authors concluded that the phytase from Phytaseed® was as effective as the commercial microbial phytase product for improving phytate P availability.

The second method incorporates phytase into soybeans. Denbow *et al.* (1998) compared the performance of broiler chicks (7 to 21 days) fed either diets with 3 different levels (400, 800 or 1200 U/kg) of added phytase of a commercial source (Nutaphos®) or raw transformed soybeans expressing recombinant phytase at 400, 800 or 1200 U/kg. Broiler chicks were also fed the basal diet containing 0.0, 0.08, 0.16 or 0.24% added nonphytate P (nPP). The authors reported that supplementing the basal diet with nPP linearly improved weight gains, fed efficiency, feed intake, toe ash weight, plus tibia shear force. As dietary phytase level increased, growth rate, feed intake, toe ash weight, tibia shear force, and P digestibility increased. Corresponding with this increase was a decrease in P excretion. Based on live performance and bone parameters measured, there was no difference (P>0.05) between the two sources of phytase. Phosphorus digestibility was higher for the chicks fed the phytase containing soybeans. Thus the authors concluded that the supplying phytase either as a commercial supplement or in the form of transformed seeds, would improve growth performance of broilers fed low nPP diets.

CONCLUSION

A number of plant genetic approaches are being evaluated to address improve P availability in plants as well as possibly reduce P excretion. These include reducing phytic acid content in corn and soybeans plus incorporating phytase into the plant seeds (soybeans, canola). Initial studies with HAP corn offer an opportunity to reduce the use of phosphate supplements in the diet and potentially reduce phosphorus excretion into the environment.

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NUTRITIONAL ALTERNATIVES TO REDUCE NUTRIENT LOADING ENZYMES

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The practice of using manure as a source of nutrients for plant production is older than commercial agriculture and land application continues to be major means of manure disposal. However, excessive land application of livestock waste has the potential to contribute to environmental pollution. The potential impact of nutrients from animal manure on the environment is perceived as one of the major issues facing livestock producers. For years, concern about land application of manure has focused on nitrogen, since nitrates have the potential to contaminate both surface and ground water. However, recent emphasis has been placed on other nutrients and their potential for pollution. Of these, phosphorus has received the most attention.

PHYTATE AND NUTRITIONAL CONCERNS

Most of the phosphorus contained in feed ingredients of plant origin occurs as phytic acid. In general, phytate phosphorus accounts for about two-thirds of the total phosphorus present in plants. Non-ruminants, such as poultry and pigs, have virtually no phytase activity of their own. Thus, the availability of phosphorus in foodstuffs of plant origin is generally very low (Table 1). This low availability of phytate phosphorus poses two problems for producers: 2) the need to add inorganic phosphorus supplements to diets, and 2) the excretion of large amounts of phosphorus in manure.

The phytic acid molecule has a high phosphorus content (28.2%) and its six phosphoric acid residues have affinities for several cations. Phytic acid has chelating potential forming a wide variety or insoluble salts with di and trivalent cations at neutral pH (Vohra *et al.*, 1965; Oberleas, 1973). Zinc, Cu, Co, Mn, Fe and Mg can also complex, but Zn and Cu have the strongest binding affinity (Maddaiah *et al.*, 1964; Vohra *et al.*, 1965).

Table 1. Phytate Phosphorus Content and Phytase Activity of Some Common Feed Ingredients[a].

	Phytate Phosphorus		Phytase[b] Activity
	%	% Total P	Units/kg
Cereals and By-products			
Corn	.24	72	15
Wheat	.27	69	1193
Sorghum	.25	66	24
Barley	.27	64	582
Oats	.29	67	40
Wheat Bran	.92	71	2957
Oilseed Meals			
Soybean Meal	.39	60	8
Canola Meal	.70	59	16
Sunflower Meal	.89	77	60
Peanut Meal	.48	80	3
Cottonseed Meal	.84	70	NS

[a]Data adapted from Ravindran *et al.* (1994).
[b]Data from Eeckout and De Paepe (1994). One unit is defined as that amount of phytase which liberates inorganic phosphorus from a 5.1 mM Na-phytate solution at a rate of 1 µmol/min. at pH 5.5 and 37°C (98.5°C).

Phytic acid forms complexes with protein (Cosgrove, 1980; Maga 1982; Han, 1989; Gifford and Clydesdale, 1990; Honig and Wolf, 1991) and inhibits amylase, trypsin, tyrosinase and pepsin activities (Nair *et al.*, 1991; Caldwell, 1992). According to Hartman (1979) 2 to 3% of soy protein complexes with phytate. Jongbloed *et al.* (1997) determined that a very strong complex between soluble protein and phytate is formed at pH 2-3. Incubating phytate with phytase prevented formation of the complex. Under neutral conditions, the carboxyl groups of some amino acids may bind to phytate through a divalent or trivalent mineral (Anderson, 1995). Phytate-protein or phytate-mineral-protein complexes may reduce the utilization of protein. Ca-phytate complexes with fatty acids form insoluble soaps in the gut lumen, thereby lowering fat digestibility (Leeson, 1993). A pronounced effect of high dietary calcium levels on fat digestibility and AME of diets containing saturated fatty acids was also reported by Atteh and Leeson (1984). Ca-phytate complexes also bind directly to starches (Thompson and Yoon, 1984; Thompson, 1988). Inhibit alpha-amylase action (Deshpande and Cheryan, 1984) thereby lowering starch solubility and digestibility (Knuckles and Betschart, 1987).

Therefore, phytate is a powerful anti-nutritive factor that significantly reduces the nutrient availability of several nutrients, thereby increasing excretion of these nutrients.

PHYTASE

Phytase belongs to a group of acid phosphatase. It catalyzes the hydrolytic cleavage of the phosphoric acid esters of inositol. Thus, it liberates ortho-phosphates, which can then be absorbed. At the same time, nutrients like Ca, Mg, trace elements, amino acids and proteins may be liberated as well.

Since phytase, like other enzymes, is a protein, it undergoes the normal protein-degrading digestion processes. Thus, no phytase activity is detectable in the intestinal tract even when phytase is administered (Jongbloed *et al.*, 1992). One unit of phytase activity (FTU = fytase unit; fytase = Dutch name for phytase) is defined as the amount which liberates 1 micromole of inorganic phosphorus per minute from an excess of sodium phytate at 37°C and pH 5.5.

PHYTASE IN POULTRY DIETS AND NUTRIENT UTILIZATION

Numerous reports have shown that microbial phytase is very effective for improving the availability of phytate phosphorus in typical diets. Nelson *et al.* (1971) reported that preparations of Aspergillus ficuum containing phytase added to corn-soybean meal diets effectively hydrolyzed phytate-P in the alimentary tract of the chick. Simons and Versteegh (1992) fed laying hens a low phosphorus diet supplemented with graded levels of MCP or phytase from 24 to 52 weeks of age and measured lay performance, eggshell quality, skeletal quality and phosphorus excretion. Phosphorus deficiency symptoms observed with the negative control diet were completely compensated by the lower level of MCP supplementation (0.06% aP) and by the lowest level of phytase (200 FTU/Kg). Phosphorus excretion data is summarized in Table 2. Phosphorus excretion via manure increased when MCP was added to the diet and decreased when phytase was added to the diet. Phosphorus excretion of the phytase groups averaged 40% less than the groups received MCP. These same authors (Simons *et al.*, 1990) using broiler chicks found similar results. Chicks fed phytase had 40% less phosphorus in excreta as compared to chicks receiving phosphorus from a mixture of dicalcium phosphate and mono-ammonium phosphate (Table 3). Phytase fed birds also showed improved performance in growth rate and feed conversion at 2 weeks of age.

Table 2. Effect of Microbial Phytase and Inorganic Phosphorus from MCP on Phosphorus Excretion by Laying Hens[a].

Phosphorus Excreted[c]	Basal Diet[b]	MCP Groups (0.6, .12, & .20% aP)	Phytase Groups 7 Increments (200-2000 FTU/kg
Total Phos. %	0.77	1.31	0.74
Phytate Phos. %	0.54	0.62	0.18

[a]Data adapted from Simons and Versteegh, 1992.
[b]Basal diet contained .33% tP and 0.14% aP.
[c]Data expressed as a % solids.

Table 3. Effect of Microbial Phytase on Calcium and Phosphorus Availability and Phosphorus Excretion in Broilers[a].

Dietary		Phytase	Calcium	Phosphorus	Phosphorus
Ca %	tP %[c]	(FTU/kg)	Avail. (%)	Avail. (%)	Excreted[b]
0.60	0.45	0	47.2	49.8	2.7
0.75	0.60	0	48.9	45.6	3.8
0.90	0.75	0	46.9	44.6	4.9
0.60	0.45	250	57.1	56.5	2.3
0.60	0.45	500	59.3	59.6	2.1
0.60	0.45	750	60.3	59.6	2.1
0.60	0.45	1000	64.3	62.5	2.0
0.60	0.45	1500	68.1	64.5	1.9

[a]Source: Simons and Versteegh, 1990.
[b]Grams tP in manure per kilogram dry matter intake.
[c]P added as mixture of DCP and mono-ammonium phosphate.

A study was conducted to investigate the response of pullets fed low phosphorus diets to phytase and to evaluate subsequent layer performance when hens were maintained on low phosphorus diets with and without the addition of phytase. For the pullet phase of the trial, diets were formulated to contain 0.43, 0.33, 0.23 or 1.03% aP (0.86% Ca) with and without the addition of 300 FTU/kg diet. Nether aP nor phytase impacted pullet weights at 18 weeks. However, pullets fed 0.13% aP without the addition of phytase exhibited poorer bone quality. The negative impact of reducing aP to 0.13% of the diet on bone quality was reversed by the addition of Natuphos at 300 FTU/;kg of diet. For the layer phase of this trial, hens were fed 0.40, 0.30, 0.20 and 0.10% aP (4.00% Ca) with and without the addition of 300 FTU/kg diet. Birds grown on low aP diets and continued into the lay cycle on low aP diets without the addition of phytase failed to achieve a level of production equal to the other treatments. Egg production was dramatically reduced, mortality was increased, feed consumption was depressed and smaller eggs with weaker shells were produced. The addition of either phytase at 300 FTU/kg or inorganic phosphorus completely restored these parameters to normal levels. Increasing the aP content above 0.20% by the addition of either inorganic phosphorus or phytase allowed hens to reach typical production peaks, and to maintain production for the duration of the trial.

Several trails have been conducted in the last 3 years that measured the ileal digestibility of individual amino acids in the presence of phytase. A summary of the effect of phytase on amino acid digestibility from trials by Kornegay (1996) and (1997), Schutte *et al* (1997) and Ravindran (1997) and Sabastian *et al* (1997) is presented in Table 4. Using adjusted averages (to 600 FTU/kg) from these studies, a trail was conducted to evaluate diets formulated to equal nutrient levels with and without phytase. A negative control diet was created by reducing the nutrient content of the diet without phytase by the nutrient levels assigned to phytase. In order to assure that the diets were at or below the nutrient requirements, three levels of nutrients were established using lysine as a reference. Weight gain and feed conversion of broilers fed diets formulated to equal nutrient levels with and without phytase did not differ. However, when the nutrient level of the diet was reduced by the calculated nutrient contribution of phytase, a significant reduction in weight gain was observed.

The above discussion clearly demonstrates the effectiveness of microbial phytase in improving the availability of phosphorus and other nutrients for simple stomached animals. When appropriate adjustments are made in formulation of diets to allow for the improved utilization of nutrients, excretion of nutrients is reduced through the use of phytase.

SUMMARY

Growing concerns about pollution have forced livestock producers to look at ways of reducing the contribution of nutrients in livestock waste to environment problems. This concern is in part a result of intensive agriculture and the concentration of animal agriculture on relatively small land acreage (fewer but larger farms). Also, environmental concerns have increased and will continue to increase in the future. In dealing with this challenge, the amount of nutrients being excreted must be reduced and the nutrients that are excreted must be recycled in an environmentally friendly way. Good stewardship regarding the environment is consistent with the desires of most livestock producers and the use of microbial phytase will allow a significant reduction in the nutrient content of most rations and a reduction in nutrient excretion in manure.

Table 4. Effect of Phytase on Apparent Ileal Amino Acid Digestibility in Several Poultry Trials.

	Ravindran, 1997		Kornegay, 1996		Kornegay, 1997		Sebastain *et al*, 1997	
Phytase, FTU/kg	0	400	0	500	0	450	0	600
Digestibility, %								
CP	81.5	83.9	87.9	88.6	76.4	79.3	82.2	83.5
Lysine	84.5	86.2	91.2	91.7	80.7	82.8	88.2	89.3
Methionine	---	-- -	94.6	94.8	82.0	83.8	---	---
Cystine	---	---	80.1	81.2	71.8	76.2	---	---
Threonine	73.4	75.2	84.5	85.5	70.1	73.6	---	---
Valine	79.2	80.2	88.2	89.1	76.3	78.6	83.9	86.5
Isoleucine	80.4	81.6	87.5	89.7	76.4	80.3	79.4	82.0
Leucine	77.9	79.2	88.7	90.6	82.6	84.4	88.1	89.6
Arginine	85.6	86.5	92.9	93.4	85.9	87.0	91.1	92.5
Phenylalanine	80.4	82.2	90.1	90.8	81.8	83.4	87.9	88.8
Histidine	81.5	82.6	90.3	90.8	80.7	82.9	85.0	88.1

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PRECISION NUTRITION AND LITTER VOLATILIZATION DYNAMICS

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Gaseous emissions from livestock facilities relate to environmental and to economic concerns. Ammonia ventilated from facilities ius associated with increased soil acidity, and represents a loss of litter nitrogen (N) to the atmosphere. Regulations aimed towards controlling the amount of ammonia released from a livestock facility, or limiting the total number of facilities in an area, have been put in place in Europe. This is perhaps a natural extension of regulations requiring sufficient land area for application of livestock manure from a facility, such as with current U.S. best management practices (BMP), and thus might be anticipated by the U.S. industry. Further, as phosphorus (P) based land-application guidelines evolve it will be beneficial to seek to maximize litter N concentration because P is often most limiting for soils where broilers are raised.

Ammonia concentrations in poultry houses vary widely, with time of year, age and condition of litter, ventilation rates and litter management generally cited as primary factors (Carr *et al.*, 1990; Elloitt and Collins, 1982). Ammonia can negatively impact broiler production (Reese *et al.*, 1978, 1980; Xin *et al.*, 1987). Recent work (Ferguson *et al.*, 1988a,b; Jacob *et al.*, 1994; Paul *et al.*, 1996) suggests that reduced dietary crude protein (CP) could maintain bird production performance and reduce the nitrogen in the litter. Litter N was reduced by feeding diets with lower CP by supplementing to satisfy essential amino acid requirements (Ferguson *et al.*, 1998a,b). In a similar manner, litter P can be reduced by diet manipulations which include addition of the phytase enzyme to enhance organic P availability (Ferguson *et al.*, 1998a). Rapid and reliable means of assessing litter characteristics to exploit the potential of precision nutrition are needed.

The relation between litter N, in the form of uric acid, pH, moisture content, and partitioning of ammoniacal nitrogen between ionized and free (unionized) ammonia-N is well known. A predictive model for the ammonia release from the litter to the atmosphere was developed by Elliott and Collins (1982) using chemical reactions for conversion of organic-N to ammonia, chemical equilibrium and transport equations. Carr *et al.* (1990) developed an empirical model to predict gaseous ammonia concentration in a broiler facility with litter. Groot Koerkamp and Elzing (1996) used this approach for layer houses where litter was used.

Both pH and temperature of poultry litter affect partitioning between ionized and unionized ammonia, the volatilization of unionized ammonia from the liquid to gas phase, and subsequent diffusion to room air. Predicting equilibrium ammonia gas concentration over manure slurries and litter beds requires a disassociation constant of ammoniacal-N, determined by Muck and Steenhuis (1982), and a Henry's Law constant, determined by Hashimoto and Ludington (1971). These constants were determined using liquid manure slurries of less than 8.5% solids. These same constants are used in many predictive models for manure slurries (e.g., Montey *et al.*, 1996). Their use has not been validated for application to poultry litter (Gates *et al.*, 1997; Groot Koerkamp and Elzing, 1996) without modification. It is of interest to learn to what extent this approach is applicable to solid poultry litter.

Recently, studies have monitored real-time ammonia concentrations in broiler house (e.g., Paul *et al.*, 1996; Wilhelm, 1996). A problem with currently used techniques is that room air was monitored during ventilation making it difficult, if not impossible, to infer the state of ammoniacal N at or near the litter surface. Since the ammoniacal N concentration is liquid phase drives diffusion, it is an important measurement.

A method to measure NH_3 at the litter surface is helpful for defining the driving potential for volatilization. Further, if this measurement can be related to total ammoniacal N (TAN) in the litter, then a rapid means for assessing different dietary treatments to manipulate TAN might be possible. To distinguish this measure of ammonia in the gas phase at the litter surface from that in the entire room, we denote it as the "equilibrium NH_3 gas concentration" (Gates *et al.*, 1997).

The objectives of the work reported in this paper were to:

1) Manipulate dietary CP, with isocaloric and amino acid supplemented diets, to determine the effect on litter and air/litter interface chemical properties.

2) Develop and test a technique for estimating litter ammoniacal nitrogen, using Henry's Law and appropriate measurements including equilibrium ammonia concentration.
3) Evaluate litter processing steps to assess potential losses of ammonia.

THEORETICAL CONSIDERATIONS

Poultry Litter Chemistry

Poultry litter consists of various organic materials such as wood shavings, wood chips, or rice hulls, and of course, poultry manure. During a flock growout, the majority of new fecal material is laid down in the last week to 10 days for birds grown to 6 weeks. Poultry litter management may be characterized as receiving increasingly larger deposits of manure during the course of a single flock, followed by a recovery period during which little manure is deposited until the next flock is about 30 days old. Litter composition varies with age, complicating efforts to control litter moisture and house ammonia.

A major source of ammonia evolves when bacterial enzymes hydrolyze uric acid contained in poultry fecal material. the overall reaction is given by:

$$\text{uric acid} + \text{water} \xleftrightarrow{\text{uricase}} \text{urea} + CO_2 \tag{1}$$

$$\text{urea} + \text{water} \xleftrightarrow{\text{urease}} CO_2 + NH_3 \tag{2}$$

Equilibrium Ammonia Gas Concentration

The equations and constants as used in the following are found in Monteny *et al.* (1996). The total ammoniacal-N disassociates in liquid into ionized and unionized ammonia. This equilibrium is affected by temperature and pH. The fraction of free (unionized) NH_3 in a liquid is defined by the following equation:

$$f = \left\{ 1 + \frac{[H^+]}{0.81 * 10^{-10} * 1.07^{(T-293)}} \right\}^{-1} \tag{3}$$

where:
f = fraction of free ammonia (dimensionless)
$[H^+]$ = concentration of hydrogen ions in liquid (kg m^{-3})
T = absolute temperature (K)

The NH_3 gas concentration is in equilibrium with free NH_3 in the liquid at the water-air free surface, and is determined from Henry's law"

$$H = \frac{[NH_3]_{liq}}{[NH_3]_{gassurf}} \tag{4}$$

where:
$[NH_3]_{liq}$ = free ammonia-N concentration in liquid (kg/m_3)
$[NH_3]_{gas,\ surf}$ = ammonia gas concentration at H_2O-air free surface ($kg\ m^{-3}$)
H = Henry's law constant (dimensionless).

Henry's law constant is also affected by temperature:

$$H = 1,384 * 1.053^{(293-T)} \tag{5}$$

Ammonia Diffusion from Litter

Transport of NH_3 gas from litter into air can be idealized using a simple one-dimensional diffusion model. This model assumes an equilibrium liquid phase concentration, $C^+ = [NJ_3]_{liq}$, exists at a liquid-air free surface within the litter. Convection from litter into the gas phase results in an equivalent gas concentration, C. Measurement of C is made by placing a sealed container over the litter and waiting for equilibrium of occur. The mathematical model for this process is given in Gates *et al.* (1997).

MATERIALS AND METHODS

Precision Nutrient Trials

Four trials were conducted. Detailed descriptions of the first two are documented in Ferguson *et al.* (1998a,b) and a summary of trial 3 in Gates *et al.* (1998). For all trials, 48 male broilers/pen were raised to 6 wk. The experimental unit was a single pen. Feeds were isocaloric and supplemented with artificial amino acids to bring them to similar levels across treatments. The first trial experimental design was a 2x2 factorial (5 reps) with dietary CP and P as treatments, using phytase supplement for the low P treatment. The second experimental design consisted of 3 levels of CP (5 reps). The third experimental design consisted of 4 levels of CP, 4 replicates/room, and two rooms. Trials 1-3 used new litter. Trial 4 was a repeat of trial 3 using the same feed but only one room. Extra pens of birds on each treatment were kept for replacement when birds died. Trial 1 was done during February, trial 2 was performed during the mid-fall season

(November), trial 3 was in late summer (August) and trial 4 during early fall (mid-October); thus room temperatures and humidities were variable.

Gas Sampling

A location mid-range of feeders and water was chosen for litter sampling. The measurement apparatus consisted of a gas analyzer connected by 1/8" I.D. Teflon^{tm} supply and return sampling lines to a plastic pail which was pressed inverted into the litter surface. To ensure forced convective conditions within the sampler pail, a small fan was fastened inside the pail and adjusted to achieve approximately 1 ms^{-1} across the litter surface. Sampler pail volume (19L) was selected to provide reasonably rapid equilibrium times (10-30 min) as determined empirically from dewpoint temperature readings on litter. the analyzer (Bruel and Kjaer, Model 1302) utilized an infrared photoacoustic technique (Sigrist, 1994).

Litter Properties

Litter Sampling and Temperature: Once the gas sampling apparatus was removed, litter temperature was measured using a meat thermometer (trials 1 and 2) and/or an RTD with digital readout (trials 3 and 4). The temperature probe was inserted into the litter surface to a depth less than 3 cm. The top layer of litter from the sampling area was scooped into a plastic freezer bag and stored in a conventional freezer until transport to a larger freezer (within 12 h) maintained at -20°C. Litter from three pens were chosen from each trial to analyze processing problems. Litter from all pens were analyzed for pH, moisture content, TAN, NO_3, total N, P_2O_5, and KO_3.

Moisture Content: Wet litter samples were dried in a convection oven at 104°C for 24 hours. Wet samples were also placed into a vacuum freezer-dryer set for 900 μm of Hg or less after samples were frozen. Moisture contents were computed from both methods and compared.

Measured pH: 6g of wet litter (3g d.m. assuming a 50% m.c.) was mixed with 50 mL of distilled, de-ionized water and stirred for at lest 10 minutes. Slope and calibration of the pH probe (Orion Ross Sure-Flow model 8765) were maintained with buffered standards before and after samples were analyzed. The pH was determined within 24 hours of sampling. For trials 3, 4, and selected samples from trial 2, thawed litter was packed around the pH probe to obtain undiluted pH measurements. Care was taken to ensure contact between litter and membrane opening. In trial 4, the pH probe was inserted directly into the litter to obtain *in situ* pH readings.

<u>Measured Litter Ammonia</u>: Selected freeze-dried and ground litter samples were analyzed by three different methods: ammonia Kjeldahl, Berthelot and a full-cell ammonia probe. The Barthelot reaction is an alkaline phenol hypochlorite method (Ngo *et al.*, 1982). Ammonia was extracted using a 1% KCl solution and filtered through a 0.1 μm nylon filter. The ammonia probe (Orion model 95-12 full reference cell) was immersed in distilled water with approximately 1M $(NH_4)_2SO_4$ under basic conditions (pH>13) at least 30 minutes prior to analyzing samples. A 1% KCl solution was used to extract ammoniacal nitrogen from the litter (Banwart *et al.*, 1972) for 60 minutes including centrifuging time. Samples were analyzed in triplicate. A 20 mL sample of supernatant was withdrawn and placed into a 30 mL test tube. Within 3-4 minutes prior to testing, 1 mL of a pH adjusting solution (5 M NaOH, 10% methanol, 1.8 g/L EDTA, 0.1 g/L Thymolphthalein blue) was added and shaken just prior to analyzing.

Standard solutions (ASTM, 1993) were used for ammonia probe calibration between each series of samples. A complete set of standards consisted of 3.312 g/L $(NH_4)_2SO_4$ for stock solution, with dilutions of 1:2, 1:5, 1:10, 1:20, 1:50, and 1:100 using distilled, de-ionized water. A full set of standards was used at the beginning, after the third sample series and at the end, while a subset of standards was used other times after each sample series. Probe drift was assessed by analyzing standard solutions made in 1% KCl and compared to standards in distilled water.

<u>pH Adjustment of Litter Samples</u>: From trial 3 pen 5 litter sample, 3 extra samples were removed and a 1M NaOH solution was added such that pH should increase to about 9.5. These samples were then placed into the freeze-dryer to be processed and analyzed like the other samples.

RESULTS AND DISCUSSION

Bird performance characteristics for the trials indicated that conventional high CP diets could be mimicked with lower CP treatments supplemented with amino acids, but that as CP was further reduced bird performance declined. Complete production results from trials 1 and 2 are given in Ferguson *et al.* (1998a,b), respectively, and a summary of trial 3 is in Cantor *et al.* (1998) More work on dietary formulation is needed to devise practical rations and to find threshold CP levels.

Litter quality parameters for trial 2 and in Table 1. All parameters listed show a decreasing trend with reductions in dietary CP. Mean values of total litter N decrease with feed CP, and comparison of the two methods shows the Kjeldahl method yields lower estimates, 0.3-0.6%N d.b. TAN is approximately ten-fold lower than litter total N. Predicted and measured gas equilibrium NH_3 concentrations agree reasonably for CP treatments of M and L, but overpredict for H. Variation within treatment was high. Comparative analysis of temperature probes showed the original device underestimated temperature by 1.1 to 3.5°C. Similarly, pH obtained from the AOAC method by dilution averaged 0.6 units lower than that obtained *in situ* with the soil pH probe. Adjustments for measurement errors in litter temperature and pH improved predictions for all dietary treatments. Thus, a method of extracting the ammonia from the litter in the field, e.g., the method used to determine soil ammonia, improved predicted equilibrium NH_3.

Table 1. Litter Composition for Trial 2 (new litter). Means and Standard Deviations from Five Replicates/ Treatment. Diets Reported in Ferguson *et al.* (1998b).

Feed Crude Protein	Tot.-N %N Dry Basis	Kjel-N %N Dry Basis	TAN* %N Dry Basis	pH	Moisture (g/g) Wet Basis	NH_3 (ppm air)	NH_3 (ppm air)	Measured NH_3[d] (ppm air)
L	4.69	4.09	0.38	5.00	0.56	63.9	49.2	53.6
	(0.46)	(0.11)	(0.14)	(0.20)	(0.01)	(58.4)	(45.0)	(16.8)
M	4.89	4.55	0.42	5.10	0.57	71.1	54.7	53.2
	(0.31)	(0.20)	(0.12)	(0.11)	(0.02)	(28.7)	(22.1)	(13.6)
H	5.86	5.33	0.63	5.50	0.59	287.5	221.3	71.2
	(0.05)	(0.10)	(0.14)	(0.30)	(0.03)	(188.0)	(144.7)	(32.8)

[a]Using Kjeldahl method.
[b]Predicted from Henry's Law (from Hashimoto and Ludington, 1971).
[c]Improved temperature and pH measurements as explained in test.
[d]Measured with photoacoustic gas analyzer.

Selected results from trials 3 and 4 are given in Tables 2 and 3, respectively. All listed parameters, except moisture content, tended to increase with dietary CP. Litter N was less, and TAN greater, than in trial 2. The increase in pH with dietary CP correlated with measured NH_3. Measured CO_2, an indication of microbial respiration in the litter, ranged from approximately 7,000 to 12,000 ppm.

Table 2. Litter Composition for Trial 3 (new litter). Means and standard deviations from 4 replicates/ treatment. Diets reported in Cantor *et al.* (1998): CP diet A < diet B < diet C < diet D.

Feed Crude Protein	Total-N %N Dry Basis	TAN[a] %N Dry Basis	pH	Moisture (g/g) Wet Basis	Measured NH_3 (ppm air)	Measured CO_2 (ppm air)
A	3.38 (0.27)	0.70 (0.13)	6.98 (0.48)	0.60 (0.004)	23.8 (8.7)	9235 (473)
B	3.57 (0.20)	0.80 (0.05)	6.90 (0.19)	0.61 (0.01)	23.8 (11.2)	7138 (2090)
C	3.54 (0.19)	0.84 (0.10)	7.16 (0.32)	0.60 (0.01)	39.0 (27.7)	8250 (1623)
D	3.69 (0.12)	0.91 (0.13)	7.23 (0.17)	0.61 (0.02)	44.3 (18.6)	11888 (3189)

[a]Using Berthelot method.

Table 3. Litter Composition for Trial 4 (raised on same litter as Trial 3). Means and Standard Deviations from Four Replicates/Treatment. Experimental Design Same as Trial 3.

Feed Crude Protein	Total-N %N Dry Basis	Kjel-N %N Dry Basis	TAN[a] %N Dry Basis	pH	Moisture (g/g) Wet Basis	Measured NH_3 (ppm air)	Measured CO_2 (ppm air)
A	3.33 (0.19)	3.20 (0.08)	0.24 (0.03)	8.441 (0.199)	0.477 (0.049)	48.8 (11.0)	7858 (1592)
B	3.59 (0.24)	3.46 (0.23)	0.22 (0.03)	8.431 (0.092)	0.490 (0.051)	52.5 (26.4)	8605 (2427)
C	3.94 (0.21)	3.76 (0.23)	0.27 (0.09)	8.500 (0.208)	0.546 (0.043)	51.8 (32.8)	8370 (3093)
D	4.12 (0.43)	4.04 (0.48)	0.21 (0.10)	8.638 (0.211)	0.504 (0.035)	76.0 (11.7)	9643 (3837)

[a]Using Berthelot method.

Comparison within CP treatments between trials 3 and 4 suggest changes which litter experienced with continued use, since treatment/pen combinations were identical, and litter was re-used. TAN and moisture content decreased but litter pH, N and equilibrium NH_3 increased in trial 4. The increased equilibrium NH_3 in trial 4 was associated with higher pH values.

From Table 4, there is evidence that freeze-drying litter samples when pH is at or above neutrality there is some loss of ammonia. When samples were tested after freeze-drying but before grinding there appears to also be a loss of ammonia. The pH increase after freeze-drying when below neutrality and decreased if at or above neutrality. Most likely ammonium is binding with wood chip in micropores and requires grinding for proper extraction to take place.

Table 4. Comparison of Litter Processing Steps.

Trial/Pen	pH Wet[a]	pH FD[b]	TAN fresh[c] (ppm)	TAN FD[d] (ppm)	TAN FDG[e] (ppm)	TAN Berthelot (ppm)	TAN Kjeldahl (ppm)
T2P2	5.18	5.55	5931	4894	6181	6150	---
T3P14	7.15	6.2	7603	5732	6918	6727	6381
T4P4	8.44	7.61	3476	2328	2220	2494	2457
T3P5-1	-9.5	7.31	7469	1435	---	1446	1663

[a]Unprocessed litter pH measured by AOAC method.
[b]Freeze-dried samples using AOAC method.
[c]Litter samples were brought into lab, unprocessed, used ammonia probe.
[d]Freeze-dried.
[e]Freeze-dried and ground.

CONCLUSIONS

Dietary manipulation to control poultry litter chemical properties, while maintaining bird performance, appears promising. The measurement system developed and described was a reliable and accurate method for determining dynamic gas concentrations over poultry litter. From this work, the following conclusions were drawn:

1. Reduced dietary CP is associated with reductions in litter N, equilibrium ammonia and carbon dioxide gas concentrations, TAN, and litter moisture content.
2. Improved litter chemical analysis methods were developed, including: use of *in situ* pH probe, accurate litter temperature, and TAN analysis using extraction with an NH_3 ion specific probe.
3. Three methods of TAN analysis were compared, and the simpler Kjeldahl N method compared favorably to the ion-specific probe and Berthelot analyses of litter extractant.

4. Litter at high pH is vulnerable to ammonia volatilization losses during sample preparation such as drying, freeze drying, etc. Thus, immediate extraction techniques are recommended.
5. Predicting equilibrium NH_3 gas concentration, using Henry's Law model and measured litter TAN, tended to over-predict measured values. The validity of Henry's Law for broiler litter, using the dissociation constant determined from liquid manure slurries, is questionable. This might be caused by the higher surface tension in a capillary versus a liquid slurry. Further efforts could improve the model resulting in a low-cost alternative means to determine litter TAN.

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CREATING ALTERNATIVES FOR EGGSHELL UTILIZATION

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I'd like to begin this presentation by giving you all a little quiz. You recall that approximately a year ago, the poultry industry in Maryland was in a panic over an outbreak of *pfiesteria* in the Chesapeake Bay.

What is *pfiesteria* and what caused the outbreak?

I read with interest a story written by richard Halpern of *The Global Food Quarterly*. He reported that the news media was quick to quote responsible organizations when the *pfiesteria* was discovered? The Environmental Defense Fund stated that "many scientists believe" that "farm runoff" had triggered the normally benign *pfiesteria* bacteria to release toxins that killed thousands of fish in the Chesapeake Bay. The Sierra Club proclaimed that an "eminent correlation" exists between toxic blooms of *pfiesteria* and "massive agricultural runoff in the area" caused by the poultry industry. The National Wildlife Foundation asserted, "When waters are warm and nutrient laden, *pfiesteria* releases various toxins that cause lesions and paralysis of fish...Runoff of manure from large, intensively worked factor farms is a 'prime suspect' in the *pfiesteria* fish kills..." The Chesapeake Bay Foundation called for a two-year moratorium on new poultry housing and a tax on chickens that would punish the industry and secure reparations for its environmental crimes. *The Baltimore Sun* newspaper reported that "Scientists have identified nutrient pollution from agriculture, especially the chicken industry in the case of the bay, as a likely factor in the fish-killing outbreaks".

So what is *pfiesteria* and what caused the fish killoff? After a comprehensive study of the evidence, Maryland's Blue Ribbon Citizen's *pfiesteria* Action Committee concluded that there is "no demonstratable cause and effect linkage" between nonpoint source pollution, such as runoff from poultry manure, and the toxic outbreak of *pfiesteria*. *Pfiesteria* has been around eons, claims the experts. Why is the nutrient theory correct now. The Rappanhannock River, not too farm from Washington, D.C. has also reported *pfiesteria* fish kills, with normal levels of nutrients. But eco-activists insist on the nutrient theory.

So, what is *pfiesteria*? It's not a bacteria. It is a natural organism whose overgrowth fed toxic blooms that killed thousands of fish in the Chesapeake Bay. The best science on the subject of *pfiesteria* links it with a chemical agent in the excreta of fish. No fish, no toxic bloom.

It's also a wake-up call that people are ready to point their finger at you in the agriculture industry and take steps to create media nightmares for you. But, this wake-up call is another opportunity. An opportunity to address waste management on a local level and possibly create a useable product in the process.

At my company, whenever I'm facing a crisis I often hear the expression, "it's another opportunity". You know what they say..."Opportunities always look bigger going than coming". But opportunities do exist if we can listen and use our heads. It's sort of like the local pastor who joined a community service club. The members thought they would have some fun with him. Under his name badge they printed "Hog Caller" as his occupation. Everyone had a big laugh when his badge was presented to him. <u>He listened and used his head</u>. His response was, "I am usually called 'Shepherd of the Sheep', but you know your people better than I do". Others too, are listening and using their heads.

At the University of Georgia in the Biological and Agricultural Engineering and Poultry Science Departments, they are developing processes to screen broiler litter. The fines are being used in cattle feed and fertilizer. Sargent Nutrients of Gainesville, GA reports that it is selling 7,000 to 8,000 tons of screened litter annually at a value-added price. Glennville Mills, Glennville, GA is producing pellets for fertilizer and range cubes. Pine tree seedlings are being fertilized with pelletized broiler litter to utilize the phosphorus. Slaughtering plants are looking at reducing their waste stream loading.

Minimization of product loss to the waste stream not only reduces environmental costs, but also recovers salable product. One egg company that boils and peels eggs, reduced water use by 80%, organic leading by 90% and recovered product for sale netting $60,000 per year. Renewed interest in fiber from feathers is creating research at the USDA in Beltsville, MD and at Auburn University to use in baby diapers, due to the improved absorbable properties of chicken feather fiber.

Let's listen and use our heads. Eggshells from breaking plants are creating those "opportunities" for consideration. ADF is processing inedible eggs from grading stations, breaking plants and hatcheries in 34 states. This program yields more than 1,000 tons weekly in eggshells.

What do we do with the eggshells? ADF has eight different locations where eggshell disposal is an "opportunity". Our methods of disposal vary depending on "opportunities" and costs. Approximately 50% of our eggshell production is disposed of at landfills; 20% is sold for composting or land application; and the balance is land applied. The landfill charges vary, depending on location, but range from $11-35/ton. Land application costs range from $10-25. Composting costs are $20/ton. When you're producing over 1,000 tons per week with those kind of charges, you can see the need to develop alternative uses for eggshells.

ADF is working with rendering companies to use this in the production formulations. We've also dried the eggshell, blended it with soy and sold it in the Far East. With the problems in the Asian market, this has subsided somewhat. The "opportunity" yet to be realized is to offer eggshells in place of limestone in poultry rations.

Procurement people are quick to reject the idea of eggshells as a replacement for limestone in their poultry rations due to cost, but when you back out the cost of disposal in landfills or land applications, it is surprisingly comparable. If you are feeding limestone then perhaps you ought to consider eggshells. the price is comparable. Dried eggshells have a calcium composition of 32% with phosphorus at 0.16%. Magnesium is nearly double the phosphorus content and Potassium is five times greater. The protein content is 9.66%, fat 1.91%, fiber 1.31%, moisture 0.61% and ash at 87.81%. Ground limestone provides a calcium composition of 38% with a trace of manganese. Oystershell provides 38% calcium. Meat and bone meal provide other nutrients such as manganese, phosphorus, potassium, but is only 14% calcium. But the added advantage of eggshells is the quality calcium coupled with the protein factor. And with a comparable price to other calcium sources, eggshells make for a feasible alternative.

As the Poultry industry experiences more environmental pressure, whether real or media-generated, the approach is to develop value-added products that increase profits rather than continue with environmental costs. Creating alternatives for eggshells makes sense...it makes dollars too.

EGG WASH WATER REDUCTION PROGRAM

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In the process of washing shell eggs, the detergent cleaning efficiency must be sufficient enough to thoroughly remove all dirt and microbial residues from the surface of the shell egg. The end result will be a bright clean glowing egg that is attractive and appealing to the consumer. The volume of water used in the process of washing shell eggs is a key component of your overall operating cost. By controlling the amount of water used in the process of washing eggs, you then have the ability to control other costs associated with this process like heat (as in BTU energy), chemical detergent and sanitizer, cost of potable water, and costs associated with effluent or water discharge.

Eggactly the Facts.....is an egg-ucational approach dealing with the fundamentals of controlling the amount of water used in the mechanical process of cleaning shell eggs. We need to ask ourselves questions like. Do we need to be better handlers of our water? What is the Best Practice used in controlling the amount of water in this mechanical process? and, what effect does fresh water and soiled effluent have on your operating costs?

FACTORS ASSOCIATED WITH WASH WATER USAGE

It's vitally important that the volume of overflow water be controlled to the bare minimum in the process of washing eggs. This control will have a dramatic effect on the cost associated with fresh water and soiled effluent in the areas of chemical treatment, heat (BTU's), and cost of purchasing and disposing of the water used.

To determine the amount of water additions to your process, the first area to identify is the final fresh water spray/sanitizer just prior to the eggs exiting the mechanical egg washer. Measuring the total flow capacity of this spray bar will be the key to determining the cost efficiency of this part of the operation. Generally you will find this total spray flow to be between 3.0 and 5.0 gallons per minute. In a finely tuned operation this fresh water spray addition to the washer can be lowered to the range of 1.0 gallon per minute.

The following information is based on actual measurements that were taken in a egg processing plant. This example represents about 75% of the egg processing plants that wash and grade eggs.

Measuring the usage at the point of the final fresh water/sanitizer rinse solution and make up now at 12 spraying nozzles delivering a total of 4.4 gallons per minute. This equals to 264 gallons of hot fresh water make up per hour.

Cost Associated with the Water:

At 264 gallons of fresh hot water make up per hour.
This equals 2,112 gallons of water per 8 hour production run.
This equals approximately 762,854 gallons of water per year.

Cost associated with treating 762,854 gallons of water.

Egg wash detergent @ 0.35 oz/gal.	=	$ 13,141.00
Egg wash defoaming agent	=	$ 5,256.00
Chlorine sanitizer at 100 ppm	=	$ 1,986.00
Heat as in (BTU's) @ $3.00/100 gal.	=	$ 2,288.00
TOTAL COST	**=**	**$22,671.00**

If you control the amount of water used in the egg washing process you then have control over the cost associated with this process. DiverseyLever suggest installing a set of Delavan type spray nozzles that will reduce the volume of fresh water rinse make up from 4.4 gallons per minute down to 1.0 gallons per minute. This will result in a 77% water reduction savings. At 1.0 gallons per minute your water volume associated cost will be significantly reduced by the following amounts.

Water and Cost Reduction Estimates:

At 4.4 gpm final rinse	=	762,854 gallons per year
At 4.0 gpm final rinse	=	173,376 gallons per year
WATER SAVINGS	**=**	**589,478 gallons per year**

Reducing the amount of water used by 77% you directly reduce the associated cost in the area of cost to heat the water, cost to chemically treat the water, and the cost of disposing of this soiled water solution.

OTHER KEY FACTORS TO CONSIDER

During the process of evaluating the lowering of your final rinse spray there are two key factors that must be considered. The first is to insure that a proper amount of sanitizer spray is covering the egg shell surface to adequately reduce the microbial population to an expectable level. The second is to insure that this rinsing action adequately removes all traces of soils and any alkali residues left from the chemical detergent cleaning process.

DiverseyLever used a testing method called System Sure ATP swab test to determine the amount of soil and alkali residue left on the cleaned surface of the shell egg. We set up a "System Sure" test swab analysis of the uncleaned shell egg surface and followed by swabbing the cleaned and sanitized egg shell surface. The test results are expressed relative light units (RLU's). DiverseyLever has established a minimum threshold of 300 RLU's to be considered a clean and sanitary surface for the processing shell eggs. Results above 300 RLU's are suspect and may pose possible microbiological concerns. This testing method does not measure bacteria directly. It is designed to measure "Dirt", both bacterial and organic. It is assumed that if there is a measurement above 300 RLU's that conditions are present that could support microbiological activity and therefore compromise product quality. Following are the results of the tests run in a egg processing plant at a flow spray rinse of 1.0 gallons per minute (Tables 1 and 2).

If we compare the raw farm fresh shell eggs that were uncleaned with the clean and sanitized shell eggs we can determine that the reduction in (RLU's) has significantly changed in a positive manner. The (RLU) value is a combination of dirt, chemical detergent alkalinity residues, bacteria, and shell fragments. We could conclude that 20 out of the 21 samples tested (exception being sample #185) are clean and present no harmful bacteria or organic dirt problem. During the process of reducing your final rinse spray it's essential that you make sure that all traces of detergent alkalinity are removed and the egg shell surface is completely covered with sanitizing agent.

DETERMINING WASHER MAKE UP WATER SOURCES AND CONTROLS

There are three main areas that you need to pay attention to. The first area is the final spray/sanitize rinse bar that we discussed earlier. The second is the washer tank capacity level, and the third is the overflow pipe to the drain.

Table 1. DiverseyLever System Sure Swab Testing Results: Soil Load Measurement.

Sample No.	Description-Shell Eggs	Results (RLU)
154	Farm Fresh Eggs	1874
155	"	1414
156	"	2406
157	"	866
158	"	946
159	"	950
160	"	2268
161	"	2372
162	"	4738
163	"	3591
164	"	1916
165	"	6871
166	"	3859
167	"	7710
168	"	1987
169	"	2688
170	"	1987
171	"	2688
172	"	1746
173	"	1984
174	"	3032
175	"	111
176	"	3309
177	"	2832
22 Samples	**Average Results**	**2748 (RBU's)**

USDA regulations now specify that a continuous overflow isn't required, but only that a continuous fresh water supply be added to the washing process. This fresh water addition is commonly the final rinse spray that flows directly back into the wash tank.

Table 2. DiverseyLever System Sure Swab Testing Results: Soil Load Measurement.

Sample No.	Description-Shell Eggs	Results (RLU)
178	Cleaned & Sanitized 100 ppm chlorine	4
179	"	6
180	"	45
181	"	21
182	"	41
183	"	173
184	"	22
185	"	483
186	"	101
187	"	373
188	"	55
189	"	76
190	"	43
212	"	37
213	"	17
214	"	13
215	"	144
216	"	154
217	"	18
218	"	153
219	"	131
21 Samples	**Average Results**	**100 (RBU's)**

In many mechanical wash tank systems water is lost during the time of process shut downs. When the flow of eggs is stopped the water that is collected in the upper cabinet (rain tray or spool bar tray) drops down into the wash supply holding tank and is lost to overflow because the wash tank is full to the overflow capacity level, you generally loose about 20 to 35 gallons of hot wash water solution during every process shut down. One way to help prevent this loss is to program the supply pumps to operate 20 to 30 seconds during the time of process shut down. If a plant has an average of six shut downs per production day they can easily loose 180 gallons of hot wash water solution to the overflow drain.

Another means to help conserve water consumption is to lower and maintain the wash water supply level in the wash tank by approximately 2" below the overflow pipe outlet. This will allow room for the hot water solution that is collected in the upper cabinet to be retained during a process shut down period. Generally, during the first 2 hours of production you will be able to recover all of the water that collects in the upper cabinet during shut down periods. After 2 hours, the final rinse spray make up source will raise the wash tank to it's set overflow level. At this point hot wash water recovery from the upper cabinet flows to the overflow drain during process shut downs. As you progress into the final two hours of the USDA requirement to dump the wash solution after 4 hours of production, it's productive to have a small fresh water addition that causes a small continuous overflow to remove some of the egg product and dirt soils that have built up in the wash tank during this time period. Always take note of the amount of water flowing out of your wash tank overflow pipe. During the first 2 hours of production you should see very little discharge. During the second half of the production run you should see about 1.0 gallon per minute or less flowing out this pipe. It's recommended that a small fresh water meter with a digital display be installed on the final fresh water rinse line for the purpose of monitoring and tracking water additions and usage. A digital flow meter is available through Poultry Management System Company. These methods allows you to monitor and control the amount of water used in the egg washing process.

POTENTIAL WATER SAVINGS

Table 3 indicates the actual water savings that took place in 12 egg processing plants. Accurate measurements were made to determine the amount of water flowing at the point of the fresh water rinse. This fresh water rinse spray was reduced to 1.0 gallon per minute in most of the plants. System Sure ATP swab test were run to make sure the shell egg surfaces were free of any alkalinity or dirt residues and that adequate sanitizer coverage was achieved. Estimated water savings amounted to 4,697,516 gallons on an annual basis. This amounted to a 66% average fresh water volume reduction per plant.

Table 3. Plant Savings Comparison.

Location	Avg. GPM Flow	Gal/Year Usage Water	Gal/Year @ 1.0 GPM or as noted*	Estimated Water Savings
Plant #1	4.4 gpm	465,616	195,048	270,568
Plant #2	4.5 gpm	653,184	173,376	479,808
Plant #3	4.7 gpm	814,867	(1.1*) 211,844	603,023
Plant #4	4.5 gpm	476,280	105,840	370,440
Plant #5	4.0 gpm	580,608	145,152	435,901
Plant #6	4.2 gpm	711,245	169,344	541,901
Plant #7	3.2 gpm	725,760	226,800	498,960
Plant #8	3.0 gpm	520,128	173,376	346,752
Plant #9	3.5 gpm	433,440	(1.8*) 334,368	99,072
Plant #10	3.8 gpm	564,710	(1.7*)294,740	269,970
Plant #11	4.4 gpm	674,309	153,252	521,057
Plant #12	2.5 gpm	433,440	(1.2*)208,051	260,064
Totals:		**7,053,587**	**2,911,319**	**4,697,516**

(*) Indicates more than 1 gallon per minute flow rate on the final rinse sanitize bar assembly. Work needs to be done on these systems to make the necessary adjustments to reduce the amount of water used at or below the 1.0 gpm flow rate.

SUMMARY

What results might you eggspect? It takes very little time to measure the amount of flow spraying through the final rinse bar assembly. This measurement will be the key to determining how much water savings might be possible in your operation. Average water savings at the point of the final spray bar assembly is 70%. Other water savings can be realized if you pay close attention to the mechanical hydraulics of your egg washing machinery. Maintaining wash tank levels at production start up time below the overflow pipe will save water during the first few hours of production. Paying close attention to these few key operating points and fine tuning them within the parameters mentioned in this report will result in significant water savings and the cost associated with treating excessive amounts of water.

FOOD SAFETY AND HACCP CONSIDERATIONS RELATED TO EGG PROCESSING WASTE WATER MANAGEMENT

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Preparing for this talk was sort of like looking into a crystal ball. I have published articles about how to develop a HACCP plan for egg operations (Curtis, 1998; Curtis *et al.*, 1996 from a food safety perspective and I have trained poultry processor for HACCP certification. However, the focus of this presentation is to discuss the environmental "back lash" of HACCP. I will be basing my comments on the poultry meat industry and trying to relate that experience to potential problems for the egg industry. Since there was no information available about HACCP or even if HACCP might be included in the upcoming regulations, I will also be discussing another regulatory change for eggs that could effect egg safety. In addition, I will mention how HACCP has changed the water usage in poultry processing plants. If you are interested in more details about the changes in water usage at poultry processing plants you can stop by our poster presentation on this topic.

Pollution incidents to water are probably the most high profile environmental impacts affecting the poultry industry. If a pesticide, disinfectant, or manure spillage gets into a rive, there tends to be a lot of bad publicity. There are many potential sources of surface water contamination from laying operations. These included manure removal (field storage and land application), septic tanks, shed cleaning and disinfecting, seepage from manure stores, melange disposal, pesticides, fuels and oils, and wash water (Sharp, 1997).

Every year egg processing plants discharge an estimated 200 million gallons of wastewater. As the industry continues to grow and as food safety concerns increase, so will the volume of water used, the amount of wastewater discharged and the waste load. At the same time, processors will face increasing water costs, rising sewer charges, and tighter restrictions on waste load parameters such as BOD_5. Some plants will be faced with the possibility of a shutdown if they cannot meet legal restrictions, cope with limited water supply, or meet increased costs for water and sewer service.

Whenever eggs or food, in any form, is handled, processed, packaged and stored, there will always be an inherent generation of waste water. The quantity of this processing waste water and its general quality (i.e. pollutant strength, nature of constituents) have both economic and environmental consequences with respect to treatability and disposal.

Research has indicated that about 3 to 6 percent of the shell eggs entering egg grading plants are broken during processing (Miller and Mellor, 1971; Morris *et al.*, 1972; Shupe *et al.*/, 1972). Much of the liquid egg contents and shell find its way into the wash water and, in turn, into the waste stream. Thus, the waste water from egg processing plants has the potential to create a high level of pollution. However, few research data are available on waste loads from shell egg processing plants. Hamm *et al.* (1974) reported median waste concentrations for wash waters in shell egg grading plants as follows: Chemical Oxygen Demand (COD) 7,300 mg/1; total solids 9,300 mg/1; volatile solids 4,600 mg/1. Carawan *et al.* (1979) reported a decrease on COD from 11,92 mg/1 to 5,005 mg/1 after modifications in one egg breaking test plant.

CHANGES IN OVERFLOW REGULATIONS

On March 18, 1998, the Agricultural Marketing Service (AMS) published a final rule in the Federal Register entitled "Voluntary Shell Egg Regulations" which became effective April 20, 1998. In this announcement, AMS removed the requirement for continuous overflow of water during the egg washing process. They felt removing the requirement for the continuous overflow of water during egg washing would decrease operating expenses of processors, and lessen the environmental impact of shell egg processing.

Basically, the egg washing process involves moving eggs through brushes under a spray of wash water delivered through a system of pipes. The wash water, a mixture of water and an approved cleaning compound, is filtered and recirculated through the system of pipes from a holding tank. The tank is designed to permit both the inflow and overflow of wash water. Overflow occurs when the volume of wash water exceed the holding capacity of the tank. When the tank is filled with water and the water is turned on, the water is pumped from the tank into the system of pipes and the water level in the tank lowers. Also, some water is lost due to evaporation, drag out (water residue on the egg) and other causes. Replacement water is added continuously and cleaning compounds are added as necessary to maintain the cleaning efficacy of the wash water. Approximately every four hours and between shifts, wash water tanks are emptied and refiled with clean, potable water.

The Agency previously required that replacement water be added continuously to the wash water in order to maintain a continuous overflow of water. Since the rate at which replacement water added to today's egg washing equipment is not always of sufficient volume to provide for continuous overflow, particularly at the beginning of shifts or when the washing equipment is stopped and restarted during the day AMS decided to omit the requirement for maintaining a continuous overflow of water in shell egg washers. However, the Agency recognizes the rate of replacement water inflow, concentration of cleaning compound in the wash water, and rate of overflow all affect wash water quality.

They felt the change in the requirement will still result in a periodic overflow of water during the washing process with the frequency and rate of overflow dependent on factors such as the rate of replacement water inflow, tank size, rate of evaporation, and the number of eggs cleaned (AMS, 1998).

A few words of caution with regard to food safety especially regarding the temperature and pH of your wash water. Alkaline cleaning formulations are designed to give an initial pH of near 11 in the was water and wash water pH during operation is usually in the range 10 to 11 which is unfavorable for growth of most bacteria (Moats, 1978). Two Canadian researchers, Holley and Proulx (1986), evaluated the effect of wash water pH at moderate temperature on *Salmonella* survival and found that *Salmonella* endured a temperature of up to 42°C when wash water pH was ≤ 9.5. This finding agreed with previous research which indicated that *Salmonella* was more sensitivity to heat at alkaline pH's (Anellis *et al*., 1954; Cotterill, 1968). Furthermore, Kinner and Moats (1981) found that when wash water pH's increase from neutral to 10 or 11, bacterial counts always decreased regardless of water temperature. They also reported that as temperature increase from room temperature to 50 or 55°C, bacterial counts decreased regardless of pH. However, these temperatures are above normal commercial processing conditions. Laird *et al*. (1991) indicated that current processing practices are not sufficient to prevent the potential contamination of washed eggs with *Listeria monocytogenes*. Their study has shown that *Listeria* is readily isolated from the egg washing station environment, including wash water.

If you are using a two tank system, you need to pay particular attention to the flow direction, flow rate, detergent concentration and water temperature to insure minimal bacterial growth in your recirculating wash water. Since both wash tanks set on the same level, you also need to pay particular attention to the potential flow of "dirty water" to "clean water" between the two tanks. Very little research has been conducted on the dual wash system. However, most plants are moving in this direction.

There are a few questions which need to be answered when conducting a hazard analysis for a HACCP plan. From a food safety standpoint, maintaining your pH in each of the wash tanks is essential to controlling bacterial growth during the approximate four hour recirculation period. Not all plants add water and detergent in the same manner. How are you maintaining control over your wash tanks? From the environmental standpoint, what effect will dumping these wash tanks have on the pH of the waste stream leaving your operation. Do you know what the pH of your waste stream during the time you are dumping your wash tanks? If you are going directly to a municipal waste treatment operation or have an aeration system, then you probably do not have a problem. However, you should check the pH of your waste stream during the time you are dumping your wash tanks especially if you live in a municipality which has a pH restriction of 6-9. The pH restriction is a high or low at any time NOT an average over time.

SALMONELLA ENTERITIDIS IN EGGS

On May 19, 1998 the Food and Drug Administration (FDA) and Food Safety and Inspection Service (FSIS) jointly issued an advance notice of proposed rule making (ANPR) and a request for comments regarding *Salmonella enteritidis* (SE) in eggs. They indicated that SE is associated with a significant number of human illnesses and continues to be a public health concern. They felt that SE infected flocks have become prevalent throughout the country and that large numbers of illnesses have been attributed to consumption of mishandled SE-contaminated eggs. As a result, FDA and FSIS has been requested to share Federal regulatory responsibility for egg safety. Through this ANPR they requested suggestions on how to reduce food safety risks associated with shell eggs. They requested suggestions on how a farm-to-table approach might be taken to reduce risks. The agencies wanted to explore all reasonable alternatives and gather data on the public benefits and the public costs of various regulatory approaches before proposing a farm to table food safety system. The comment period on this ANPR closed on August 17, 1998. A final rule is expected before the end of the year. Depending on the outcome of this final rule, any number of different scenarios could take place. One possibility could require that eggs be given a mandatory expiration date based on how fast they are cooled. A second scenario would be a Federal-State cooperative program under which overall regulatory oversight is let primarily to State agencies using mutually agreed-upon standards and procedures and Federal assistance.

This approach could be similar to the cooperative programs for handling interstate shipment of Grade A milk and shellfish.

Another possible scenario is a mandatory or voluntary HACCP-like plan. Regulations may be proposed to mandate HACCP-like process controls to reduce the microbiological and other food safety hazards in shell egg production, processing and handling. If this were to happen it could greatly effect the way you currently handle sanitation, water usage, etc. Under a HACCP approach east step from production through distribution would have to be evaluated for hazards and each hazard would then have to be controlled and monitored.

WHAT WE HAVE LEARNED FROM HACCP IN POULTRY PROCESSING PLANTS

If you asked both FSIS and the poultry industry how well HACCP implementation has gone, I believe you would get two totally different answers.

Data presented by researchers at the University of Massachusetts on the costs of implementing HACCP in breaded fish plants showed that FDA's estimates were very unrealistic. Talking with poultry plants, it appears that cost estimates included in the final rule were also unrealistic. Water usage has increased as much as 50 percent in many plants, they have had to conduct more testing procedures than expected, additional personnel have been hired to carry out HACCP related activities, additional equipment has been installed and many more people have been HACCP trained than originally expected and many had to hire consultants to assist with plan development or audits.

More and more responsibilities have been transferred to plant personnel that were previously carried out by FSIS personnel. FSIS no longer approves equipment, cleaners, sanitizers, etc. There is now a new pilot inspection system which will turn more of the FSIS inspection responsibilities over to plant personnel. It is anticipated that performance standards *Salmonella* and generic *E. coli* which were set by baseline studies will become gradually more restrictive. In addition it is anticipated that a performance standard will be set of *Campylobacter* in the not too distant future. These more restrictive performance standards and new pilot inspection system which would require additional preventative measures will most likely continue to increase water usage and potentially add new waste issues like additional phosphorus levels or antimicrobials which may interfere with current waste treatment systems.

OTHER THAN FOOD SAFETY, WHY SHOULD I CARE ABOUT THE WASTE LOAD

Every drop of water that goes down the drain becomes waste water that must be treated. Therefore, water conservation plays an important role in reducing processing waste. Curtis *et al* (1994) reported the average water use per dozen of eggs processed at the test plant was 0.15 liters. This is identical to the figure reported in the 1975 national survey for shell egg grading plants.

Table 1 provides the average values for each of the variables measured and a comparison of that value with research cited (Curtis *et al.*, 1994). Note the difference between the mg/dozen column and the mg/liter column. I believe that mg/dozen is a better basis for comparison, especially between plants, because of the difference the number of eggs processed in each plant. However, only mg/liter values are available in the literature.

Table 1. Wastewater Characteristics.

Variable	Project (mg/doz)	Project (mg/liter)	Research Cited (mg/liter)
FOG	18	93	Not Available
COD	1492	10587	7300
BOD_5	854	6038	Not Available
TS	1045	7632	9300
TSS	159	1013	Not Available
TDS	540	4090	Not Available
TVSS	117	697	Not Available
TVS	434	3065	4600

BOD_5 from of wash water from food plants is directly related to amount of the food in the waste load. In fact, BOD_5 can be estimated in food plant waste waters by estimating the fat, protein and carbohydrates in a particular wastewater and using the following factors (Carawan *et al.*, 1979):

Food Component	Lbs Bod_5/lb Food Component
Carbohydrate	0.65
Fats	0.89
Protein	1.03

When these relationships are applied to eggs, we find that the estimated BOD_5 for whole eggs is 0.24 pounds BOD_5 per pound of product. If we were to discharge 66,459 lbs of BOD_5 in a month, (66459/0.24-276912) our calculation would reveal that we lost 276,912 pounds of eggs. In one plant we tested this averaged 1.7 cases of eggs lost per 100 cases processed.

SUMMARY

It seems regulations are constantly changing. We are challenged to keep ahead of the changes. We face the challenge of consistently looking for ways to improve our product, reduce costs and prove our product's safety and our commitment to maintaining the environment. To do this we must continually reevaluate our production and processing practices and look for ways to improve our operation and meet current and future regulations. And speaking of regulations, it is to your advantage to be aware of proposed regulations and submit comments regarding those regulations.

And last but not least, concern about what is going down the drain could save your money. How many of us would willing toss two cases of eggs or more down the drain for every 100 cases we produced? Not anyone I know! If you can find a way to recoup that lost product you not only reduce your waste load, but you also have a product with value.

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THE TMDL PROCESS: A PARTNERSHIP TO ACHIEVE STATES' WATER QUALITY GOALS

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A TMDL, or total maximum daily load, is a total that may be used to establish an allowable pollutant level that will maintain the appropriate chemical, physical and biological properties necessary for the protection of a waterbody's water quality standards. The TMDL establishes the allowable loadings or other quantifiable parameters for a waterbody and thereby provides the basis for States to establish water quality-based controls. These controls should provide the pollutant reduction necessary for a waterbody to meet water quality standards.

In accordance with Section 303(d) of he Clean Water Act, each state has compiled a 303(d) list that identifies and priority-ranks waterbodies in which technology-based effluent limits are not expected to maintain applicable water quality standards. States target waterbodies from this list for TMDL development. The United States Environmental Protection Agency (EPA) stands ready to provide technical assistance for the development and implementation of TMDL's in an effort to achieve the water quality goals of the states and of the Clean Water Act (CWA).

INTRODUCTION

Each of our states has been blessed with a varied array of natural resources. One of the most plentiful and enjoyable natural resources is the states' waters. Reservoirs, lakes, estuaries, and streams provide for an abundance of uses including water for drinking, swimming, fishing and boating. The states are committed to the protection of all waters. One of the ways that our states protect their water resources is by establishing water quality standards (WQS). WQS include designated uses, numeric and narrative criteria to protect designated uses, and an antidegradation policy. the WQS designate specific uses for each body of water. Along with each specific use, specific water quality criteria have been developed for each designated use. A TMDL is a tool that can be used to establish an allowable pollutant level that will maintain the appropriate chemical, physical and biological properties necessary for the protection of a waterbody's WQS. In short, the TMDL process ensures that the waterbody maintains its WQS.

The TMDL process has been shown to be a valuable tool for environmental protection by attaining a state's stated WQS. Every state has established WQS which apply to surface waters in the respective state, including wetlands, during periods of surface inundation. For example, Texas WQS state that,

"It is the policy of this state....to maintain the quality of water in that state consistent with public health and enjoyment, propagation and protection of terrestrial and aquatic life, operation of existing industries, and economic development of the state; to encourage and promote development and use of regional and area-wide wastewater collection, treatment, and disposal systems to serve the wastewater disposal needs of the citizens of the state; and to require the use of all reasonable methods to implement this policy."

As one can see, there are many variables in the equation for establishing and maintaining state WQS. The TMDL process may be employed as a tool to integrate both point source and non-point source (NPS) considerations to account for the effects of pollutants on the water body. In effect, the TMDL process seeks to quantify all sources of pollutants that may impact the waterbody, either by direct (empirical) measurement, by the use of best professional judgement (BPJ) or by incorporating factors of safety that may reasonably be expected to protect the intended use(s) of the waterbody.

In seeking to account for all pollutants that may impact the waterbody, one must look at the makeup of the general area that surrounds the waterbody. Understanding this surrounding land, or watershed, is the key to accurately defining and accounting for waterbody pollutants. The TMDL process may be thought of as the technical "backbone" of a holistic approach to protect the waterbody and its surrounding watershed. This holistic approach is termed the "Watershed Protection

Approach" and may be defined as "ecosystem management within watershed boundaries." The approach requires initial consideration of all environmental concerns within a watershed and a process for identifying priorities and addressing water quality impacts. These environmental concerns include threats to public health, ground water, drinking water, critical habitats, such as wetlands, biological integrity and surface waters. In this way, the TMDL process provides for a state-led procedure for priority setting and targeting of water bodies.

The TMDL process facilitates innovative and cost-effective solutions. Since the TMDL process requires a holistic understanding of the waterbody and its surrounding watershed, the process allows managers to look at many management scenarios. The development of these management scenarios allows managers to determine if innovative strategies, such as trading of loadings among points sources, and/or between point and non-point sources, is a viable management option.

The TMDL process is a water quality problem solving process. The following steps are one way to break down the water quality problem solving process:

1. Identify Problem.
2. Set Goals (% reduction, water quality standard, annual load).
3. Determine Existing Conditions (data, estimate).
4. Determine Load Reduction to Achieve Goal.
5. Implement Controls to Achieve Load.

IDENTIFY PROBLEM

The TMDL process requires that each State identify their water quality problem waterbodies. Section 303(d) of the Clean Water Act requires States to identify waterbodies that do not or are not expected to maintain applicable WQS with technology-based effluent limitations alone. This list is known as the State's 303(d) list. The 303(d) list is a list of waterbodies that are in need of TMDL development. Each State's 303(d) list is due to the EPA by April 1, of each even year (40 CFR Part 130, 1994). The 303(d) list includes a priority ranking of all listed waterbodies, probable sources and pollutants causing the violation of the applicable WQS, and designates which waterbodies will be targeted for TMDL development during the next two years. In addition, states' make the list available for public review and comment. This enables the State to get feedback from interested parties.

States identify these waterbodies by assembling and evaluating all available water quality-related data and information.

Sources of this readily available data and information include but are not limited to the State's most recent Section 305(b) report, tools (mathematical models) that seek to predict applicable WQS violations and waterbodies where problems have been reported from the public or other sources and activities.

SET GOALS

As was defined earlier, WQS include designated uses,numeric and narrative criteria to protect uses, and an antidegradation policy. The goal of all TMDLs should be to protect and maintain the applicable WQS of a waterbody. This can be achieved by understanding the processes that will maintain the appropriate chemical, physical and biological properties necessary for the protection of a waterbody's WQS. Understanding these processes will enable a quantifiable goal to be established for the TMDL.

DETERMINE EXISTING CONDITIONS

Many times there are enough data to determine that a waterbody is not maintaining its applicable WQS. However, the data needed to determine where, what and how much of an impact a particular activity is contributing to a problem is rarely available. Typically, one of the first steps in the TMDL process is to quantify the pollutant contributions from activities in the watershed. One way to approach this would be to conduct intensive monitoring to adequately characterize the impacts from suspected activities. Another approach would be to use predictive tools (models, relationships) in conjunction with available data to estimate impacts from current activities.

When establishing a TMDL for a waterbody it is important to determine the critical conditions under which the waterbody is most threatened or impacted. This information will be pertinent in determining pollutant contributions and recommended controls.

DETERMINE POLLUTANT REDUCTION TO ACHIEVE GOAL

This part of the problem solving process is where the actual TMDL is established. A TMDL equals the sum of the allowable wasteload allocations plus the sum of the allowable load allocations.

$$TMDL = \sum WLA + \sum LA$$

WLA = Wasteload Allocation (point source load)
LA = Load Allocation (nonpoint source)

In addition, § 303(d) states that TMDLs shall be established with a margin of safety which takes into account any lack of knowledge concerning the relationship between effluent limitations and water quality. The margin of safety (MOS) can be implicitly or explicitly included in the TMDL. An example of implicitly including a MOS in a TMDL would be to state that conservative assumptions were used for the design conditions and inputs for the predictive models account for the margin of safety.

The TMDL addresses a single pollutant. If a waterbody has numerous problems caused by different pollutants, a TMDL should be developed for each problem. Some pollutants may have different properties under certain conditions. In this case, it is appropriate to develop a TMDL for one property of the pollutant. For example, ammonia exerts an oxygen demand during nitrification; however, the unionized component of ammonia is toxic to aquatic life under certain conditions.

When determining the allowable TMDL, it is not necessary to allocate loads to all sources; however, the loadings from all sources should be taken into account during TMDL development. For example, the dioxin TMDL for the Columbia River in Idaho, Oregon and Washington; the TMDL allocated 35% of the loading capacity to eight United States chlorine-bleaching pulp and paper mills located on the river or its tributaries; the remainder of the loading capacity was left unallocated to account for dioxin releases from other sources, (such as publicly owned treatment works, wood preservers, nonpoint sources and a Canadian pulp mill), and to provide a marginal safety. the TMDL included specific wasteload allocations for each of the eight chlorine-bleaching pulp and paper mills (Brady, 1993).

IMPLEMENT CONTROLS TO ACHIEVE LOAD

A TMDL establishes an allowable pollutant level that seeks to maintain the appropriate chemical, physical and biological properties necessary for the protection of a waterbody's WQS. However, a TMDL does not have any enforceable mechanisms for implementation. The TMDL process relies on either state, regional, local or other established Clean Water Act mechanisms for implementation.

Once a state has developed a TMDL (EPA and state should work through technical concerns before formal submittal), the TMDL should be submitted to the Environmental Protection Agency for formal action (approval/disapproval). Following EPA approval, the state should incorporate the TMDL into its Water Quality Management Plan (WQMP). The States' WQMP identifies priority point and nonpoint water quality problems and considers alternative solutions. TMDLs are one of the many elements required in the WQMP. The inclusion of TMDLs in the WQMP requires that the technically approved TMDLS be made available for public comment. Involving the public and the TMDL process is anticipated to increase the probability of success.

If a TMDL requires pollutant reduction from point sources, the WQMP is used to write enforceable National Pollutant Discharge Elimination Systems (NPDES) permits. If a TMDL requires pollutant reduction from nonpoint sources, the WQMP is used as a reference to implement voluntary nonpoint source controls. If a State or local community feels enforceable nonpoint source controls are necessary, it is up to the State or local community to develop enforceable ordinances or laws.

HOW ARE THE STATES AND EPA DOING?

EPA has been involved in legal actions in approximately thirty states. The common complaint in these actions is that the states and EPA have not developed enough TMDLs. As a result of this legal attention the Administrator of EPA appointed a Total Maximum Daily Load (TMDL) Federal Advisory Committee Act (FACA) with twenty members. Committee members included representatives from academia, community/environmental advocacy groups, agriculture, forestry, industry, and government (municipal, state, and tribal). The Administrator charged the Committee to provide EPA with a report containing recommendations on changes and improvements to the TMDL program. A final report is expected in the fall of 1998. Utilizing recommendations in the FACA report, EPA is anticipating revising the regulations (40 CFR 130.7) and guidance dealing with § 303(d). EPA hopes to have proposed regulations and guidance out for public comment in November of 1998. All interested parties should get involved in the review of these documents. The EPA TMDL home page (http://www.epa.gov/OWOW/tmdl/) contains additional information on the FACA report and TMDL lawsuits.

CONCLUSION

The Total Maximum Daily Load (TMDL) process was developed by the U.S. EPA, as a mechanism to assist States in an effort to protect their waters. TMDL's may be developed for a waterbody where technology-based effluent limitations or other legally required pollution control mechanisms are not sufficient or stringent enough to implement the water quality standards that are applicable to the waterbody. In these cases, the TMDL process can be used as a "problem solving" tool to help states to maintain their waters many uses for generations to come.

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NUTRIENT REMOVAL FROM POULTRY PLANT WASTEWATER

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INTRODUCTION

Discussion of N&P Removal Requirements in the Poultry Industry

CASE STUDIES

Plants 1-4

a. Review of Permit Limits
b. Description of Pretreatment System
c. Description of Overall Wastewater Treatment System
d. Discussion of N&P Removal Process
e. Pollutant Removal Efficiencies

CONCLUSIONS

1. DAF Pretreatment and SPN Quality

2. Anaerobic Lagoon vs. Anoxic Reactors

3. Biological Phosphorus Removal vs. Chemical Phosphorus Removal

4. Attainable N&P Removal Efficiency

TERTIARY FILTRATION AT A TURKEY PLANT "THE FUZZY PROJECT"

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In 1994, butterball Turkey company began investigations into compliance issues at the Wallace, NC plant. These issues included both TSS and BOD_5. Tests were completed and it was determined that a substantial portion of the BOD_5 in the effluent stream was tied to TSS. The ratio of $B)D_5$ to TSS was determined by testing for "filtered" BOD_5. The difference between filtered and unfiltered BOD_5 will provide valuable information as to the feasibility of mechanical removal of BOD_5. Results on the Wallace final effluent established that there was virtually no residual BOD_5 after filtration and any TSS removed would also translate into BOD_5 removal. Based on this testing, it was then recognized that a mechanical filter would benefit the plant effluent and support water reuse. A pilot unit was received from Schrieber and testing began in 1995. In early 1996, Chronic Toxicity was added to the list of parameters to improve at the Wallace plant. In December 1996, butterball Turkey Company entered into a Special Order by Consent (SOC) with the NCDEHNR (North Carolina Department of Health and Natural Resources) to correct these problems. The SOC with the state established interim limits for the effluent, resolved past violations, and provided appropriate time to complete pilot testing, engineering, construction and completion of the upgrades by June 1, 1998.

HISTORY

The Wastewater treatment process is a 1.5 MGD extended activated sludge system. The sequence of waste operations is screening, dissolved air flotation, stabilization, aeration, clarification, dissolved air flotation, disinfection, and emergency holding basin. Historically the Wallace plant has experienced problems with BOD_5, TSS, and Chronic Toxicity. During 1992-1995 there were 26 violations of the NPDES permit limitations. The Chronic Toxicity difficulties are due to the physical limitations of the existing chlorination system and the absence of dechlorination. The BOD_5 and difficulties occur during the change over from fall to winter that produces poor settleability of the MLSS within the clarifiers. Cationic polymers have been utilized to combat this problem with mixed results.

Table 1. Waste Water Treatment Plant Limits.

	Summer		Winter	
Flow	1.5 mgd		1.5 mgd	
BOD_5 (pounds)	37.5 avg	75 max	75 avg	150 max
TSS	140 avg	280 max	104 avg	280 max
Chronic Toxicity	Test at 57% in March, June, September, and December			

PILOT STUDY

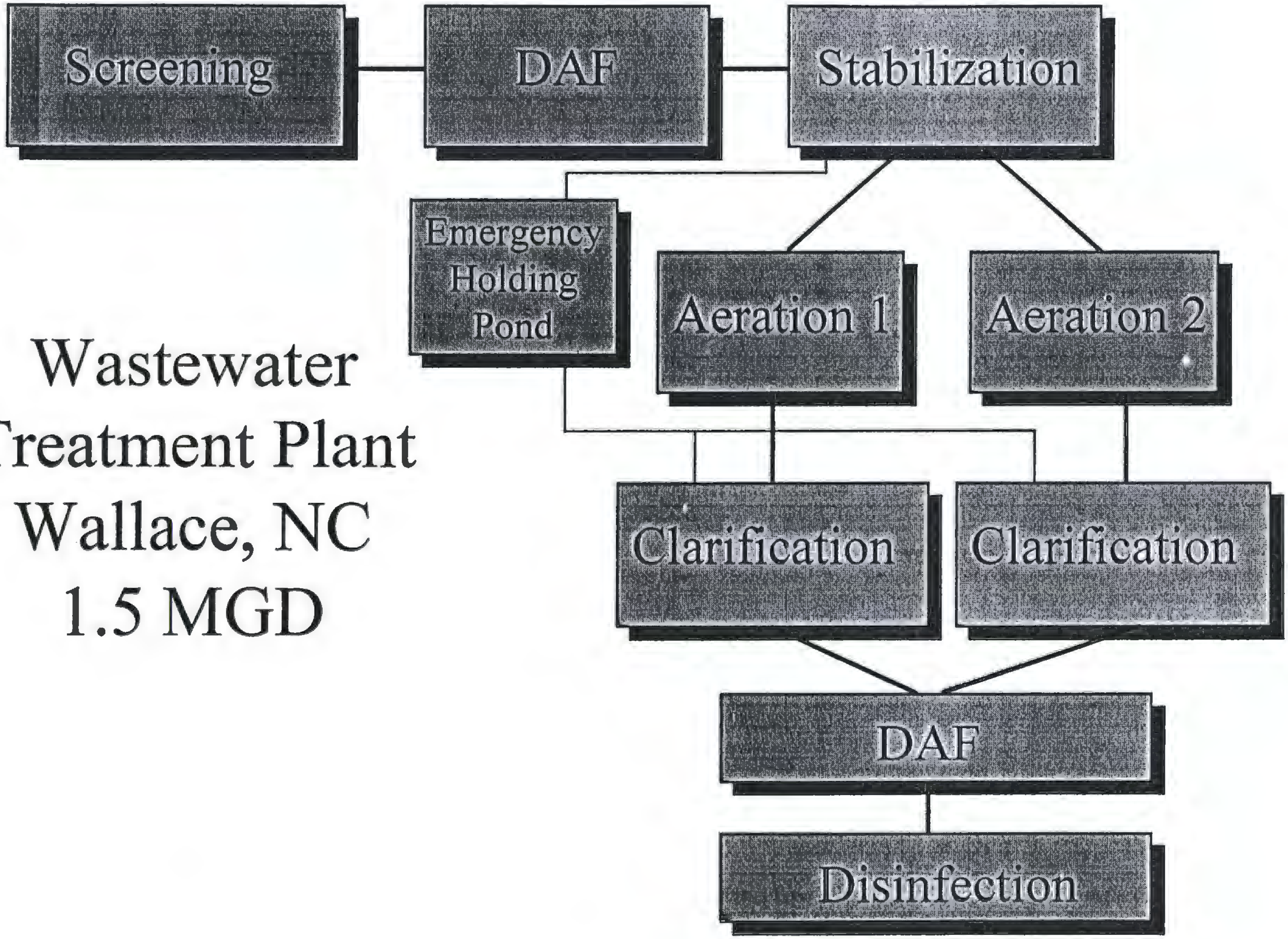
The Schreiber Unit had been run for one year with an excellent mechanical record to reduce BOD_5 and TSS at the Wallace facility. the unit was put in line with the Trojan unit. The Trojan UV unit had three sites for sampling. These sampling points allowed testing after various exposure levels to UV energy. This was useful to the consulting engineer for sizing of the unit at the Wallace plant. Both the Fuzzy and Trojan UV units operated with no mechanical problems during the ensuing trials. In-depth testing was completed to determine several things:

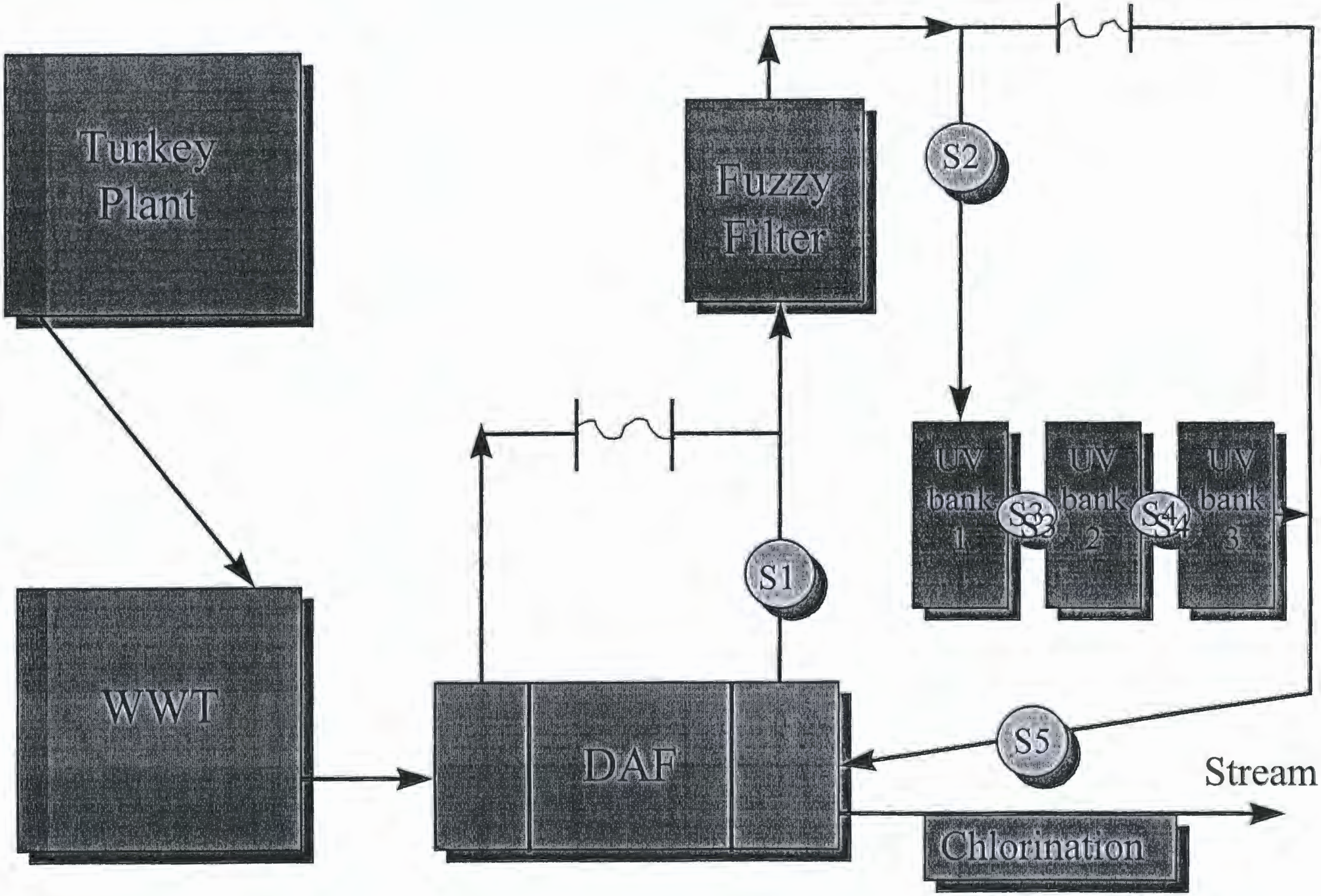
- Would the unit allow the UV to perform consistently?
- How would TSS be affected by the Schreiber unit?
- Would any BOD_5/TSS reduction continue to be seen in the testing?

RESULTS

The results of the trial were very successful. The Schreiber unit competed well both in cost and performance with existing filter technologies. We were able to achieve a positive kill in fecal testing without the addition of chemicals to the waste stream. The Schreiber unit reduced the particle size (as determined by Trojan) in the effluent stream. The analysis used to measure for this reduction was turbidity. The unit was able to consistently reduce turbidity by one full unit. The Fuzzy filter continued to realize a 30-40% reduction in both TSS and BOD_5 in the effluent as documented in the original Fuzzy trial. This reduction of 30-40% is very

Wastewater Treatment Plant Wallace, NC 1.5 MGD

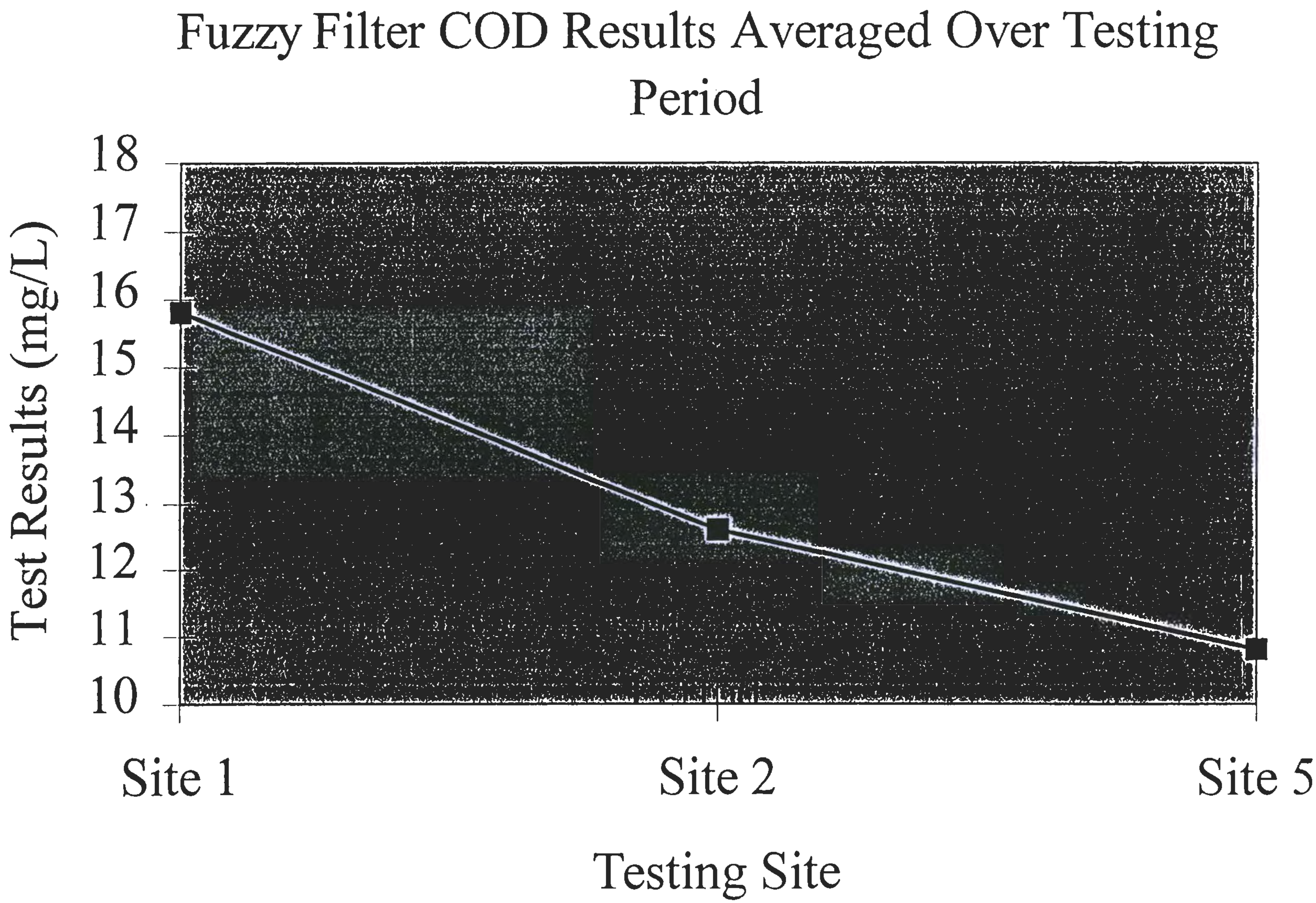



Turkey Plant
WWT
DAF
Fuzzy Filter
S1
S2
UV bank 1
S3
UV bank 2
S4
UV bank 3
S5
Stream
Chlorination

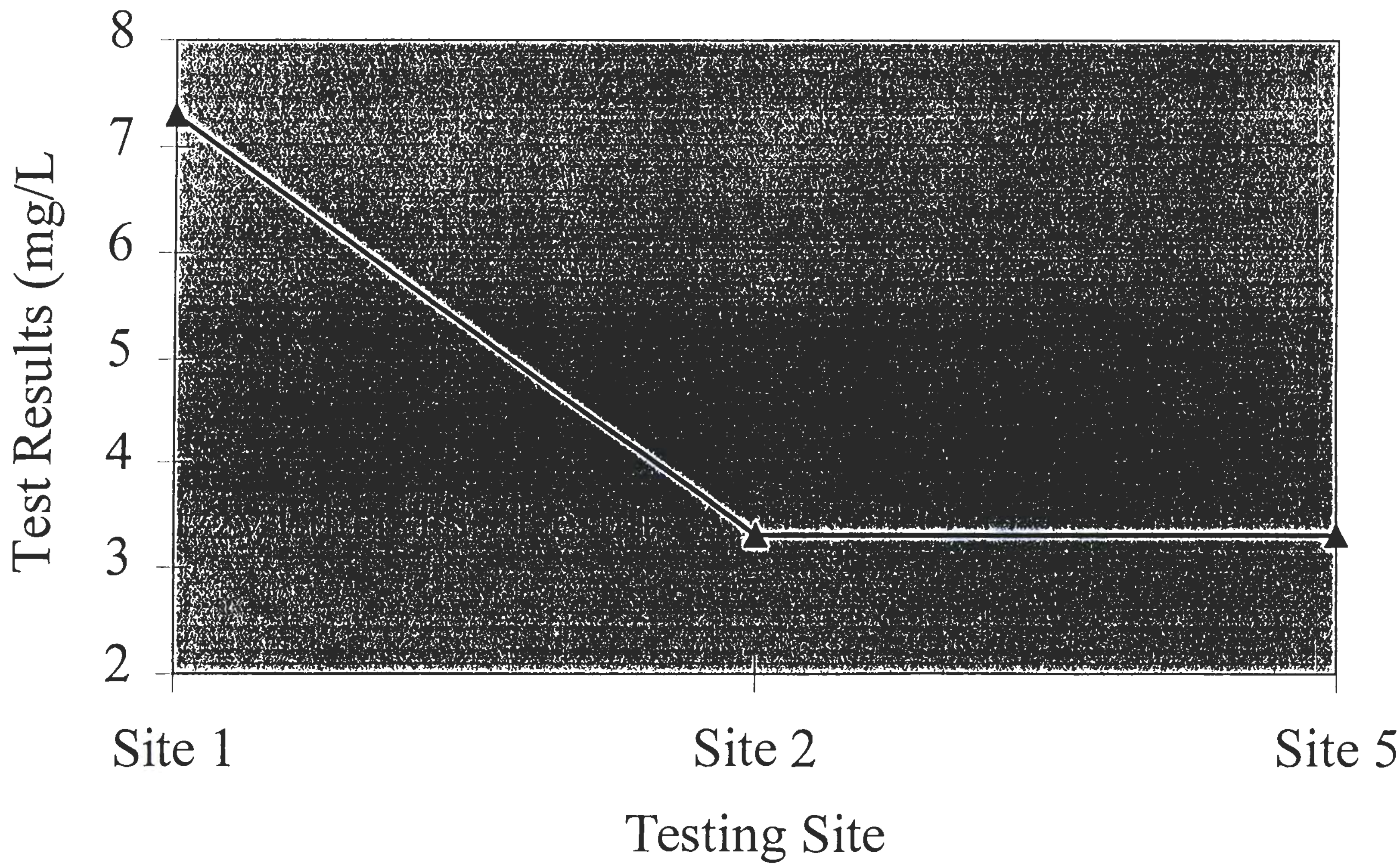
significant indeed! If we compare past results with those lowered by 30% we would have had no TSS or BOD_5 failures at the Wallace plant. In addition to lowering overall results, the Fuzzy will help with recycling. We will be able to reuse from 200-300 gpm of water. The significance of this reuse is that the Wallace plant NPDES permit limits are in total pounds not percent. By reducing water volume in the effluent, we assist with compliance by lowering the multiplier in the mass calculation by 25%. This is calculated by the relationship of 200 gpm saved *vs*. 750 gpm average flow.

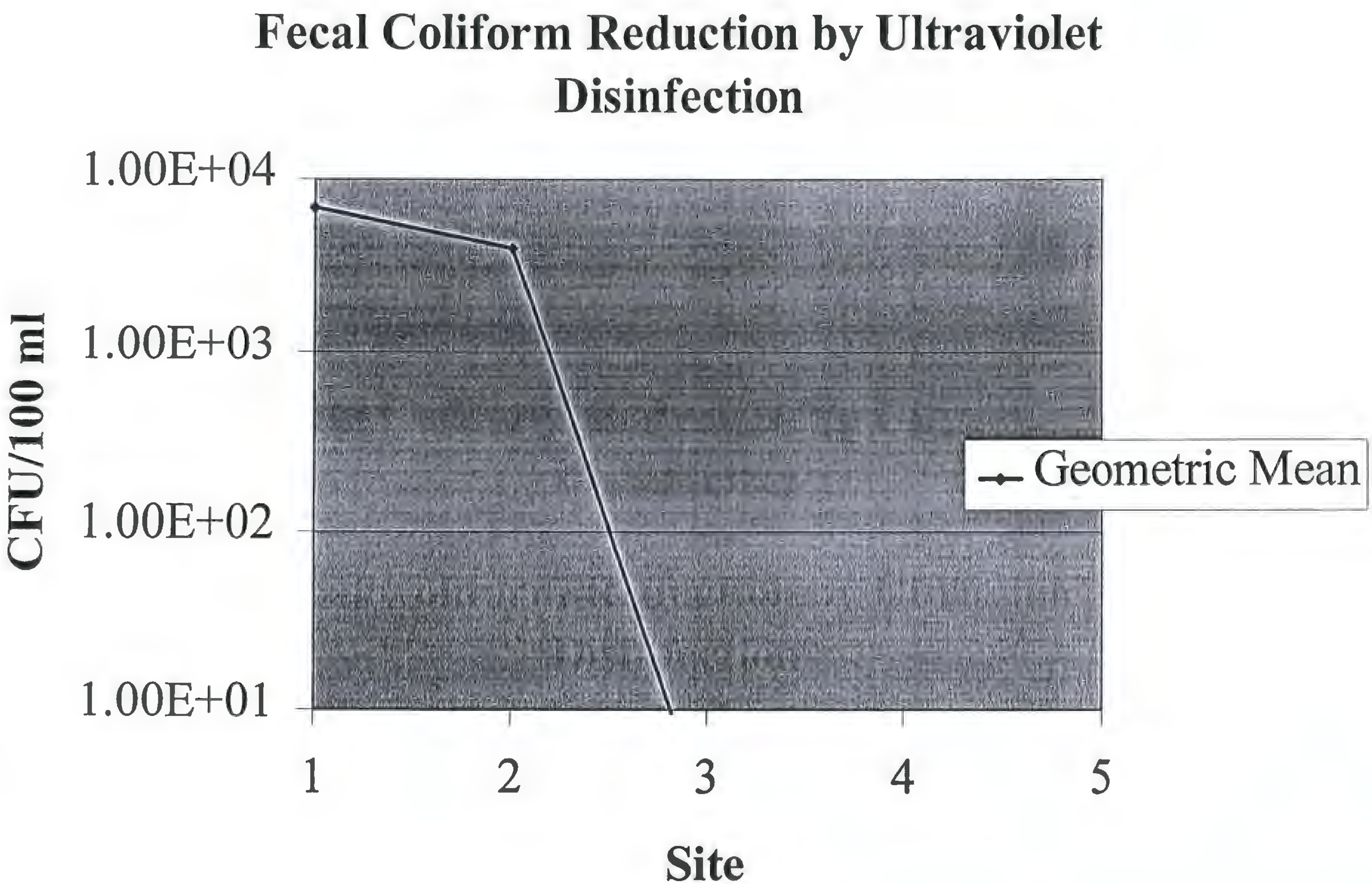
FUTURE

We will be installing our system in the upcoming months. the system will include two Schrieber fuzzy systems in parallel followed by three Trojan UV disinfection units. Any interested parties are invited to contact Robert Harris [910-285-5752] at the Wallace plant for a tour or to answer any questions.

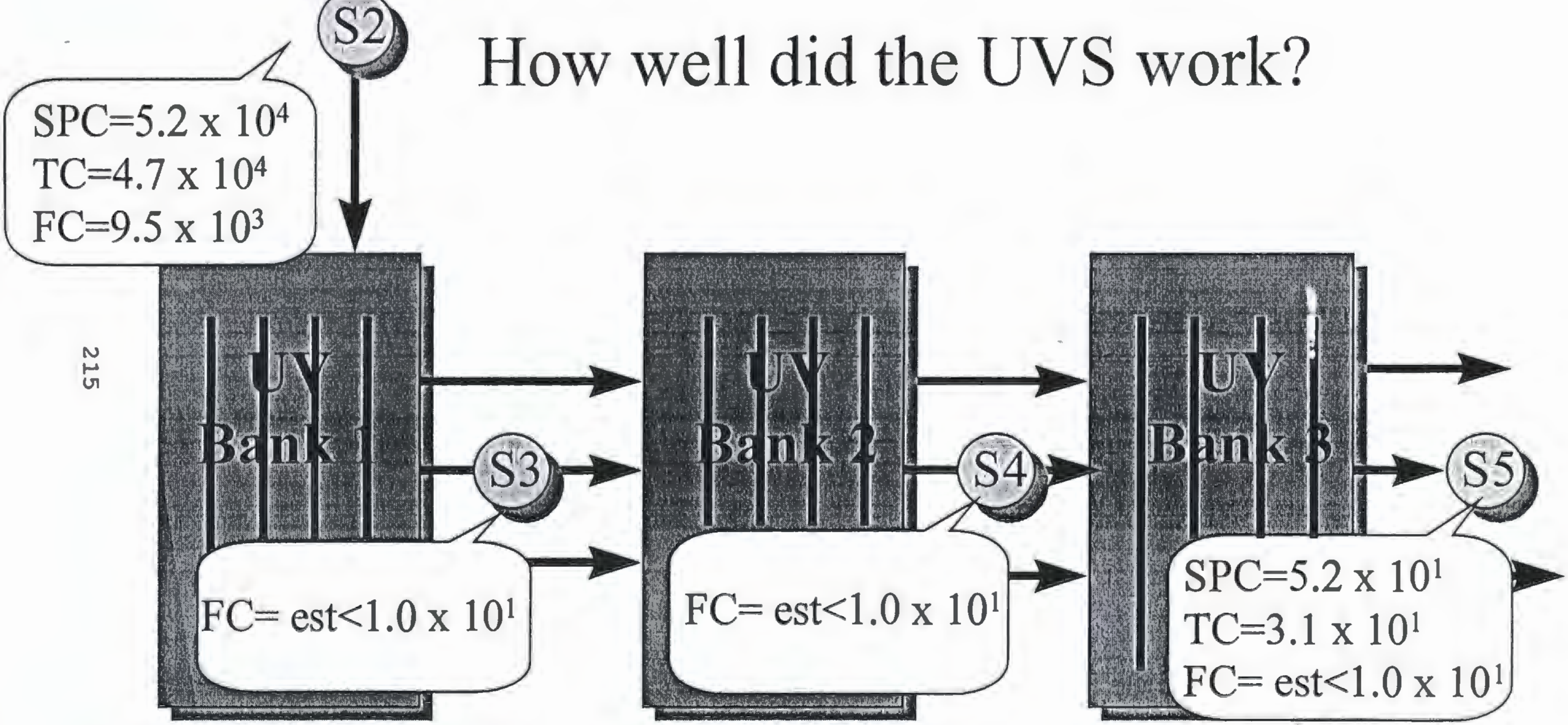

Fuzzy Filter COD Results Averaged Over Testing Period
Test Results (mg/L)
18
17
16
15
14
13
12
11
10
Site 1
Site 2
Site 5
Testing Site

Fuzzy Filter TSS Results Averaged Over Testing Period




Fecal Coliform Reduction by Ultraviolet Disinfection
1.00E+04
1.00E+03
1.00E+02
1.00E+01
CFU/100 ml
1
2
3
4
5
Site
Geometric Mean

How well did the UVS work?



THE USE OF STABLE ISOTOPE TRACERS TO DIFFERENTIATE NITROGEN SOURCES PROXIMATE TO LIVESTOCK PRODUCTION FACILITIES

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Concern over the environmental impacts from the rapidly expanding livestock industry in eastern North Carolina has focused attention on the practice of treating animal wastes in open pit lagoon systems and spray-irrigating these wastes on adjacent fields. Production of swine, turkeys and broiler chickens have increased dramatically in North Carolina over the past 10 years, with swine populations increasing from 2.35 million in 1985 (Cahoon in press) to well over 9 million animals in June 1997 (NC Dept. of Agriculture, State Veterinary Office). Intensive livestock operations are located in different regions of the state. As of June 1997 there were approximately 100,000 beef and dairy cattle, 9 million swine and 207 million poultry (NC Dept. of Agriculture, State Veterinary Office, Figure 1). Cattle operations are predominately located in the western part of the state, poultry operations are concentrated in the north western, south central and eastern areas, while swine operations are concentrated in the eastern areas of the state where water quality problems are found. As North Carolina and other states address the practice of treating animal wastes in open pit lagoon systems and spray-irrigating these wastes on adjacent fields, the question of the impacts of animal waste nitrogen on water quality has become a nationwide issue. To better address issues of water quality concerns, the natural abundance differences in the stable nitrogen isotopic composition of nitrate and ammonia can be used to identify and differentiate the sources of nitrogen nutrients to aquatic ecosystems.

ISOTOPIC SIGNALS FROM DIFFERENT NITROGEN SOURCES

Showers *et al.* (1990) measured the isotopic signal from different point and non-point sources in the Neuse River basin. Fertilizers fell near the 0 per mil range, non-point source runoff from cultivated fields fell in the +6 to +9 per mil range, and MSTP effluent fell in the +11 to +14 per mil range. Fixation of atmospheric N_2 into fertilizers has little isotopic fractionation, resulting in fertilizer isotopic values that range from -4.1 to +1.9 per mil near atmospheric composition (Black and Waring, 1977; Freyer and Aly, 1975; Showers *et al.*, 1990). Nitrogen isotopes in soils exhibit some variation according to soil type (Cheng *et al.*, 1964; Bremner and Tabatabai, 1973). Naturally occurring soil nitrogen therefore can have a wide range of isotopic values, but natural soils generally have low nitrogen concentrations and therefore export little nitrogen.

In cultivated fields with fertilizer application, the soil nitrogen concentration rises and the soil microbial cycle slightly fractionates excess nitrogen in the soil organic pool. Non-hydrolyzable soil nitrogen (-1 to +4 per mil) is similar in isotopic composition to fertilizer nitrogen, while hydrolyzable soil nitrogen that is exported from soil systems is usually isotopically more positive in the range of +4 to +8 per mil (Heaton, 1986). Naturally occurring soil nitrogen can be differentiated from fertilizer nitrogen contaminated soils by an increase in nitrogen concentration and a depletion of 15N below the 5-6 per mil range (Heaton, 1986). The nitrogen isotopic composition of plants is determined by the nitrogen nutrient pool available to the plant (Letolle, 1980), while animal matter is usually enriched compared to the vegetable matter the animals consume (Gaebler *et al.*, 1963). There is also an enrichment in the heavier isotope with each higher tropic level in the food chain (Peterson and Fry, 1987).

Nitrogen in excreted waste is mainly in the form of urea which is hydrolyzed to ammonia and converted to nitrate with resulting nitrogen isotopic values that are found to be in the +10 to +20 per mil range (Kreitler, 1975, 1979). The degree of 15N enrichment in nitrate derived from sewage is controlled by the amount of ammonia volatilization. These processes are constant and controlled in Municipal Sewage Treatment Plants (MSTP) by regulated sewage treatment procedures. MSTP effluent has nitrate nitrogen isotopic values constrained to a narrow range from +11 to +15 per mil (Heaton, 1986; Showers *et al.*, 1990). Ammonia volatilization of animal manures should also concentrate 15N in animal wastes, but the amount of 15N enrichment in animal waste will depend upon how the manures are handled and will not be as controlled as MSTP procedures, and must be determined for each particular study area (Heaton, 1986).

NITROGEN ISOTOPIC SIGNALS FROM ANIMAL MANURE SOURCES

Previously published studies document that groundwater nitrate sampled adjacent to cattle barnyards in Texas (Kreitler 1975, 1979), Nebraska (Gormly and Spalding 1979), and near livestock pens in Pretoria South Africa (Heaton, 1986) have 15N values in the +10 to +20 per mil range with most values higher than +15. Recent measurements from animal waste lagoons in the Neuse and Cape Fear River basin (Figure 2), shows that the animal waste lagoon nitrogen is enriched in 15N. Swine lagoon nitrogen falls in the +16 to +19 per mil range, dairy lagoon nitrogen is +20 to +23 per mil, and poultry lagoon nitrogen is +27 per mil. The isotopic difference between these manures may be due to different waste handling procedures.

To assess the seasonal variation in a swine lagoon, the 15N isotopic composition of a commercial lagoon in Duplin County was monitored (Figure 3). During the summer months the isotopic composition of the lagoon is about 15 to 18 per mil, and decreases to about 12 to 10 per mil in the winter months. The concentration of nitrogen in the form of TKN and NH_4 varies from -250 mg/1 in the winter to over 350 mg/1 in mid-summer in this particular lagoon. The isotopic and concentration changes are likely due to increased NH_4 volatilization and water evaporation in the summer months, and decreased NH_4 volatilization and increased rainfall in the winter months. Shallow groundwater in the spray fields and adjacent streams were monitored for N concentration and isotopic composition at the Duplin County site to investigate the fate of animal waste nitrogen that is spray-irrigated on open fields. Three transects of wells from the center of a spray field through the field edge into the adjacent riparian buffer were monitored for 12 months. Transects covered the upper and lower portions of the spray field and well depth varied from 3 to 20 feet (Figure 4). In the winter, the spray field wells have a four per mil variation (12 to 17.5 per mil). Shallow groundwater in the center of the field is generally less enriched in 15N. In the summer months, the isotopic variation in spray field wells is about 20 per mil with 15N values varying from 14 to 34 per mil. Shallow groundwater in the center of the field is most enriched in 15N (Figure 5). The weighted mean average of the lagoons, spray field wells and adjacent stream samples are similar isotopically (Table 1), but decrease in concentration from the Lagoon through the spray field and into the adjacent streams.

Table 1. Weight Mean Average of 15N and N Concentration Duplin County Swine ILO.

Description	Conc. Mean (mg/1)	15N Mean (per mil)
Lagoon	228.5 (NH_4)	15.2
Spray Field Wells	29.6 (NO_3)	15.5
Stream Samples	7.4 (NO_3)	15.3

The winter 15N depletion in the center of the spray field may be attributed to isotopically depleted NJ_4 being sprayed on the field from the lagoon, since the lagoon is depleted in 15N during the winter months. The summer time 15N enrichment if the shallow spray field monitoring wells could be explained by denitrification, or increased volatilization of ammonium during spraying operations in warmer weather. All of the summer 15N elevated well samples do not have lower concentrations, so both processes are probably operating during he summer period. Spray caught before hitting the ground during the summer at sites in Duplin and Robeson County has decreased N concentration and 15N enrichment compared to the lagoon composition. The spray concentration is decreased by 25 to 40% and the measured isotopic enrichment is 10 to 25 per mil. When the isotopic composition of the spray, lagoons and spray field wells are compared during the summer months, elevated 15n in the spray field wells is associated with elevated 15N in the spray. The field edge wells have significantly less isotopic variation than the wells in the center of the field and the deep spray field wells have significantly less variation than the shallow spray field wells. The seasonal isotopic variation that is observed in the lagoon is amplified in the shallow center spray field wells by the spray-irrigation method of applying liquid waste. This variation is reduced as intermediate and deep groundwater flows towards the field edge. The residence time of the groundwater as it migrates out of the spray field averages the shorter term variation during transport. Nitrate that reaches the adjacent streams is reduced in concentration, does not show significant isotopic variation, and has an isotopic composition that is nearly identical to the weighted mean average of the lagoon and spray field samples.

NITROGEN ISOTOPIC SIGNALS FROM GROUND WATER NEAR SWINE OPERATIONS

To evaluate the effects of swine operations on groundwater, wells in the Sampson County area with elevated nitrate concentrations were analyzed for 15N. While nitrate contamination of groundwater is almost synonymous with highly productive row-crop agriculture (Komor *et al.*, 1996), septic systems in rural areas are also well known to be one of the most numerous point sources of contamination in shallow groundwater systems not serviced by municipal sewage systems (Aravena *et al.*, 1993). Duplin and Sampson counties have the most concentrated swine populations in the state. Aerial photographic data shows that multiple agricultural activities are focused in this area, and there is a potential for several different agricultural and human nutrient sources to impact upon the groundwater resources. Figure 6 shows the nitrogen isotopic data for some of the drinking wells in the Sampson area with high nitrate levels. Data is also shown for groundwater under spray fields and for swine lagoons in and outside the area. Swine lagoons are in the +16 to +19 d15N per mil range and groundwater under the adjacent spray fields are also in this isotopic range with nitrate concentrations of 15 to 40 mg/l. Drinking wells have d15N composition of +1 to +9 per mil in this area. Fertilizers fall in the -1 to +4 per mil range and septic systems have been measured in the +9 to +10 per mil range. Collectively, this data suggests that the spray field groundwater nitrate is characteristic of the swine sourced isotopic signal, however, the elevated nitrate levels in the drinking water wells are the result of fertilizer nitrate with some local septic sources.

In summary, the goal of these isotopic monitoring efforts are to quantify the impacts of various nutrient sources on water quality. It is anticipated that this methodology and resulting data will allow the tracking of various sources of nitrogen sufficiently far through the water transport system to allow the use of models to show the fate of various sources of nitrogen throughout a drainage basin. This will allow better informed environmental management and regulatory decisions regarding nitrogen loading from animal agriculture.

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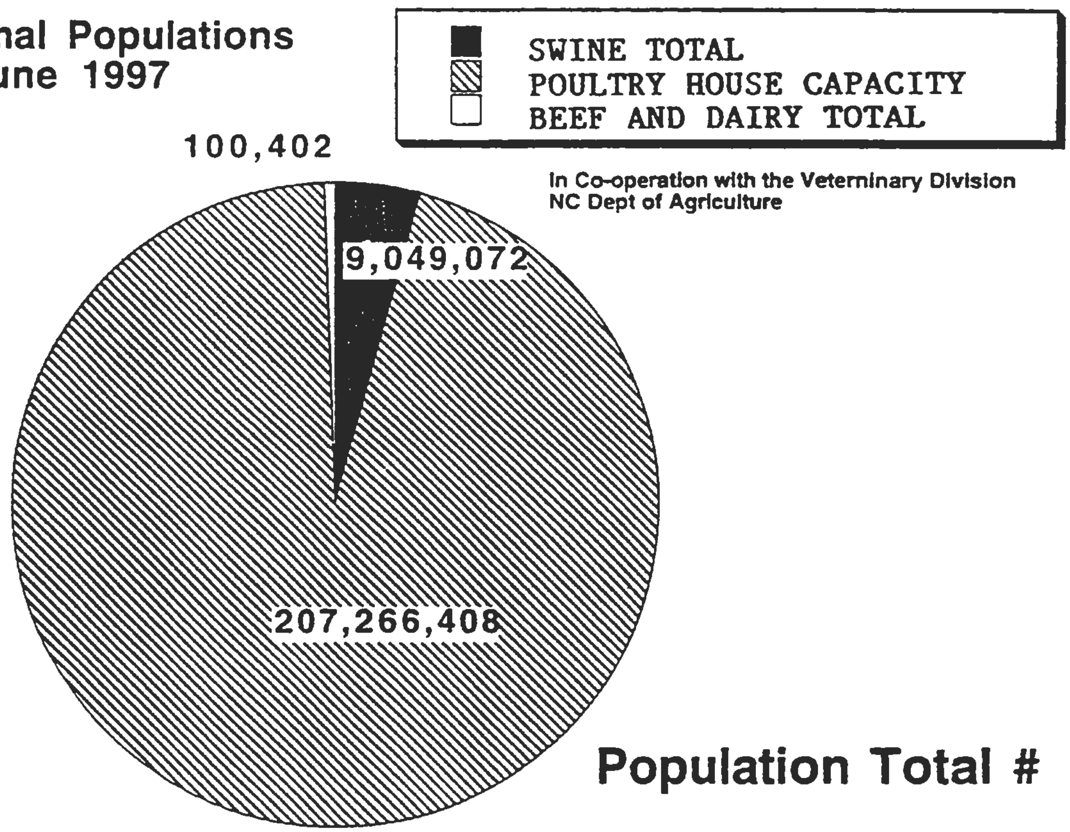

Figure 1

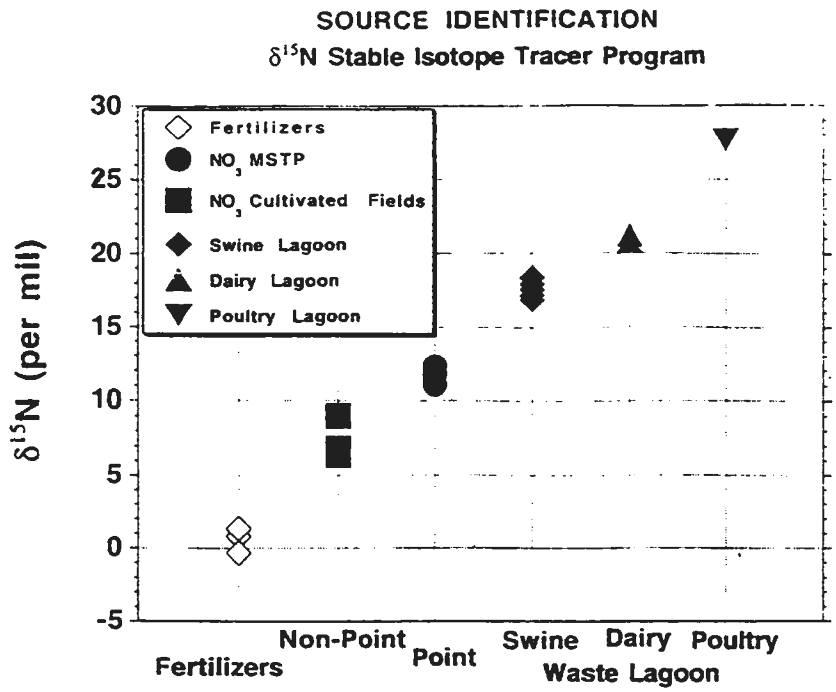

Figure 2. Source Identification
$\delta^{15}N$ Stable Isotope Trace Program.

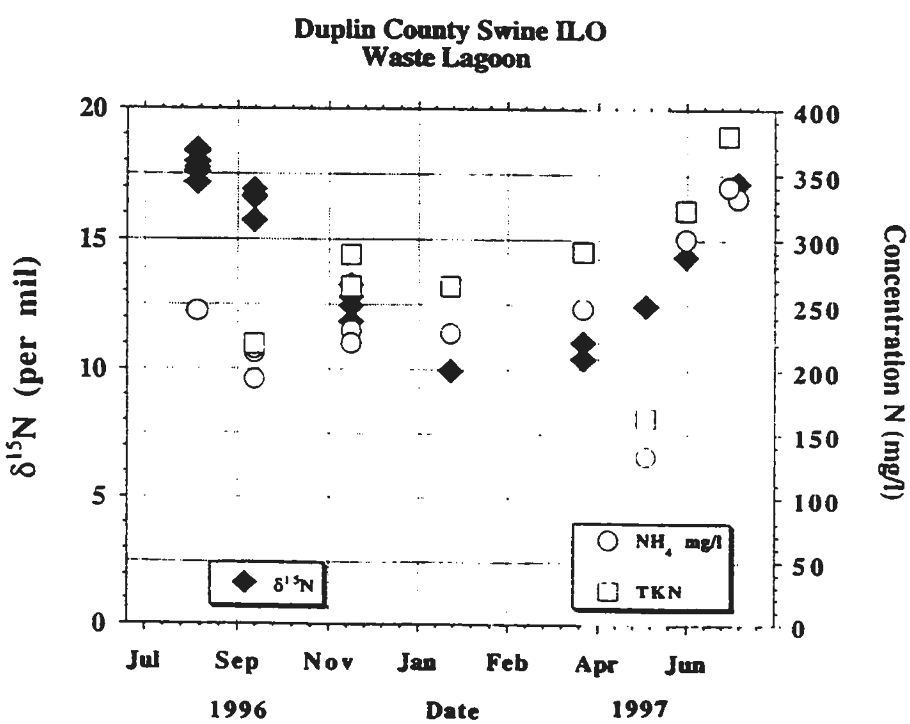

Figure 3. Duplin County Swine ILO Waste Lagoon.

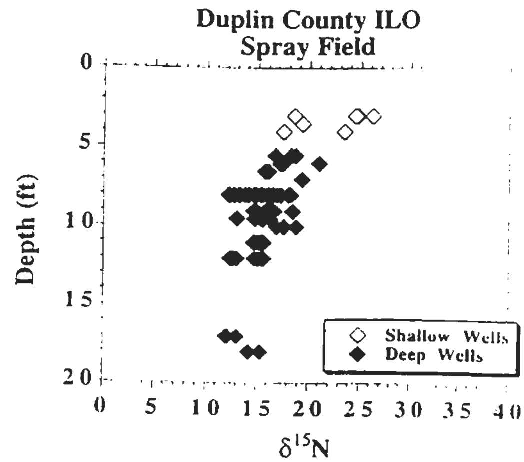

Figure 4. Duplin Country ILO Spray Field.

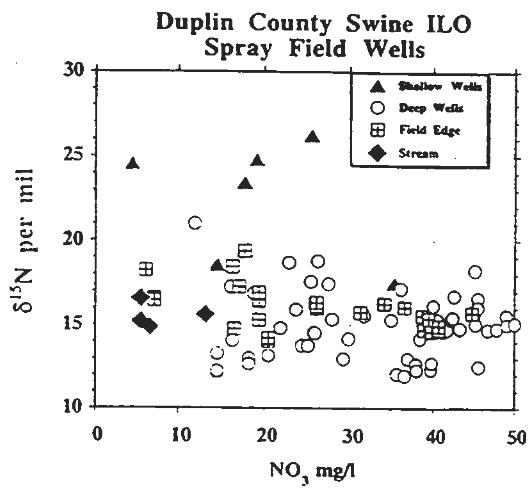

Figure 5. Duplin Country Swine ILO Spray Field Wells.

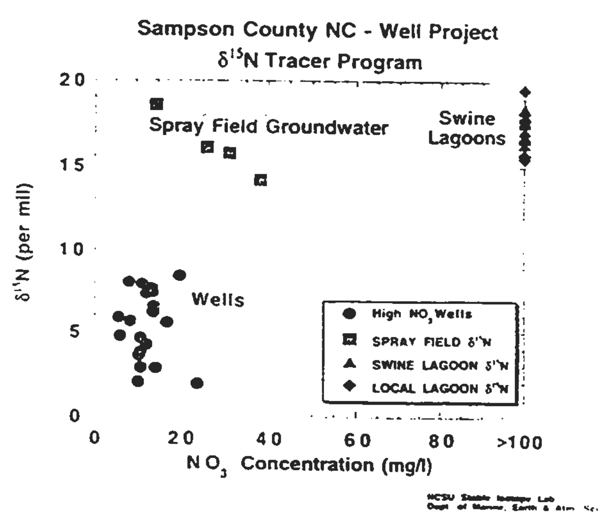

Figure 6. Sampson County NC - Well Project $\delta^{15}N$ Tracer Program.

RECENT EXPERIENCES WITH REDUCED OR NON-LITTER SYSTEMS FOR GROWING BROILERS AND TURKEYS

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Most commercial broiler and turkey flocks around the world are currently grown in floor houses on some type of wood chips or shavings as a moisture absorbent bedding material. In North America, six or more broiler flocks may be grown on the same litter base, with only one inch of clean shavings added after the caked litter and feathers have been removed between flocks. Generally, after the sixth or seventh flock, broiler houses are thoroughly cleaned before the cycle is started over. In Europe, all broiler houses are cleaned out and replaced between all flocks. Turkey flocks in the U.S., on the other hand, are almost always brooded until five to six weeks of age on new litter in a cleaned and disinfected brooder house. Most are then moved to a growout house containing either new or used litter. Depending on the disease history of the farm, the litter in the turkey grow-out house may be used for two to four flocks before the grow-out house is cleaned and disinfected. Over the past two years, due to some especially severe disease situations, east coast turkey integrators have been moving from this multiple age two-phase grow-out system to single stage all-in all-out brood-grow system. The litter in the single stage system is generally removed after each 16 to 20 wk flock, so the house can be cleaned and disinfected between flocks. From epidemiologic data collected during 1997, this change in turkey management appears to have had very positive effects on reducing the incidence and severity of several types of turkey diseases in North Carolina (Carver and Vaillencourt, 1998, NC State University, personal communication).

The litter systems commonly used for growing meat type poultry have several major drawbacks, including: 1) the decreasing availability and increasing cost of wood shavings; 2) the buildup over time as the litter ages of disease agents and pest populations (especially litter beetles, flies and rodents); 3) the emission of odor and ammonia due to the microbial decomposition of the litter; and finally, 4) the cost and inconvenience of having to handle bulky shavings in and out of the house that must eventually be land applied. Several pests found in poultry litter have also been shown to be carriers of a number of poultry pathogens (Axtell and Edwards, 1983; Brady, 1970; Horsfall, 1983; Skewes and Monroe, 1991). Because of these drawbacks with litter floor systems, cage systems can be a favorable alternative, especially as the cost of housing space increases. Until a few years ago, however, cage systems that had been tested were very inferior to litter systems for meat-type birds, because birds reared in them had considerably higher than normal rates of carcass downgrades from breast blisters (Reed *et al.*, 1966; Reece *et al.*, 1971) and/or bone breakage problems. The breast blister problem was largely overcome by changing from wire to various rubber, nylon and plastic coated cage floors (Reed *et al.*, 1966; Walpole and Lloyd, 1970; Lloyd and Chaloupka, 1972, Andrews and Goodwin, 1973). However, downgrades from broken wings (Walpole and Lloyd, 1970) and, sometimes downgrades and poor performance due to severe leg problems (Reece *et al.*, 1971) continued to plague researchers who were attempting to develop cage systems for broilers (Chaloupka, 1970 [as reported by Merkeley, 1976]; Lloyd and Chaloupka, 1972; Yates and Brunson, 1971). Some investigators suggested that these bone breakage problems were due to inactivity by the cage grown birds. Others thought that they were due to inadequate mineral nutrition. Merkeley (1976) reported fluoridation of the drinking water partially mitigated the bone fragility problem with cage reared birds.

Over the past three to five years, several reduced-litter or non-litter systems have been developed for the growing of broilers and turkeys, and these system appear to have overcome most of the problems associated with previous systems. Following are brief descriptions of four systems, one of which was developed and tested in Minnesota, and three others that were developed in Europe. Some performance data from birds reared in these systems has been gathered from researchers in the United States and Europe as well as from commercial operations in the Netherlands and in Egypt will also be presented.

One of these systems, the partial slotted floor consisting of plastic pipes, is a modern version of a system that was tried many years earlier. This system was recently described by Noll *et al.* (1997) from the University of Minnesota. Two of the European systems include ventilated or partially ventilated floors which greatly reduce the amount of shavings required and at the same time promotes rapid drying of the manure produced. These ventilated floor systems were developed and field tested by scientists at the Centre for Applied Poultry Research (CAPR), het Spelderholt, Beekbergen, The Netherlands (Van Middelkoop, 1998; Ferket 1997, 1998). A ventilated salted floor, an adaptation of the broiler system, was later developed by the CAPR for use with turkeys. These systems have been described in detail by Ferket (1997, 1998), so will be only briefly described herein. The third system is a cage facility that was also developed in Europe for growing broilers by the Josef Kuhlman Co., Laer, Germany. It is now being used successfully in commercial operations in at least 10 countries around the world; and the primary reason for its apparent success is a very well constructed and supported soft plastic floor that allows the broilers to walk around quite normally on a nearly feces-free surface. Their unit is being marketed in North America by Farmer Automatic of America, Inc., Register, GA, as the Farmer Automatic Broilermatic® Cage system.

SLOTTED FLOOR SYSTEM FOR TURKEYS

Early attempts to use 2 inch x 2 inch wooden slats to form a partial slatted floor system for turkeys (similar to what has been used for high rise Leghorn breeder houses and 2/3 slat and 1/3 litter systems for broiler breeders) produce disastrous results with excessive downgrades, leg problems, and poor growth performance (Brewer, 1987, NC State University, personal communication). Noll *et al.* (1997), however, reported good performance for market turkey toms reared from 5 to 18 wk of age on partially slotted plastic pipe floors. The plastic pipe floor covered approximately 2/3 of the floor space and was placed on a wooden frame under the feeders and waterers. It was constructed of 2.2 cm plastic pipe spaced 2.2 cm apart. The remainder of the floor consisted of conventional litter. Performance results from the slotted floor system (Noll *et al.*, 1997) compared to that from a conventional all litter floor system showed approximately equal mortality and feed conversion, but improved growth rate (Table 1).

Leg problems were significantly reduced in the first but not in the second experiment. Differences in breast button and breast blisters were inconsistent between the two experiments, possibly due to the fact that the birds in the first experiment were brooded in cages; whereas, those in the second experiment were brooded on litter during the first 5 weeks of the birds life. The birds in Experiment 1 had fewer breast blisters than those reared on litter (Experiment 2), which was consistent with field reports of reduced breast buttons on poults brooded off the litter in North Carolina (Knapp, 1997, WLR Foods, personal communication).

The partially slotted floor also showed several advantages from an environmental standpoint over the conventional litter floor system. It results in significantly less ammonia production, reduced litter moisture, and reduced energy usage; but dust levels were significantly higher with the slotted floor system.

Table 1. Performance of Tom Turkeys Reared on Conventional Litter vs. Partially Slotted Plastic Pipe Floors (Noll *et al.*, 1997).

Measurement	Experiment 1[a] Litter	Experiment 1[a] Slotted	Experiment 1[a] Difference	Experiment 2[b] Litter	Experiment 2[b] Slotted	Experiment 2[b] Difference
5-18 Wk. Gain	10.5	11.8	+1.3	11.2	13.1	+1.9
5-18 Feed/Gain	3.46	3.41	-0.05	3.26	3.29	+0.03
Mortality Rate %	4.3	2.2	-2.1	14.3	10.0	-4.3
Leg Problems%	31.7	21.0	-10.7*	34.0	17.5	-16.5
Breast Buttons %	3.7	2.1	-1.6	3.9	13.1	+9.2*
Breast Blisters %	0.3	0	-.3	0.4	17.6	+17.2*

	Litter	Slotted	Difference
Ammonia, ppm	37.7	24.3	-13.4*
CO_2, ppm	2.22	2.17	-.05
Dust, mg/m^3	3.73	6.99	+3.26*
Litter Moisture, %	37.4	23.8	-13.6*
Energy Usage, kBtu/bird	25.5	13.0	-12.5*

[a]Nicholas toms brooded in cages until 5 wk of age.
[b]BUTA toms reared on litter floors until 5 wk of age.
*Difference significant at the 0.05 level.

VENTILATED FLOOR SYSTEM FOR BROILERS

In the Netherlands, in order to meet severe environmental regulations that limit ammonia and odor emissions from animal facilities, researchers at the CAPR have worked for a number of years on the development of a ventilated floor system for the growing of broilers. A number of commercial broiler houses have been constructed which utilize this system (van Middelkoop *et al.*, 1994). It consists of a slatted floor (positioned on legs about 40 cm above the cement floor) which is covered by a permeable fabric (Nicolon 66303) similar to landscape cloth, which allows air to be forced through it. The fabric is then covered with about 1 to 2 cm of soft wood shavings on which the chicks are brooded. Large metal pipes containing fans force air down under the floor and up through the litter. The drying of the litter eliminates bacterial action and, therefore, there is very little odor produced. The end of the fabric is wound around a long metal pole that serves as w winch. At market time, the flooring fabric is slowly pulled toward one end where the litter falls into a cross auger for removal, and the broilers are caught and loaded. Broiler performance is somewhat different in ventilated floor houses compared to litter systems (van Middelkoop *et al.*, 1994). Birds grow at a slightly reduced rate during the first few weeks, but at a higher rate during the latter few weeks on the ventilated floor. Summer grown birds performed somewhat better on the ventilated floor than on litter floors. The primary drawbacks for the ventilated floor broiler house include the cost and labor involved in purchasing, set up, cleaning and re-set up of the floor system; the cost, installation and maintenance of the ventilation system; and the handling of the dry, dusty litter as it and the birds are removed from the house.

PARTIALLY VENTILATED FLOOR SYSTEMS FOR TURKEYS

Because of the strict environmental regulations in the Netherlands mentioned earlier, several Dutch turkey producers have installed partially ventilated floors in their turkey houses. This system, first reported by van Middelkoop *et al.* (1994), and later by Veldkamp *et al* (1997) is an adaptation of the original full ventilated floor system for broilers developed at the CAPR. The partially ventilated floor allowed those producers to significantly improve productivity and growth rate with their market turkeys which off-set the cost of installation (Ferket, 1997). In this system, a slatted floor was constructed covering 30% of the floor space. Feeders and waterers are placed above the slats. The slats are covered with a perforated cloth (Nicolon 66303) which is then covered with a 4 to 6 cm layer of wood shavings. Air is forced down ducts and under the floor by fans. It then flows up through the cloth and litter at a rate of about 1.5 m^3/hr/kg of bird live weight (Ferket, 1997).

Veldkamp *et al.* (1997) compared the performance of two flocks of turkeys in summer and winter with part of the birds grown in a house with half litter and half ventilated floor, and the others grown in a total litter floor house. BUTA Big 6 toms and hens were used, with stocking densities of 3.5 males or 5.0 females per m^2. Males and the females were grown to 141 and 106 days in the winter, and 147 and 115 days of age in the summer, respectively. The ventilated floor improved body weight of males by 4.5% in the summer and 1.6% in the winter, and it improved the body weights of the females by 5.0% in the summer but had no effect in winter. Feed to gain ratios improved over 3% in summer for males on the ventilated floor, but the difference was not significant for the males in the winter. The investigators concluded that the advantage of the partially ventilated floor in the summer time was due to the improved ventilation and cooling effect on the birds of the air moving through the floor. The partially ventilated floor also reduced the incidence of breast buttons, breast blisters and foot pad problems resulting in improved carcass quality.

In addition, the partially (50%) ventilated floor was shown to reduce ammonia emission by 60%, it required about 50-70% less wood shavings, and it reduced by 40% the amount of litter that had to be removed (Veldkamp *et al.*, 1997). Commercial installations of this system have confirmed its advantages over conventional all litter systems. Although the partially ventilated floor requires more capitol, labor and utility investment, the combined savings in feed costs/kg of meat produced, reduced medication, litter costs, and cost for manure disposal totaled 0.30 U.S. dollars per bird with prevailing prices in the Netherlands in 1996 (Ferket, 1997).

BROILERMATIC® CAGE SYSTEM

One of the keys to the apparent success of the Broilermatic Cage system, mentioned earlier, is the well designed plastic covered nylon cage floor which is supported every 11 cm with metal bars covered with plastic strips running the length of the cage. These bars rest on three crossbars (one at each end and one in the middle of the cage) that run the width of the cage. The lengthwise bars support the plastic covered nylon. This unique design provides a very rigid yet soft non-abrasive flooring that appears to have completely overcome the breast blister, folliculitis, and wing and leg breakage/downgrade problems previously associated with broiler cage systems.

Cage growing of broilers has a number of potential advantages over conventional litter floor systems, including at least the following:

- No wood shavings are required (the advent of pressed board and particle board has resulted in pine shavings becoming more expensive and harder to obtain).
- The feces drop onto a manure belt where they are dried. Feces are then automatically removed from the house via a cross-auger located at the end of the cage row, thereby reducing the time and labor involved for clean out.
- Belt drying results in the manure being in a easily handled non-offensive form in which the nutrients are concentrated in a smaller amount of material. Belt drying in a tunnel ventilated house in the summer time in

the humid broiler growing areas of the U.S. is difficult, however.

- Due to the belt drying of the manure, there is a considerable reduction in nitrogen volatilization.
- Very low ammonia levels are produced (the Dutch have rated the Broilermatic® system as producing 5 g of nitrogen per yr versus 50 g per yr with conventional systems - Van Middelkoop, 1998, CAPR, personal communication). Ammonia is reduced by 85% compared to the Dutch government standard (van Horne and van Middelkoop, 1998).
- Smaller group sizes are used (approximately 40 to 55 broilers/cage -- depending on the age and size to which they are being grown) with less apparent stress on the birds than in floor systems.
- Higher stocking density is achieved per m^2 of house (due to the multiple [3 or 4] decks of cages approximately 2.5 times as many birds can be placed as in litter floor system - depending on the configuration).
- Males and females can be grown separately and marketed at different ages. Once the females are marketed, if placed in every other cage, a door between the cages allows the males to be spread into two cages to be grown out to further processing weights.
- Greatly reduced dust levels are produced. If the house floor is properly constructed, dust that is produced can be quickly brushed down and washed out of the house.
- Few if any litter beetles are present. Therefore, house insulation damage from beetles, and direase risk from beetles as pathogen vectors should also be reduced. Nuisance complaints about beetles should also be reduced when the manure is spread.
- Due to the manure drying and frequent removal, no fly reproduction occurs within the house.
- The Dutch use no coccidiostats or antibiotics.
- Less overall labor is required per bird.
- Footpad dermatitis is practically non-existent. Birds have no hock burns or burns on the breast skin.
- Lower mortality rates: the Dutch report slightly less mortality in recent flocks in the cage than on litter floors with the same source of birds (Table 2). The Egyptians report 50 to 75% reduction in mortality when the chicks are infected with PPLO and/or *E. coli* (Table 3).
- Cage birds have improved body weights and fed conversions. Market weights have been achieved several days earlier than with litter floor grown birds in the Netherlands and in Egypt.
- Flock turn around time is reduced to 4 to 7 days. The Dutch have been using dry cleaning and fumigation only for over two years without problems. Cleaning and fumigation of the house requires 1 - 2 days. This

results in approximately one extra flock per year, for the Dutch.

- Less labor is required to load and unload the house. With a proper belt transfer system to move the birds from the manure belts to a catching and loading table, Dutch experience indicates a flock of 24,260 can be loaded out in about 1 hour with 4 to 6 people.
- Load out is a much easier and less distasteful task; and, it can be done at any time of the day or night.
- Bruises, broken bones, and other downgrades from load out trauma are reduced.

Cage growing of broilers also has a number of potential disadvantages, including:

- The cage system has higher initial investment cost per square meter of house space.
- Operating costs are increased due to mandatory tunnel ventilation with cool-cell type systems in hot areas. Stocking density requires this type of ventilation for successful operation of the system.
- Warm room brooding for the first few weeks utilizes thermostatically controlled perimeter ventilation.
- A higher level of management is required to operate and maintain the mechanical systems (manure belts and cross augur, feeders, fans, lights, ventilation system, etc.) is required.
- The manure clean-out belts must be emptied at approximately 14, 21, 25, 30, 33, 36, 39, 42, 44, 26, 48 and 50 days of age. Manure is dry (approximately 15 - 30 percent moisture - except during hot-humid months when cool cells and tunnel ventilation is being used, when it is closer to 60 to 70 percent moisture), and may need to be placed in a storage shed until it can be further processed or spread to meet crop needs.

Field Performance with the Broilermatic® System in the Netherlands

A commercial Broilermatic® house was constructed in the Netherlands in 1996. The owner kindly supplied Van Middelkoop with the figures in Table 2. The owner is "very pleased, since he now has better feed conversions, and less dust in the poultry house, which is also very important to him." He is replacing his floor houses with a new cage house for 70,00 birds. Based on these performance figures and prevailing costs in the Netherlands, van Horne and van Middelkoop (1998) conducted a general economic analysis of the Broilermatic® cage system versus a litter floor system and came to the following conclusion. "The final economic calculation shows that the higher gross margin and the lower annual costs for buildings can compensate for the higher investment cost of the

[cage] equipment. Even in a situation with the same number of broilers per worker the labor income is higher. However, the experience is that a farmer can handle 90 - 100,000 broilers compared to the traditional 60,000 on litter." They further concluded that for different situations (e.g. countries) with specific price levels for broilers, feed, chicks, and variable costs, as well as for investment in buildings and equipment, every farmer should make his own calculations. The broiler contract can obviously also influence the calculations.

Table 2. Average Field Performance of the Most Recent Seven Flocks of Broilers Grown on Litter Floors Versus in the Broilermatic® Cage in the Netherlands[a].

Housing System	Av. Age Marketed	Av. Market Weight, g Days	Av. % Mortality	Av. Feed Converison g:g	Cleaning Period Days	Cycles/ Year
Litter Floor	40.4	1915	3.2	1.73	11	7.1
Cage	40.5	1955	3.0	1.68	7	2.7

[a]From van Horne and van Middelkoop, 1998.

Field Performance with the Broilermatic® System at the Cairo Poultry Company in Egypt

A three story Broilermatic cage house which holds approximately 50,000 birds per flock was built in Egypt in early 1996. Based on the performance of the first few flocks in that house, four additional cage houses have been or are being constructed, and about 20 more are in the planning stage to be completed by June, 1999. Following are some field data received from that operation (Nagel, 1998, personal communication):

Table 3. Average Field Performance of Broilers Grown on Litter Floors Versus in the Broilermatic® Cage in Egypt.

Housing System	Av. Age Marketed	Av. Market Weight gm	Av. % Mortality[b]	Av. Feed Conversion
Cage	37	1700	3.5	1.82
Litter Flood	40	1700	7-12	2.20

[a]Hatching eggs from flocks not owned by the company are often PPLO and *E. coli* positive.
[b]Worst mortality in a cage flock to date has been 5 percent (Nagel, 1998).

"Uniformity of the caged broilers is excellent. Breast blisters and other skin damages are practically unknown. Body weight has always exceeded 1600 g and feed conversion has never been over 1.90 in the cages at 37 days of age" (Nagel, 1998, personal communication).

Broilermatic® Cage Unit at the NC State University Poultry Education Unit

During 1996-97, a 36' x 80' curtain sided broiler house on the NCSU Lake Wheeler Road Field Laboratory was totally remodeled into a light and temperature controlled house with cement floors and the Broilermatic® cage system. The remodeled facility has thermostatically controlled sidewall slot ventilation for mild and cold weather, and tunnel ventilation with Kool-Cells® for hot weather. Three rows of cages (8 cages/row [120 cm w x 194 cm l x 42 cm h]) were installed, two with 3 decks and one with 2 decks equipped with automatic chain feeders and Lubing® nipple drinkers. Three upward directed fans (Dayton® 24 inch) are placed approximately 45 cm from the flat corrugated ceiling, and are equally spaced down each of the center aisles. Two 75,000 BTU Hired Hand® Super Saver XL Heaters hang between the circulating fans at approximately the same height as the fans. An additional heater was placed at the back end of the building in order to even out the temperatures in that area of the house. Thus, the total house has five heaters and six circulating fans. Air output from the heaters is directed toward the circulating fans. The heaters are thermostatically controlled and are used for warm room brooding and for supplementary heat as needed during cold weather. The upward directed fans run continuously throughout the flock's life to create a nearly uniform temperature throughout all areas and levels of the house, and to pick up moisture from the manure. The manure belt moves the dried manure to the end of the cage row where it is dropped through a metal grate into a cross augur for removal from the house into a manure spreader. At market load-out time, the manure belts are cleaned, the floor is pulled to one side, the birds drop onto the belt where they are conveyed to the end of the cage row for loading into market crates.

Adjacent to the above NCSU broiler cage facility, is an identical sized curtain-sided house with a central feed room and two bird-rooms each containing sixteen 1.17 m x 3.8 x dirt floor pens with litter shavings. A cement floored center aisle in each end contains two 75,000 BTU L.B. White® Heaters, and three of the upward directed high speed Dayton® 24 inch fans installed at the same height from the flat corrugated metal ceiling as in the cage house. Just as in the cage house, the heaters are thermostatically controlled, and with the sidewall curtains up are used for warm room brooding. The upward directed fans are used to circulate the warm air to provide very even temperatures throughout the house. With this system, temperature at bird level can be maintained within one to two degrees F throughout all pens. Again, the upward directed fans are operated throughout the flock's life to maintain bird comfort, and to keep the litter dry. During hot weather, when the side curtains are down, a 45 cm canvas baffle (stretched over small cables at a slight angle away from the fans) is placed from the ceiling down over the center of each row of pens in order to direct the air from the high speed stirring fans down into the pen to maintain bird comfort and to dry the litter. The ventilation systems for these houses were designed by Dr. R.W. Bottcher and Dr. J.T. Brake.

To date, two trials have been conducted in the NCSU Broilermatic® cage unit, one with broilers and one with turkeys. Following are summaries of some of the performance data from those trials. These and other data will be published in more complete form in the near future. Both trials involved comparisons of birds from the same hatch and breeder flock brooded on litter.

NCSU Cage Versus Floor Broiler Trial

A broiler trial was conducted from June 23 through August 5, 1998, and involved 64 pens of 40 broilers in the Broilermatic® system, and 32 pens of 40 broilers per pen in the curtain-sided litter floor house. Ambient temperatures throughout the trial period included daily highs of 84 to 99° (av. 92.4) and daily lows of 64 to 75°F (av. 69.9). Even so, both flocks performed very well, with quite low mortality and very good growth rates and feed conversions. The overall design of the experiment involved a randomized block factorial design with varying levels of Ca and P, with and without the addition of phytase enzyme,a nd with and without the addition of sodium selenite or SelPlex-50® being added to normal corn soy diets. Following are the performance figures obtained for each house as a whole over all treatment groups. These data are provided to simply show the type of performance achieved in the two housing systems. All feed was provided as mash, so the feed conversions are probably slightly higher than they would have been if the feed had been pelleted.

Broilers brooded in the cage facility had better growth rate and markedly better feed conversion than those grown in the litter floor house, even though conditions in the litter floor house were certainly better than average for that type of housing system. Mortality was slightly but not significantly higher in the cage facility, and the livability of both groups was excellent, especially considering the high ambient temperatures under which these broilers were grown. All of the broilers were individually examined at 42 days of breast blisters, and none were found in either house. Data from all of the treatment groups involved in this trial will be published in the near future.

Table. 3. Performance of Broilers Grown on Standard Corn/Soy Broiler Diets in the NCSU Curtain Sided Litter Floor House and in the LTC Broilermatic® Cage House, June 25-Aug 5, 1998.

House	Days of Age	Mortality %	Body Weight gm	Feed Conversion gm/gm
Liter	21	1.02	773	1.37
	42	1.72	1971	2.04
Cage	21	1.67	782	1.17
	42	2.38	2008	1.77

NCSU Cage Versus Floor Turkey Trial

A preliminary trial was conducted during the early Spring of 1998 to determine how turkey poults would perform when brooded in the Broilermatic® cage unit. Forty poults were placed per cage in eight cages in one cage level, and were brooded with and without paper, and with and without filling the water cups under the nipples during the first six days of their life. Those tom poults were carried to 21 days of age on a standard turkey starter diet, and were then weighted and terminated. Briefly, this pre-test indicated that there was no advantage to brooding on paper or to triggering the nipples to fill the water cups. All groups performed nearly equal, except those located in the last cage of the row, where the temperature was cool. The poults in the first seven cages showed very consistent weights averaging 655 g (National performance estimate for 21 day toms is 562 g, Turkey World, Jan., 1997, pg. 22), whereas those in the eighth cage averaged 636 gm. Feed conversion at 21 days was 1.24 for the cage grown birds versus the figure of 1.56 published for this age in Turkey World. It appeared that the problem with the weight in the eighth cage was probably related to a slightly lower temperature in the end of the house. Based on this observation, an additional thermostatically controlled heater was placed at the end of the house, and air leakage was corrected around the load out doors and the Kool-Cells® at that the end of the building.

During April, 1998, a second turkey trial was started with 2560 tom poults (40/cage) placed in the cage unit, and another 960 poults brooded in 48 litter floor pens on the NCSU Lake Wheeler Road Field Laboratory Turkey Educational Unit. All of the toms were delivered from one commercial hatchery, and all were supplied with the same commercial starter and grower rations. Performance of these turkeys through 28 days of age is provided in Table 4.

At 35 days of age, 120 randomly selected poults from the cage house were placed in eight litter floor pens; and, another 120 randomly selected poults from the litter floor house were placed in eight adjacent litter floor pens. Their performance during the remainder of the grow-out period to 140 days of age was then compared. Grow-out data from 36 to 140 days of age is shown in Table 5.

Table 4. Performance of Tom Poults Brooded in the Broilermatic® Cage Unit Versus in Litter Floor Pens.

Day of Age	Body Weight (g)		Feed Conversion (g/g)		Mortality (%)	
	Cage	Litter	Cage	Litter	Cage	Litter
28	1002	970	1.29	1.37	6.7	4.6

Turkey World, Jan., 1997 indicates the national averages for 28 day body weight and feed conversions should be 970 g and 1.35 g/g, respectively.

Table 5. Grow-out Performance of Turkey Toms in Litter Floor Pens from 28 to 140 Days Following Their Being Brooding in the Broilermatic® Cage Unit Versus in Litter Floor Pens.

Day of Age	Body Weight (kg)		Feed Conversion (g/g)		Cumulative Mortality (%)	
	Cage[a]	Litter[a]	Cage	Litter	Cage	Litter
56	4.01	4.11			0	0
70	6.26	6.46			0.25	0.50
91	10.39	10.34			0.63	1.12
112	14.02	14.20			2.01	2.24
140	18.14	17.92	2.52	2.59	3.38	2.62

[a]Brooding location.

None of the above differences in performance were significant.

The remainder of the cage brooded poults were returned to the company for grow-out. Unfortunately, as is sometimes the case with field trials, data were not kept, except that they experienced some additional mortality from compacted crops, because the cage reared birds consumed considerable litter when they were first transferred to the floor. This type of mortality was not seen in the NCSU comparison, although it did take some time for the cage reared birds to adapt to the feed and water systems in the litter pens. The cage reared birds actually fell behind the litter brooded birds in body weight for about 8 weeks post transfer until they were about 13 weeks of age.

At the time the poults were removed from the cage to the floor (35 days of age), 10 poults from each group were necropsied and the entrails were weighed. Most parts of the intestinal tract were numerically, although not significantly, larger in the floor grown birds than in the cage reared birds. A striking difference existed between the weight of the gizzard in the floor grown (43.6 g ± 2.6) versus the cage grown (22.2 g ± 1.2) poults. This difference probably indicates that some changes need to be made in the feeding program for such birds to increase the activity and strengthen the gizzard and other intestinal organs of cage reared poults.

SUMMARY

Several alternative housing systems have been developed for broilers and turkeys to reduce the amount of litter utilized, to reduce ammonia emissions, and to improve performance. These systems not only improve bird performance, but they also have a number of other advantages from an environmental viewpoint. Breast blister, folliculitis and bone fragility problems associated with previous cage systems for broilers appear to have been almost totally overcome with a new Broilermatic® cage system. This system was also used for brooding turkeys up to five weeks of age, and even though some design changes would need to be made (*i.e.* the cage height needs to be increased so the nipple drinkers can be raised higher, and the feeder meeds to be modified to better accommodate the turkey), the system appears to show promise for the brooding of that species as well.

All of the systems discussed result in reduced waste output, and they eliminate many of the pest, ammonia emission, and bird handling problems associated with current litter floor growing systems. Additional studies should be conducted, however, to determine nutritional requirements in these systems for maximizing performance, and to provide data for economic assessments of the competitiveness of these systems for the commercial industry.

Use of trade names in this publication does not imply endorsement by the North Carolina Agricultural Research Service of the products mentioned, nor criticism of similar products not mentioned.

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OKLAHOMA REGULATION OF INTENSIVE POULTRY OPERATIONS

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The state of Oklahoma has experienced a significant amount of change in the past year in its relationship to poultry operations. Traditionally, poultry operations were only regulated to the extent that they used a liquid waste management system. Dry litter operations were virtually exempt from regulation unless they voluntarily obtained an Oklahoma Concentrated Animal Feeding Operations License from the state. Only voluntary participation in conservation practices through the United States Department of Agriculture Natural Resources Conservation Service and other entities allowed management of nutrient application of poultry litter.

OKLAHOMA BOARD OF AGRICULTURE EMERGENCY RULES

However, in December of 1997, based on meetings and discussions with Oklahoma poultry growers and poultry companies, the Oklahoma Board of Agriculture approved emergency rules on Commercial Poultry Operations which required all poultry operations raising more than 30,000 birds to obtain and follow Animal Waste Management Plans, perform soil and litter testing, and attend mandatory waste management education courses. In response to issues of excessive litter application resulting in water supplies being threatened by excessive phosphorus levels, the emergency rules included stricter requirements for areas identified as phosphorus threatened. Producers in these areas were required to perform annual soil and litter testing, instead of every three years, to determine if land application sites were overloaded with phosphorus. In addition, producers in phosphorus threatened areas were required to obtain or apply for Animal Waste Management Plans within six months, instead of the one year time period required of other producers.

GOVERNOR FRANK KEATING'S ANIMAL WASTE AND WATER QUALITY PROTECTION TASK FORCE

Prior to the passage of the Oklahoma Board of Agriculture's Emergency Rules, Governor Frank Keating's Animal Waste and Water Quality Protection Task Force provided a final report recommending legislation to regulate the poultry industry in the state. The Task Force recommendations included legislation that required licensing of all facilities with more than 30,000 broilers. The Task Force also recommended penalties for violations of the assessment of fines. Other proposed provisions included reporting of violations to the public, soil and litter testing, covered waste storage, and financial incentives for transporting poultry waste from sensitive watersheds to other areas. These recommendations were provided in a Final Report to the Governor on December 1, 1997.

SENATE BILL 1170

In the 1998 Oklahoma Legislative session, a number of poultry bills were introduced. Some of them mirrored the recommendations of the Animal Waste and Water Quality protection Task Force. In May of 1998, Senate Bill 1170, titled the Oklahoma Registered Poultry Feeding Operations Act, was approved by the Oklahoma Legislature and signed by Governor Frank Keating. This bill incorporated many of the recommendations of the Task Force and also took some of the ideas from the Board of Agriculture's emergency rules on commercial Poultry Operations.

Registration

Generally, the Act provides for registration of all poultry feeding operations with the Oklahoma Department of Agriculture. A poultry feeding operation is defined as any property or facility where poultry have been, are or will be confined and fed or maintained for a total of 45 days or more in any twelve month period; crops, vegetation, forage growth or post-harvest residues are not sustained in the normal growing season over any portion of the lot or facility; and producing over ten tons of poultry waste per year.

All facilities meeting this definition are required to register annually with the Department of Agriculture and provide a copy of their Animal Waste Management Plan with the registration. The Animal Waste Management Plan must include parameters for phosphorus and include, in addition to land application requirements, measures for carcass disposal.

Violations of the Act can result in penalties, or may result in the facility being deemed a significant polluter.

Designation as a significant polluter is achieved through the violation points system where points are assessed per violation. When an aggregate number of points is reached, the facility is deemed by the Board to be a significant polluter and required to be licensed under the Oklahoma Concentrated Animal Feeding Operations Act.

SB 1170, like earlier rules, requires soil and litter testing, mandatory education on poultry waste management, and special rules for facilities in nutrient limited watersheds or nutrient vulnerable groundwaters. Recordkeeping is also required.

Poultry Waste Applicators

In addition to the Oklahoma Registered Poultry Feeding Operations Act, Senate Bill 1170 creates the Oklahoma Poultry Waste Applicators Certification Act. This portion of the Act requires commercial and private applicators to obtain an applicator's certificate from the Oklahoma Department of Agriculture. Commercial applicators must renew their certificate annually; private applicators renew every five years. Penalties also exist for violating the requirements of the applicator provisions.

AIR QUALITY: WORKER HEALTH, SAFETY, AND PUBLIC HEALTH CONDITIONS

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Air pollutants such as dust and ammonia are typically generated within poultry production facilities. In order to maintain bird well-being and productivity, ventilation is needed to remove indoor air contaminants including bird heat in warm weather, bird moisture in warm and cool weather, and air pollutants in all weather. High ventilation rates in summer may provide acceptable indoor air quality but problematic emissions of dust and odors toward neighbors. Indoor air quality is typically worse in cool weather than in warm weather, due to the need to reduce ventilation rates to avoid chilling the birds and control heating fuel costs.

Although respiratory protection programs are recommended to protect worker health when ventilation and other control methods do not provide sufficiently good indoor air quality, such programs have often not been implemented in agricultural settings. Improvements in respirator designs have been recommended in order to allow the kind of strenuous labor done by catchers and others in poultry buildings while providing good respiratory protection.

Due to the typically hugh differences in ventilation rates between cold and hot weather, it is unlikely that a single approach will solve both indoor air quality and air pollution emission problems. Producers should not assume that a single affordable "magic bullet" or new technology will solve all their air quality problems. A combination of good management practices and respiratory protection when necessary can improve worker health, while a combination of good management practices and affordable air pollution control technologies should reduce emissions and any risks to public health.

AIR POLLUTANTS

Aerial pollutants commonly occurring within poultry facilities include dust, ammonia, microorganisms such as bacteria, endotoxins (toxic substances secreted by bacteria), and odorous compounds. In many cases these are not in sufficient concentration to pose acute health risks or may not even be measurable, but they often occur at levels that do cause adverse effects which have been documented (Perkins and Morrison, 1991; Donham *et al.*, 1990; Lenhart *et al.*, 1990; Whyte *et al.*, 1993). Studies involving poultry facility workers indicate that respiratory problems can be associated with several years of work in the facilities (Whyte *et al.*, 1993; Perkins and Morrison, 1991). The two most pervasive and troublesome air pollutants in poultry facilities are apparently dust and ammonia. Working conditions in poultry buildings and the hanging areas of poultry processing plants are about as dusty as any workplace, so there is a need to protect the health of poultry growers and catchers in the buildings, and hangers in processing plants (Lenhart, 1995). Ammonia levels can also be moderate or high and cause respiratory problems.

Dust

Dust is primarily produced from litter, feathers, and feed although insects, pollen, and other sources contribute to dust levels. Dust levels are measured in terms of the amount of dust per unit volume of air, such as milligrams per cubic meter (mg/m^3), or in numbers of dust particles per unit volume of air, such as particles per cubic meter. Dust particles smaller than a certain size can be inhaled deeply into the lungs and cause lasting damage; these are called respirable particulates. The size of respirable particulates is generally considered to be 5 microns (where a micron is one-millionth of a meter or one-thousandth of a millimeter) or less. Therefore, both mass-based measurements and particle counting methods have been developed which sort the dust into size classes; for example, less than 0.5 microns, 0.5 to 1 microns, etc.

Governmental and scientific organizations have adopted standards for permissible or recommended levels of particulates or dust. For example, governmental hygienists have recommended an 8-hour, time-weighted average threshold limit value (TLV-TWA) for total dust (all sizes) of 10 mg/m^3 (Popendorf and Reynolds, 1997). Dust levels in poultry buildings often exceed this value (Lenhart *et al.*, 1990). Also, the EPA in the past imposed regulations on ambient air quality (the outside air) based on controlling the levels of six important air pollutants. One of these is particulate matter smaller than 10 microns in size, known as PM-10, since these can be inhaled deeply and cause more respiratory health problems than larger particles. Recently the Clean Air Act has brought about additional regulations for PM-2.5, since particulate matter smaller than 2.5 microns (as is produced by combustion) is especially harmful, so now there are regulations for both PM-10 and PM-2.5. The indoor air quality-based recommendations or permissible limits (such as 10 mg/m^3 of total dust) are intended to protect human health in the workplace, while the ambient air quality standards (such as PM-2.5) are intended to control air pollution outdoors. These distinctions are important since they both can apply to animal facilities; ventilation of indoor air out of poultry and livestock buildings causes emission of the pollutants that are in the indoor air to the outdoor air, including odorous compounds carried on the dust.

Ammonia

Ammonia is produced by microbiological action on uric acid in bird excreta. Ammonia can be present at moderate to high levels, especially when conditions have been humid, the litter floor is especially moist, or ventilation rates have been low. Thus, control of litter moisture, ventilation, and indoor humidity provide opportunities for controlling ammonia in poultry buildings. Unfortunately the costs associated with stringent ammonia control using such methods, such as heating fuel use in cool weather, have typically been too high for practical implementation.

Ammonia concentrations are generally given in parts per million (ppm). The recommended 8-hour threshold limit value (TLV-TWA) is 25 ppm, while OSHA has set an 8-hour permissible exposure limit (PEL) of 50 ppm (Popendorf and Reynolds, 1997). Ammonia levels in poultry buildings typically range from 0-50 ppm (Sneath *et al.*, 1996; Wilhelm and Snyder, 1996) although higher levels can occur in poorly ventilated buildings (but will adversely affect the birds).

Variability and Measurement

The concentration of pollutants in poultry buildings will vary both in space (due to incomplete air mixing, animal and manure locations, and other geometric factors), time (due to diurnal and seasonal variations, bird growth, etc.) and composition (due to animal type, size, and production system). This can make accurate measurement of contaminant levels and interpretation of such measurements difficult. Air quality evaluations can be made through sample collection and laboratory analysis, or with direct reading, portable devices (Popendorf and Reynolds, 1997). The direct methods, such as colorimetric detector tubes for ammonia, are helpful when measurements are needed quickly, but are usually not as accurate as the laboratory-based methods. Determination of exposure levels can be conducted using personal air sampling equipment attached to the humans (or birds), since these account for the variations in concentration to which the individual is exposed.

RESPIRATORY PROTECTION

Although control methods such as air cleaners and prevention of pollutant generation are the best way to protect people from respiratory hazards, the economics of poultry production has generally prevented them from being completely successful. Since evaluations of poultry workers have documented adverse health effects due to air quality, respiratory protection is recommended in many cases. OSHA requires that, whenever respirators are needed for worker health, employers must establish and maintain a respiratory protection program (Lenhart, 1995). A respiratory protection program includes selection of respirators, medical evaluation of employees, fit testing to ensure the respirators fit tightly, maintenance and care of respirators, training in their use, recordkeeping, and program evaluation.

Respirators are assigned protection factors to help distinguish between different classes of respiratory protection. For example, a full facepiece respirator with high-efficiency filters may have a protection factor of 50. More expensive, powered air-purifying respirators with tight-fitting facepieces also have a protection factor of 50, but provide the advantage that filtered air is constantly delivered to the face so resistance to breathing is less, which would be helpful for strenuous work (Lenhart, 1995). Disposable dust masks can also provide some protection (e.g. a protection factor of 5) but may be uncomfortable and cause sufficient breathing resistance that they wind up being unused by laborers. There will always be trade-offs between respirator cost, effectiveness, and comfort. Protection against ammonia and other gases can be achieved using appropriate cartridges to absorb the gases.

Although poultry and livestock producers have not typically instituted complete respiratory protection programs, it should be to their benefit to do so. Not only will work health be improved, but a good program can provide protection to the employers through the medical surveillance.

INDOOR AIR QUALITY AND AIR POLLUTION EMISSIONS

Although the terms air quality and air pollution are related, they are generally not considered to be identical. Air quality refers to the amount of air pollutants in the air, so indoor air quality is of concern to the people and birds who will spend time in the buildings. Air pollution emissions refers to the rate of flow of the air pollutants into the environment. Since ventilation is needed to move fresh air into the buildings and move indoor air out (for several reasons), the ventilation airflow contributes to air pollution emissions. In fact, the emission rate is calculated as the airflow rate multiplied by the concentration of the air pollutant. For example, suppose the indoor dust level is 2.7 mg/m^3 (a moderate level), and the ventilation rate is 100,000 cfm (cubic feet of air per minute), which is a typical summertime rate. The dust emission rate, obtained by multiplying these numbers and converting the units, is 1.0 lb/hr (one pound of dust emitted from the building per hour), or in metric units, 127 milligrams per second.

This distinction is important when weighing worker health and public health (or nuisance) concerns. With a high enough ventilation rate, the indoor air quality can generally be made good enough that worker health is not jeopardized (for the period that the ventilation rate is high). However, the rate of emission of air pollutants from the buildings is not necessarily reduced by increasing the ventilation rate. The indoor concentration of the pollutants is reduced while the ventilation rate is increased, so their product - the emission rate - stays about the same. In the case of dust, the emission rate may actually be increased by increasing the ventilation rate (Sneath *et al.*, 1996), since the increased airflow can dry the floor and other surfaces and generate more dust. This has implications for odor control when dust particles carry significant amounts of odorous compounds; many researchers are therefore focusing on dust control as a means of reducing odor emissions.

ODORS AND PUBLIC HEALTH

Although it stands to reason that emission of air pollutants that are objectionable to neighbors of poultry and livestock farms may also cause a health risk, there is a limited amount of evidence that serious risks to physical health occur. The same effects of dose and response occur in the outdoor unconfined spaces, but outdoors, wind and atmospheric turbulence can effectively dilute the concentration of air pollutants that people are exposed to, compared with the indoor environment. Measuring the concentrations of air pollutants and odors downwind of a farm can be difficult for several reasons. Odor episodes can happen and change so quickly that an odor that causes one to complain may not be present in the same concentration or at all by the time a regulator or researcher arrives to measure the odor. However, research suggests that odor-causing substances can cause health effects such as eye, nose, and throat irritation, headache, and drowsiness, and possibly aggravate allergies, asthma, and bronchitis (Schiffman, 1998).

A recent study of neighbors living within a two-mile radius of a 4,000 sow swine farm showed that neighbors experienced significantly higher rates of symptoms indicating toxic or irritating effects on their respiratory tract, compared to other rural residents not living near livestock farms (Thu *et al.*, 1997). There was little evidence that neighbors experienced higher rates of anxiety or depression.

CONTROL METHODS

Several approaches to reducing the generation of air pollutants in animal buildings, and cleaning them from the air, appear to be promising, but many proven industrial methods remain much too expensive for producers at this time. As noted above, indoor ammonia can be controlled by avoiding wet surfaces and wet litter, e.g. by increasing airflow over the floor and controlling humidity. Also, good indoor air mixing is helpful, especially in cold weather, in order to mix air pollutants into the air which leaves the building and avoid dead air spaces.

Several promising areas for reducing dust levels in animal buildings have been identified, including adding fats or oils to feeds, spraying mists of water or oil indoors, and air cleaning by filtration, air ionization, or wet scrubbing (Maghirang *et al.*, 1993; Carpenter, 1986). Although oil spraying is controversial inasmuch as respirable oil droplets may be formed, the documented improvements in indoor dust level make it attractive (Feddes *et al.*, 1995; Zhang, 1997).

Numerous odor control methods are being pursued, such as biofilters and bioscrubbers (which use microbes in moist biomass to convert odor compounds over time), and dust filtration. A problem with many industrial methods is that sizing the systems to handle the hugh airflow rates needed in hot weather, without imposing such a resistance to airflow to endanger the animals, can make them prohibitively expensive. Two examples are cyclones and bag filters, which are industrial dust control methods that impose much more resistance to airflow than most existing building ventilation fans can handle.

One promising approach for reducing the flow of odorous dust toward neighbors involves windbreak walls placed downwind of building exhaust fans (Bottcher *et al.*, 1998). Such walls are used on hundred of poultry farms in Taiwan to reduce the horizontal fan airflow and cause some dust to settle on the walls and ground. Vegetated windbreaks may also provide some benefit downwind.

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POULTRY LITTER MANAGEMENT OPTIONS

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The poultry industry in the United States is an important component of the country's agricultural sector and rural economy, particularly in areas where production is concentrated. However, poultry producers are facing significant economic challengers as they embrace new litter management practices in response to increasing public and regulatory pressures. Litter management options are needed that are environmentally acceptable and ensure the economic vitality of the producers, the poultry industry, and the industry's contributions to local communities. Adoption of viable litter management alternatives will position the U.S. poultry industry to expand to meeting increasing global demands for poultry products.

LITTER EXPORT STRATEGIES

Transport excess litter away from the production farms, converting it into value-added products, and selling the material into commercial markets is an attractive option that is receiving increasing attention. Several technologies are available for processing liter into value-added products.

But the cots and complexities associated with litter export, processing, and marketing are significant and generally exceed the resources available to poultry producers, who are typically individual contract growers. Successful adoption of off-site litter management strategies will entail large-scale, regionally-coordinated strategies. Establishment of such regionally-coordinated strategies will likely entail public-private partnerships, and will need to consider:

- Feedstocks: coordinated collection and aggregation of litter (in some instances this may also include other feedstocks);

- Processing/Logistics: identification of the appropriate processing technology(s), given the nature of the feedstocks(s) being managed and the markets available (or that can be developed) for the litter-derived, value-added products; logistical issues include materials handling, transportation, storage, distribution, and spreading (for bulk, agricultural markets and certain other markets);

- Markets: expansion of existing markets or development of new markets for raw litter and litter-derived products (this includes indirect stimulation of product demand by public sector organizations as well as direct marketing activities by private enterprises); principal market categories include: fertilizers/soil amendments; feed (primarily for cattle); and energy (solid, liquid, and gaseous fuels;

- Economic, Policy, and Institutional Barriers: identify and address constraints/barriers that inhibit the collection, processing, transport, and/or use of raw litter or litter-derived products; where possible, policies and support programs should be established that support or incite export activities.

Education and information development and dissemination are essential components of any regionally-coordinated strategy and would be included within each of the foregoing activities. Partnerships and effective collaboration amongst numerous public agencies, private companies, educational institutions, nonprofit organizations, and the research community are also required for successful pursuit of strategies for coordinating litter export activities on a regional basis.

CONVERSION TECHNOLOGIES

An overview of the various litter management/conversion technology options is provided below. A given area of concentrated poultry production will likely entail a mix of conversion technologies. In general, it is unlikely that a single, centralized facility would be economically feasible, given the high costs of transportation of raw materials; instead, de-centralized or satellite processing facilities may be necessary. (These factors are offset, however, by the fact that most conversion technologies are subject to economies of scale, i.e. larger facilities tend to be more economically feasible.) The selection of the type and size of processing facility appropriate for a given area or sub-area of concentrated poultry production will based in large part on the available (or potentially available) markets for the litter-derived products, as well as local transportation logistics, facilities siting options, bio-security issues, and other factors.

- Raw litter: Export (off-site) markets for raw litter already exist in many areas. Markets tend to be seasonal, with demand primarily during field preparation in the spring. Raw litter markets are generally within 10-30 miles of the supply, although some markets have been successfully developed for raw litter 100-200 miles from the supply. Transportation is the major cost. Given the biologically active nature of the material, there can be problems with handling and storage problems (as well as odor and pathogen control). It is the author's opinion that the potential markets for raw litter markets are constrained by numerous factors, and that expansion of existing markets or creation of new markets will be limited.

- Composting: Experience, expertise, and careful attention to the composting process can produce a superior quality compost product from poultry litter that is odor-free and pathogen-free. Compost products can be sold into a variety of markets, although there is significant competition in many compost markets (e.g., the lawn and garden industry), margins are generally thin, and consumers are generally unaware and unappreciative of quality differences of compost products. A significant advantage of composting is that the process can accommodate a variety of feedstocks,many of which the enterprise would be paid to take (e.g., mortality, processing byproducts), thereby enhancing the economics of the operation and providing a more comprehensive waste management service to the region.

  It is the author's opinion that, although opportunities for increasing demand for compost products in conventional compost markets is limited, potential demand for compost for large-scale agricultural applications is almost unlimited. However, there are several factors that are constraining our ability to establish such markets-public sector assistance will be needed to overcome many of these constraints and open up these potential markets.

- Pelletizing/extrusion: Pelletizing is an expensive process, primarily due to the high maintenance costs of the processing equipment. This requires relatively high product prices, and markets have been somewhat limited. However, pellets potentially enjoy multiple markets, ranging from fertilizers to cattle feed to energy options. Litter pellets can also be handled, transported, and spread more readily than raw or composted litter. In general, pellets still retain some odor, although the process can kill undesirable pathogens. Pellets tend to have greater bulk density and higher nutrient content than raw or composted litter. Some processes enable other ingredients to be added that increase the pellet value for certain markets (e.g., fat for cattle feed, or odor-reducing chemicals). Some processes include break-up of the pellets into granules, further increasing the bulk density and "spreadibility" of the end products. Extrusion is similar to pelletizing, although extruders are not often used for litter processing applications. There are opportunities for expanding current markets for litter pellets, particularly for horticultural and organic farming applications. While litter pellets are viable fed supplements for cattle, these markets will likely be limited (if not eliminated) by public sentiment.

- Air desiccation-pulverization: This is a relatively new technology in which a high-speed air jet is used to dehydrate and break apart the feedstocks. According to the company that is currently trying to commercialize the technology, the system can effectively utilize a wide range of feedstocks, including poultry litter. The company claims that, using litter, the system can deliver a dry, pathogen-free product with very small particle size (down to powder size). The company also claims the process has very low processing costs (relative to conventional processing technologies such as composting or pelletizing) and the system is relatively mobile. The end product would be used primarily as a fertilizer/soil amendment. In the author's opinion, this technology could have widespread applications for poultry litter, providing the company's claims can be met and that the product can be sold into agricultural markets at competitive prices.

- Combustion/gasification: Poultry litter can be burned in conventional systems, although there are significant technical issues that must be addressed such as low slagging temperatures, high ash content, and potentially high NO_x emissions. Several combustion/gasification technologies are currently being promoted specifically for use with poultry litter (for converting the material into thermal and/or electric energy). For example, three large-scale, conventional bottom-grate combustion systems have been installed and used successfully in the U.K. that utilize poultry litter as the sole feedstock. However, this technology is particularly subject to economies of scale, requiring an extremely large system (e.g., 200,000-500,000 tons per year of litter) for economic viability. Other vendors are promoting smaller-scale gasification systems for converting litter into thermal/electrical energy, although the systems would also entail a central processing facility. One U.S. company is trying to develop and commercialize a farm-scale system for converting litter into thermal/electrical energy. Several companies are developing and commercializing systems for on-farm, litter-fired space heating, thereby avoiding the expensive equipment components associated with the steam cycle and electrical generation. In general, it is very difficult for any biomass-fired power plant to be competitive with conventional, fossil fuel-fired system under current economic conditions in the United States. Given the additional technical challenges noted above, this is particular true for poultry litter.

- Low-temperature gasification: This new technology, which originated in the oil and gas industry, promises to convert a wide range of biomass feedstocks into a medium BTU gas, which can be used directly or further refined into other value-added products (the equipment vendor has successfully used poultry litter as a feedstock in the system on a trial basis). A unique feature of this technology is its ability to produce a low temperature gas through a process with minimal (external) heating of the feedstock (i.e., the feedstock is not heated up through an oxidation process as with a conventional gasification system). The technology is probably too complex for farm applications, although there is a possibility of making a modular, transportable system.

- Anaerobic digestion: This technology is generally associated with relatively high moisture feedstocks (e.g., layer manure or swine effluent), although there have been some use of this process for litter. The end products of anaerobic digestion are primarily a low-to-medium Btu biogas and water (in most situations, the process water still contains some nutrients/pathogens so cannot be discharged and therefore represents a potential wastewater management challenge). In the opinion of the author, there are limited applications for anaerobic conversion of poultry litter.

- Enzymatic/chemical conversion: There are several technologies that have been developing within this category, most of which produce a liquid fuel (ethanol or methanol) and/or other industrial feedstocks. Some of the emerging technologies in this arena have significant potential, although the economics are presently elusive (given the relatively low prices of fossil fuels); there are currently no commercial facilities using these processes with poultry litter feedstocks. The technologies are being developed both in the public sector (e.g., by DOE's National Renewable Energy Laboratory) and by private companies.

MARKETING ISSUES AND OPPORTUNITIES

The key factor, of course, in successful deployment of any of these litter conversion technologies is the ability to sell the resulting product-at prices that have acceptable margins and for the potentially large volumes of material that may need to be processed in the coming year.[1] The niche markets that already exist for most of these technologies (whether for compost, pellets, or energy) are important and can be expanded somewhat. But in the long term, agricultural markets will emerge, and will demand large volumes of organic amendments, particularly litter (since litter-derived products tend to have slightly higher nutrient contents relative to other organics-derived products and because litter is more "collectible", transportable, and manageable than other manure streams).

Efforts are needed now to develop these markets. In most cases, stimulation of demand for litter-derived fertilizers and soil amendments will need to start with education of potential consumers (e.g., row-crop farmers), along with informational campaigns and demonstration projects. Thus, there is an important role for the public sector in developing these markets.

There are also important steps that should be undertaken by the poultry industry. Coordination of feedstocks is a significant issue, given the contract grower mechanism employed by the broiler and turkey industries. Even where markets exist and the economics are feasible, the challenges associated with collection of feedstocks from dozens, perhaps hundreds, of independent farmers may preclude private investments in processing and marketing facilities. Regionally coordinated strategies are needed that include coordinated litter management enterprises.

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[1]For example, in the southwest Missouri-northwest Arkansas-northeast Oklahoma region, litter production exceeds one million tons per year (wet basis). If, within the next five years, 25% of the material must be moved off of production farms (and out of the respective watersheds) to address management concerns, then over 250,000 tons of litter will need to be exported each year. Although some of this material will be sold into raw litter markets, most of the litter will need to be processed and sold into associated markets.

Transportation of litter products, whether raw or processed, is a major cost and, commonly, the constraining factor to litter exporting. However, back-haul opportunities can often be tapped to make transport of litter products to markets feasible. From a "big picture" perspective, the nutrients contained in poultry litter could be used to produce the feed grains that are imported into the regions of concentrated poultry production. In theory, using litter products for production of feed grains would lead to a "closed loop" for the nutrients and a sustainable management system with significant environmental attributes. If the litter products could be back-hauled on the feed grain transport systems, this theoretical strategy could become a reality. The poultry industry is encouraged to evaluate such potential opportunities.

PUBLIC POLICY AND OPINION TOWARD FARMING

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The increasingly close interface between agricultural production units and residential areas is forming the predominant force reshaping public opinion toward agriculture. In many geographic areas, the public's opinion of production agriculture, especially that of animal production, is becoming so negative that evolving public policies are placing unprecedented restrictions on agricultural activities. This presentation will focus for the most part on those opinions and policies that are occurring in local communities and how those impact on state government regulatory activities.

The movement away from what were formerly "rural" attitudes that accept the inconveniences of living near farms is rapidly becoming evident. Simplistically, two major factors are responsible: (1) more densely populated areas "in close" to farms and (2) larger and more intensive animal production units. Another factor, which is often subtle but molds negative opinions about animal agriculture, is the animal rights movement. News media reports and editorials are with few exceptions biased in favor of those who complain about farms because the complainants are well-organized and have the loudest voice.

The phenomenon of changing attitudes is seen even in traditionally agricultural states but appears to be most evident in densely populated states like Connecticut. The rural areas have experienced an influx of people who enjoy the aesthetics of open space land but do not have an appreciation that such land remains undeveloped because of agricultural production. "As the population becomes further removed from its farming roots, appreciation of agriculture's value declines" (Andrews, 1998).

For a small, densely populated state, Connecticut continues to enjoy progressive agricultural production. The poultry industry, with over $100 million in annual receipts, leads the other New England states in egg production. It is also the home to Arbor Acres Farm, Inc. which provides 20% of the world's parent breeding stock for the broiler industry and SPAFAS, Inc. which provides eggs for research from specific pathogen free chickens. The dairy industry has 30,000 milking cows with an average herd size of over 100 and ranks 11th among other states in milk production per cow. Other livestock industries are important but the poultry and dairy industries seem to draw the most attention from the public.

I will describe what I view as the factors and forces at work in the public opinion/policy arena in Connecticut. Not all of the same issues or the importance of those issues may be facing agricultural interests in other states, but if they are not presently, there is a good change they will in the near future.

Agricultural groups focus on the regulatory burdens imposed by federal and state agencies. My sense is that the greatest potential for implementing new policies that will restrict agriculture is simmering at the local community level. There is a wide range between individual communities as to their opinions of agriculture. This can be seen even in neighboring communities with similar demographics. Some communities are "farm friendly" and some are very "farm unfriendly". As an example, one town in Connecticut with rural areas lists chicken, cattle, and pig farms as "Locally Unwanted Land Uses" in its Plan of Development. Unlike the process at the state or national level, anti-farming policies at the local level may be proposed and adopted with little publicity and, as a result, the only opportunity to challenge such policies rests with the courts after the fact.

A negative opinion of farming usually starts in the local community with residents objecting to environmental impacts of farming activities. They perceive, and legitimately so at times, that these impacts are an inconvenience to them. In the extreme, they perceive that their lifestyle and even their health is affected. Once the term "health" is used by the complainants, the emotional and political level of the situation escalates and local officials feel compelled to take some kind of action.

The most contentious tissues that we face in Connecticut is that of flies in relation to poultry farms with deep pit manure storage. A fly infestation in a neighborhood may be the result of flies coming from a neighboring farm but, even if its isn't the farm is usually the target of complaints. Dairy farms are also involved in the fly issue because most of the poultry manure produced in Connecticut is used on corn ground by dairy farmers. If the manure is infested with fly larvae and stockpiled it can cause a fly infestation at nearby houses.

Complaints by neighbors trigger a rather complex process. Many times we will receive the initial complaints at the Department of Agriculture either directly from the complainant or from a local official. The Department of Agriculture will then conduct an inspection of the "accused" farm and surrounding area if an inspection was not recently done. (Connecticut has quite extensive laws and regulations governing intensive poultry farms [over 20,000 birds] that were adopted in 1982 after a series of particularly disastrous environmental events at poultry farms). The Department does not have authority to enter private property in the neighborhood to verify complaints unless invited. We rely on local health department and municipal officials to do so. Because poultry farmers are keenly aware of the publicity over flies, most are conscientious managers and realize that being a "good neighbor" is paramount to their future on a farming operation. Consequently, with one or two exceptions, our inspections reveal most farms to be consistently in compliance with intensive poultry farm laws and regulations.

The problem is straight forward if the "accused" farm is found to be in violation. Differences of opinion begin when neighbors continue to have excessive flies and we declare the farm in compliance. The Department of Agriculture is often accused of "protecting" the farm either by not setting strict enough standards for flies and larval activity or just turning our heads the other way. We know that there are instances in which a fly bloom has occurred at a farm in the interim between inspections which has legitimately caused a neighborhood problem. People become very frustrated when they are unable to enjoy their yards for cookouts and other activities because of excessive flies.

The level of frustration often causes neighbors to ban together and pressure local municipal officials to take action. In most cases, the municipal officials will rely on the Department of Agriculture's inspection record of the farm. However, there are instances in which municipal officials have taken unilateral action in an effort to reduce the risk of excessive fly populations from farming operations. Two separate municipalities in conjunction with their local health departments have issued letters to farmers advising them of the authority of the Public Health Code (state regulations of the Department of Public Health enforced by local health directors). The test of those letters is as follows:

To: **Poultry and Dairy Farm Owners/Operators**
Property Owners of Leased Farm Land

Subject: **Handling of Poultry Manure**

Section 19a-206 of the State of Connecticut Public Health Code grants local Directors of Health and Town Sanitarians the authority to abate a nuisance or condition detrimental to the public health and well being.

The stockpiling and spreading of larvae infested poultry manure causes a severe infestation of flies and is a violation of the Public Health Code which can no longer be tolerated within the Town of ____ ______________. All poultry manure delivered to local farmers should be relatively free of larvae. If poultry manure is found to be infested with larvae, the Town sanitarian may require it to be returned to the sender or immediately covered and secured under black plastic until the larvae is baked and destroyed. This occurs on a sunny day when the temperature reaches 100 degrees Fahrenheit.

If the above procedures are not followed, the Town Sanitarian will seek a Court order to abate such conditions, and ask that the statutory fine of $250.00 a day be imposed until such violation is abated. This may take several days in the event larvae infested manure is spread and a fly infestation occurs.

The public demands that we reduce the fly infestation and this can only be accomplished if farmers and landowners work together. We appreciate your cooperation in this effort. Should you have any question, please contact any or all of the individuals listed below.

(signed by):
First Selectman, Director of Health, Town Sanitarian

This brings us to another important policy issue at the local level. Local Directors of Health have extremely broad powers through their enforcement of the state Public Health Code that can affect agricultural activities. Until recently, it was assumed that only the Connecticut Departments of Agriculture and Environmental Protection had regulatory authority on farms in the state. Local Directors of Health have now entered the picture as a result of residents' complaints. The legal authority of local Directors of Health is summarized as follows from Connecticut law.

> "Directors of Health within their respective jurisdiction are required to examine all nuisances and sources of filth injurious to public health, cause such nuisances to be abated and cause to be removed all filth which in their judgment can endanger the health of the inhabitants. Any Director of Health or his authorized agent or a sanitarian authorized by such Director may enter all places within his jurisdiction where there is just cause to suspect any nuisance or source of filth exists, and abate or cause to be abated such nuisance and remove or cause to be removed such filth."

The authority granted to Directors of Health in Connecticut raises some interesting points regarding their potential involvement in farm waste management. The law states that the Director shall use his "judgement" in deciding whether a situation constitutes a nuisance or source of filth injurious to the public health. The law allows a Director to take action quickly and independently and without interference from other municipal officials or political pressures in situations that constitute a real public health threat. However, the recipient of an abatement order may be unjustly accused if the order is issued arbitrarily as a result of a director either not having sufficient technical expertise, being unfamiliar with requirements set forth in the laws and regulations, or his involvement in an area in which regulatory jurisdiction is with another agency or a combination of these factors. Orders can be appealed through an administrative hearing at the state Department of Public Health but in some cases the appeal takes place after the fact -- after the damage, either financial, emotional, or to someone's reputation, has already occurred. Directors of Health have made judgements that certain agriculturally related situations, specifically fly infestations, constitute a nuisance injurious to public health when in others' expect opinions they do not and such situations are under the regulatory authority of another agency.

As an example, recently an abatement order was issued by a Director of Health to a poultry farm to abate a fly infestation on the farm and in the surrounding neighborhood. Department of Agriculture inspections conducted every two weeks had determined the farm to be in compliance on each inspection. A fly breeding area on a horse farm in the neighborhood was completely overlooked by local health authorities.

One other interesting aspect of the legal authority of local departments of health is that they are authorized to enter all places where they feel they have just cause. This authority is unusual in scope considering that most agencies that have regulatory or law enforcement authority must first obtain a search warrant before entering a residence or place of business without prior consent. Regulatory agencies have the authority to enter certain places at any time but usually the types of places are narrowly spelled out in law and regulation. So, in the case of local health departments, what is or who defines just cause? Who or what agency other than the state Department of Public Health and eventually the courts can rein in an over-exuberant Director of Health? How deferential would the courts be to a Director of Health accused of entering a place without just cause? An finally, considering the Fourth Amendment of the U.S. Constitution, what is the balance with this authority between a compelling interest and the prohibition of searches unless certain conditions are met?

The word "nuisance" is commonly used in the context of complaints about farms and in "Right-to-farm" laws. "Not all complaints of annoyance or disturbance are indicative of nuisance activity that courts will routinely proscribe through the exercise of their power. Slight inconvenience or petty annoyance when measured by a normal healthy person of ordinary habits and sensibilities does not rise to the level of nuisance activity. People with super sensitivities, or insensitivities, are not considered part of the pool of individuals who measure reasonableness of questioned activities. For the court's intervention authority to arise, the activity must unreasonably interfere with or disturb a person's comfortable use and enjoyment of their own property."

As many other states have done, the Connecticut legislature enacted a "Right-to-farm" law in 1981 to protect the interests of agricultural production from changing attitudes. The law is in the Department of Public Health laws and states that odors, dust, noise, and the application of chemicals shall not be deemed a nuisance in agricultural or farming operations. To qualify under this law, the farm must have been in existence for more than one year and not changed substantially within a year. It also must follow general accepted agricultural practices as determined by the Department of Agriculture. The validity of "Right-to-farm" laws may be questioned if states classify intensive animal feeding operations as something other than farms in a similar manner to the determination made by the Attorney General in Kentucky.

There are a number of positive steps that can be taken by producers, allied organizations, and regulatory agencies to create more positive attitudes toward animal production agriculture. The goal of any of these steps is to establish a dialogue between all parties involved.

On two separate occasions (1995 and 1997) the Commissioner of the Connecticut Department of Agriculture established advisory committees to study and develop policies regarding poultry manure management and fly control issues in specific communities. The committees were made up of state officials, local officials, and experts in various areas. An example of the composition of one such committee is as follows:

- Commissioner of Agriculture
- Director, Bureau of Regulation and Inspection, Dept. of Agriculture
- State Entomologist, Connecticut Agricultural Experiment Station
- Department of Environmental Protection, pesticide division
- State Legislature, Representative from the particular district
- Chief municipal officials of the towns involved
- Local Director of Health
- Poultry Extension Specialists, University of Connecticut
- IPM and Field Crop Extension Specialists, University of Connecticut

Complainants and "accused" producers were not officially appointed to the advisory committees. We worked to move the issues from an emotional arena to a scientific one. the meetings were open to the public and were often attended by the news media, Farm Bureau, and other interested parties.

As a result of the work of these committees, we took a proactive role in educating producers in good manure and fly control management practices through the distribution of written materials and on-site visits. We have tried to increase the awareness of producers that, in the current socio-political climate, they have to do all that is reasonable to be good neighbors or the decision whether to remain in business or not may be made by others. We also assured producers that homeowners would be provided with educational materials for fly control and prevention in and around their homes.

It is important for homeowners in problem areas to know that producers and others are working together to find a solution to a problem if one exists. We provide homeowners with information on yard and house keeping methods to discourage fly populations. We also provide information on basic fly identification to enable them to distinguish domestic house flies from other types of flies. Finally, we provide the homeowners with a protocol for reporting complaints.

The formation of such an advisory committee leads to better networking between all parties involved. For example, the

Department of Agriculture has developed a close working relationship with municipal officials in some communities. My experience has been that municipal officials have taken a balanced approach to residents' complaints about environmental impacts of farming even though they can be under intense pressure from the complainants to take steps as drastic as issuing case and desist order to farms.

A public meeting such as a town meeting is not productive in reaching any kind of common ground in solving problems between residents and farmers. Farmers are always outnumbered in these meetings. Such a meeting provides a forum for complainants to express their anger about how no one is doing anything about the problem even if there isn't a legitimate problem. The Department of Agriculture is commonly incriminated in being in a conspiracy with the farmers. "Expert" opinions are abundant and political posturing should be expected in these kinds of meetings. As public officials, we are obligated to attend if invited by local officials. However, any facts that are presented are usually overlooked because the meetings are so emotionally charged.

There are two other factors mentioned previously shaping public opinion about farming that must be taken seriously. The first is the animal rights movement. Most farmers believe that animals should be housed, fed, and cared for in a reasonable manner that makes them comfortable - this is "animal welfare". The "animal rights" groups at times go beyond this to the extreme of equating the rights of animals to that of people. We may see these extremes more commonly in the northeast than in major agricultural states in other parts of the country. These groups are well organized and funded, politically astute, and are skilled at using the media to promote their cause. They are opposed to intensive animal housing and feel that people exploit animals by eating animal derived food products. The concern is that the potential is real for state legislatures in non-agricultural states like Connecticut to be lobbied hard enough to enact laws that will restrict the way in which farm animals are kept. If successful, new laws and restrictions in one state can set a precident for the passage of such laws in other states - the "one foot in the door" phenomenon.

The second factor is the new media. The fly issues in Connecticut have drawn the most media attention. Like national broadcasts regarding food safety, local newspaper accounts and editorials are often biased against agriculture. Those who read the accounts or see television reports form opinions based on inaccurate information. In one case in Connecticut, there were over 20 newspaper reports and three television reports within a three-week period regard flies in a neighborhood bordering a poultry farm.

CONCLUSION

Livestock producers should expect more restrictive ordinances to be enacted at the local level. Local communities are now trying to correct what they allowed to happen in the past, which was expansion of farms in residential areas and building residences without adequate set backs from farms. There will be legal challenges to such ordinances based on whether state or national law supersedes a particular local ordinance (Copeland, 1998).

Agricultural groups must be proactive in selling to the new media and policy makers the idea that today's farmers are concerned about the environment and are implementing management practices to protect the environment. Legislators must be approached in a business-like manner and not in a manner based on the attitude that farmers have a God given right to farm no matter what. At the local level, farmers and allied groups must work together to solve problems with neighboring residents. The days of the "I was here first" defense for farmers is long gone.

Finally, we must realize that, no matter how proactive agricultural interests are in promoting their concern for the environment and "good neighbor" policies, some people will never change their negative attitude toward farming.

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EXAMINATION OF GRAS POLYMERS IN PRIMARY DAFs

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INTRODUCTION

HISTORY

- Alternatives
- Economics

OPERATION OF SYSTEM

LESSONS LEARNED

- Pro/cons
- Performance

NEXT STEPS

OZONE TECHNOLOGY FOR RECYCLING PROCESS WATER

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As "Food Safety" and "HACCP" seem to have occupied the minds of most poultry, and yes, most other food producers and processors in the last decade, water, its availability, treatment and conservation will most likely be the major concern of the next. If you combine food manufacturing with agriculture, the food industry is the largest consumer of water in the U.S. Approximately 4000 gallons of water are required to grow, process, package and prepare an average person's daily diet of 2,000 calories. Water can be as expensive as gas and electricity in food plants and must be used with the same care and accountability.

As the very name of this conference, the "National Poultry Waste Management Symposium" suggests, the poultry industry is very concerned about the environment. The conservation of water is a real part of these concerns. The poultry industry, including it largest processor, Tyson Foods, has made a major financial and human resources commitment to water quality. It is reported that Tyson, alone, has invested over $200 million over the last five years to meet state and federal EPA standards for water returned to waterways or publicly-owned treatment facilities. In all plants, water quality managers, assisted by line supervisors are committed to conserving water to reduce the need for treatment.

Water usage in poultry processing plants, as you might expect, varies widely. It is currently estimated at between five and six gallons per bird, about one half gallon for bird chilling and one quart per bird for scalding, a significant amount for moving offal, "sluicing", and the remainder using for clean-up and sanitation. Dr. Bill Merka, the water expert from the University of Georgia, estimates this has been reduced from 10-15 gallons per bird 20 years ago. Water costs can vary from "$2 to $8 per gallon in different parts of the country. In some parts of the United States the availability of water even effects plant sites. Figure 1 is an estimate of the cost of water through the year 2000.

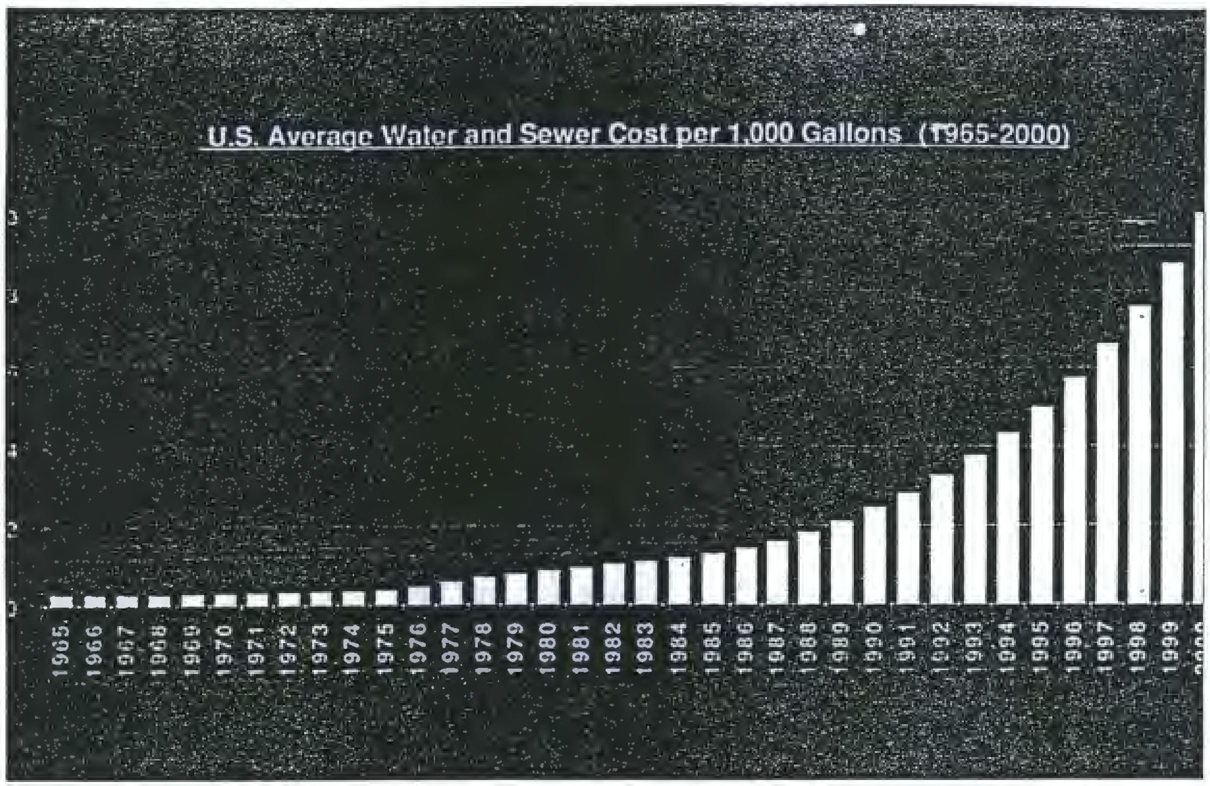

Figure 1. U.S. Average Water and Sewer Costs per 1000 Gallons.

Implementing the HACCP programs has caused a significant increase in water usage in poultry processing plants. According to Dr. John Marcy, University of Arkansas, plants are using a lot more water, at least a gallon per bird, in the hope of reaching the zero tolerance requirement for poultry carcasses under the new "command and control style" of USDA-FSIS inspection.

The USDA-FSIS requires that poultry be cooled to 40°F or below at the end of the slaughter process and before packing, unless the product is to be frozen at the official establishment. The United States poultry industry, for over 40 years, has been cooling by immersing the birds, following the final wash, in cold (near 32°F) water and often added chlorine at 20-50 ppm to improve sanitation. The European industry does not permit immersion chilling because of concerns for sanitation. The Canadian poultry regulations in the past did not permit the use of chlorine. Scientists around the world have been concerned about the formation of carcinogenic compounds from the reaction of the chlorine and organic matter in the chill water. Chill tank sanitation has been the subject of much concern in industry protagonists and the media. Many industry investigations have demonstrated that while some cross contamination of carcasses may occur, the overall chilling process is a cleansing one and bacteria counts on carcasses are reduced as birds are chilled. In order to reduce contamination, the USDA-FSIS requires that 1/2 gallon of cold water must be added to the chill tank for every broiler chicken going through. Some poultry firms have shown that using more of the overflow replacement water (more than 1/2 gallon) improves carcasses microbiological quality and when feasible, do actually use as much as two gallons per bird.

Because of the increasing limitations of supply and the cost of water and sewer treatments, many firms have investigated the possibility of recycling processing water. Chemical and physical treatment of the chill tank effluent have received considerable attention over the last ten years. As these efforts have made progress, USDA-FSIS has issued guidelines and regulations that must be met to recycle this water. The degree of reduction of bacteria (total plate count (TPC), coliforms, *E. coli* and salmonella) and the improvement of light transmission determine the amount of water than can be recycled. For instances, with a reduction of 90% in bacteria levels and 80% light transmission, 1.25 gallons of reconditioned water can replace one gallon of fresh water.

The benefits of recycling poultry chill water are:

- Decreased Daily Water Usage (and costs)
- Decreased Electrical Costs (pumping and refrigeration)
- Decrease in Total Discharge Water to be Treated
- Potential to Increase Overflow Rate Without Using More Water

The system I will describe today is the Ozone Treatment System developed and being marketed by American Water Purification, Inc. of Wichita, Kansas. There are other systems using ozone, chlorine, filtration or a combination of these that do not appear to be as efficient at this time.

The overflow water exits the chiller to the left into the wedge-wire screen filter which is actually a dewatering filter and into a separation tank where more solid material is removed. The water then enters Tank 1 where ozone is added. This and the other three tanks act as air flotation tanks which remove organic solids and sanitize from the contact with the ozone. The organic foam is removed at an overflow and discharged to the plant offal collecting system. As the water exits Tank 4 it is nearly potable and still is under 40°F. As a precaution to remove any residual ozone, it is passed through an activated carbon filter and then to the blend tank where the required amount of new city water is added, cooled and returns to the chiller. It should be understood that water from other sources, i.e. the final bird wash, can be treated and recycled.

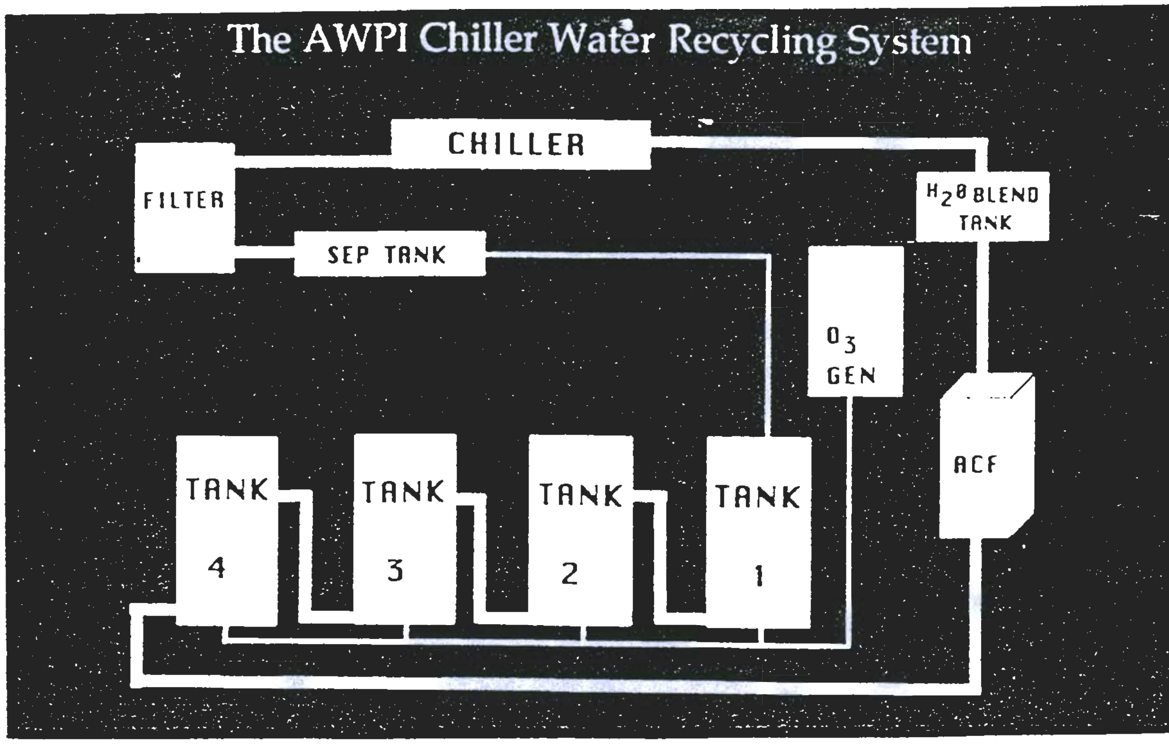

Figure 2. Schematic of the AWPI Ozone System.

Ozone is the clean fresh smell in the air following a thunderstorm. It is a more powerful disinfectant than chlorine. Ozone has been effectively used in water treatment plants and food processing installations in Europe for nearly a century. It does not remain in the water long and has no residual. Oxidation by-products are less likely to have deleterious health effects than chlorine by-products. It works as a sanitizer by rupturing the bacterial cell wall. An expert (Graham, 1997) panel has declared that ozone is GRAS (generally recognized as safe).

RESULTS

A system similar to that described above has been installed and effectively working in a Gold Kist plant in Carroltown, Georgia since October 1997. A unique feature of this system is the instrumentation that permits the continuous monitoring of its performance. If at any time, the return water does not meet the design characteristics, the recycled make-up water is reduced and the new city water increased. These monitored characteristics have been correlated with the bacteria counts, light transmission and Total Organic Carbon (TOC) so that the operation is always in control of those regulatory requirements. This recycle control is actually a Critical Control Point (CCP) in the HACCP system that is monitored continuously with corrective action imposed immediately.

The following three figures illustrate the performance of light transmission, TOC and Total Plate Count over an almost six month commercial operation. Total coliform and *E. coli* were present in such low numbers they could not be reported. The light transmission shown in Figure 3 is consistently above the 85% chosen and for most of the time above the 90% level.

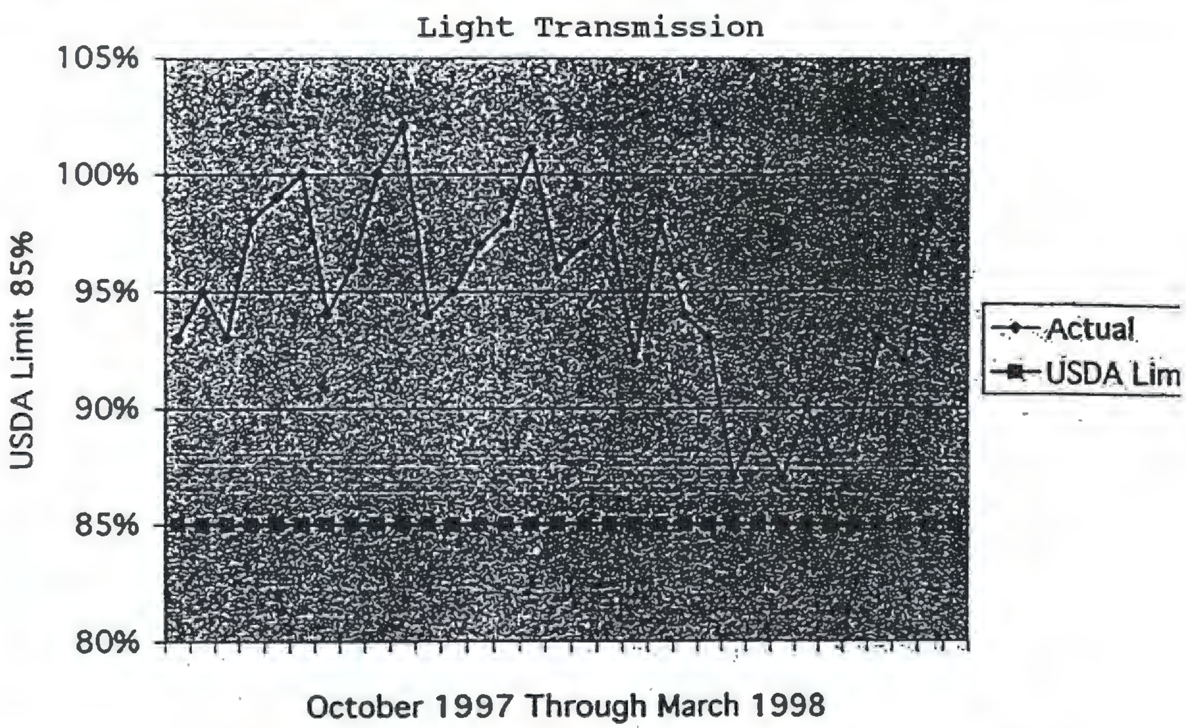

Figure 3. Light Transmission in Gold Kist Recycle Water.

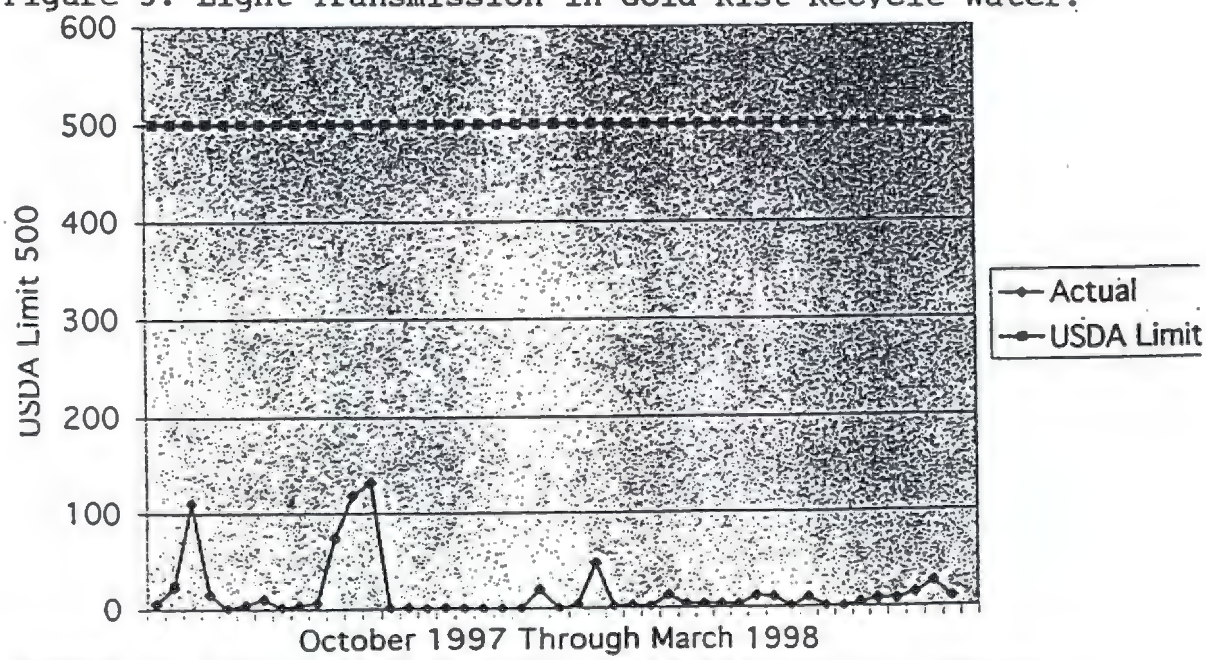

Figure 4. Total Plate Counts - Gold Kist Recycle Water.

Total Plate Counts shown here are consistently below the 500 cfu/ml level chosen as the target and generally under 100 cfu/ml. In experimental trials, when ozone was shut down, the total plate counts rose almost immediately which resulted in the transfer of intake water to the alternate city course.

TOC Results

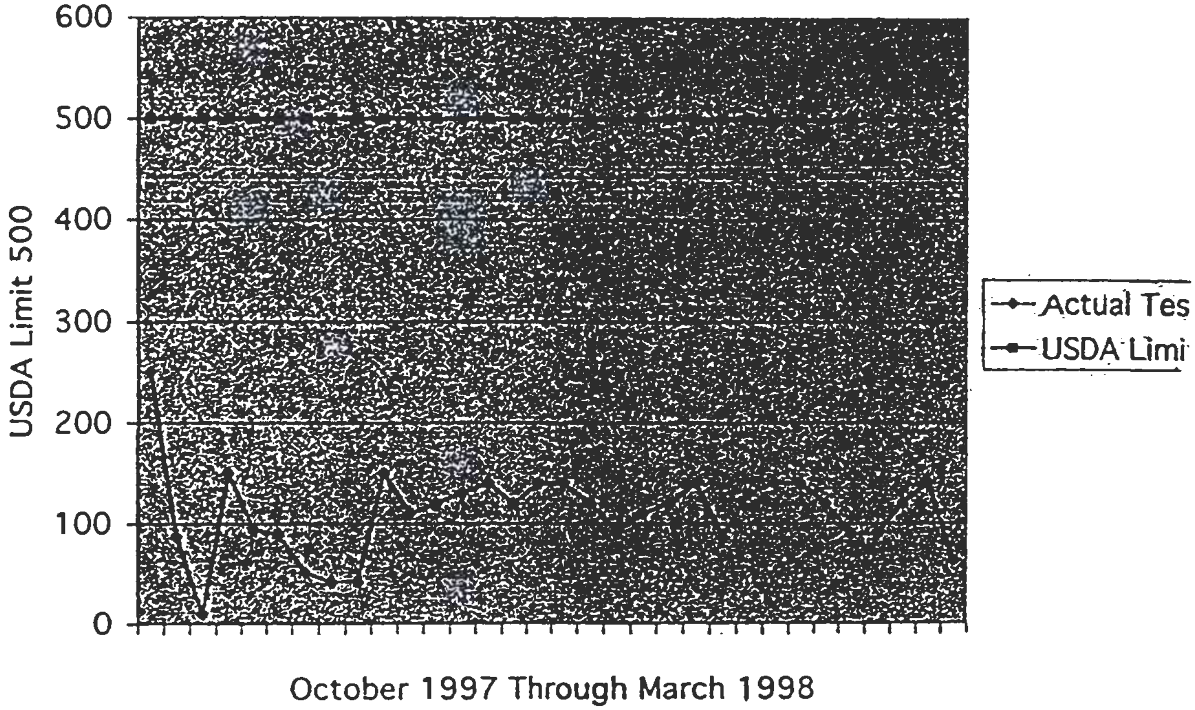

Figure 5. Total Organic Carbon - Gold Kist Recycle Water.

Total Organic Carbon, which is an indication of any residual organic matter and particularly of carbon compounds that might be formed as a result of ozone interactions, is consistently below 200 ppm and well below the 500 ppm target.

In other studies by Waldroup *et al*. (1993) at the University of Arkansas bacteria (*E. coli*, coliform, and TPC) were reduced by 99.9%. Light transmission was increased from 82 to 97%, and TOC was reduced from 168 to 36 mg/l.

SAVINGS

It is difficult to generalize on savings because each plant differs in water and sewer costs, water used, refrigeration costs, cost of recycling system etc. Every plant must estimate its potential savings but data to date indicate they will be significant.

CONCLUSIONS

* Water and sewer costs are increasing
* USDA-FSIS requirements will become more stringent
* Ozone is a safe and powerful disinfectant
* Ozone is safer than chlorine
* The AWPI Ozone System provides for recycling
* The AWPI Ozone System is cost effective
* The AWPI System provides for continuous monitoring
* The AWPI System provides for a CCP in a HACCP system

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INNOVATIVE FEATHER UTILIZATION STRATEGIES

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Why make a meal out of feathers? Presently, there are about 2-4 billion pounds of feathers produced annually as a by-product of poultry production. The largest component volume of poultry by-products is feather meal. Yet this has often translated into a hidden cost, and not an open asset for poultry producers.

Why is that? The economic value of the feather meal end product sometimes does not even return the cost of preparing it. The nutrient value of feather meal is unpredictable at best. The process of making feather meal is wasteful and inefficient. Feather meal under the microscope contains abundant amounts of microcrystalline feather fibers intact throughout the mixture. This is unambiguous evidence that despite the extensive thermal and mechanical processing, feather fibers have not even been broken down at the microscopic level.

CHEMISTRY OF FEATHERS

Feathers are made out of the protein keratin. Keratin can be a fiber or a non-fiber. Wool, the air on sheep and goats, is keratin fiber; so are the hair of dogs, cats, and humans. In avian species, the corresponding fiber is as feathers. However, keratin is the major chemical component of tiger claws, rhinoceros horns, antelope hooves, finger nails, and feather quills, none of which are fiber.

Feathers are composed of amino acids, the building blocks of protein. The five most abundant are serine (16%), proline (12%), glycine (11%), valine (9%), and cysteine (7%) (Murayama *et al.*, 1986). there is no lysine, histidine, tryptophan or methionine in any of the avian keratin proteins. Only small differences occur in comparing the amino acid profile of feathers from ducks, pigeons and poultry. In most diets, serine, proline and glycine are typically in abundant supply. Moreover amino acids which can be readily produced from other amino acids in the liver are not considered essential amino acids. Keratinases hydrolyze protein in feathers (Shih, 1993), but the protein value depends upon the amino acids present in the protein. The most nutrient value of keratin as a hydrolyzed protein is from cysteine.

The fiber and the quill have fundamentally different physical properties. The quill melts at 15°C lower than that of the fiber (Schmidt and Line, 1996). This means it inherently takes more energy to break down the fiber than the quill under mechanical and/or thermal stress. In any process to obtain nutrient value from feathers, the quill is always mechanically and/or thermally broken down first.

Sailing ships a century ago used twisted fiber rope which resisted mechanical stress in their riggings. This tightly ordered rope is a macroscopic example of a helical structure. the stability of the feather fiber is because the fiber is ordered as alpha helices at the molecular level. In contrast, the quill exists in a less ordered beta sheet conformation.

Not only does this molecular ordering affect physical properties, but also the chemical properties of the fiber. In the hydrolysis of feathers for particles/fibers of the same surface area, the quills will always digest faster than the fibers. Nutrient value is more accessible in the quill than the fiber.

UNIQUE PATHWAYS

The source of feather fiber is uniquely different than commercial fibers on the market. Feather fiber is effectively a self sustainable, continuously renewable source of fiber. Synthetic fibers are renewable only to the extent that they are recycled. Trees can be harvested every twenty years; wool, cotton, kenaf maybe twice a year. Almost seamlessly, poultry are raised for food at a steady rate day after day, month after month. Concomitantly, a predictable supply of fiber always occurs.

Acres of land on which plant fiber is raised are always in danger of routinely occurring natural disasters like frost, drought, pests, fire, floods and market forces. The longer the fiber takes to grow, the greater the risk of a significant loss of valuable assets. The supply of fiber for fiber users from feathers is potentially as dependable and as "risk free" as that for poultry meat.

Nothing additional has to be tilled and planted, fertilized and watered, harvested and collected. Feathers are already concentrated within centralized locations. Therefore no transportation costs for collecting the fiber for processing is required. No one has to be paid for any of these labors because they are already paid for in full within the purchase price of every broiler sold. Other agricultural fibers do include the cost of each of these price components.

In contrast, viewed from the end product, processing feathers into feather meal is an expensive, wasteful process. The process engineering makes sense only because it continuously and successfully removes 10,000 pounds of by-product an hour from a poultry production line. The time for each step in the process, the high temperatures and pressures used in rendering are effectively determined by the inherent stability of the feather fiber. Yet partial thermal degradation of the feathers impart only marginal improvements in the nutrient value of end product.

If feathers were removed from the rendering operations,the time, temperatures and pressures required in rendering the remaining poultry by-products could be considerably less expensive. Indeed processing parameters would be much more able to affect the quality and value of the rendered end product. Increased efficiency can occur because 1) the starting material is physically much more uniform and 2) the chemical stability of the starting material is much more uniform. Ironically, the same presently used processing parameters, which are not harsh enough to fully "desirably degrade feathers, also progressively thermally degrades the remaining components in the mixture. Thus removing the feathers from the feather meal should actually increase the nutrient value of the remaining rendering end product.

Thus very good processing reasons and value exist for the poultry industry to collect feathers and sell the fiber. What happens to that fiber from there? End use selection further adds unique value of feather fiber.

SPECIFIC DIRECTIONS, MULTIPLE PATHS

The fiber end products which require the least time for research and development are the best initial paths for marketing strategies. Routinely used dry laid processes (Turbak, 1993) are both simple and effective ways of binding loose feather fibers into mats. A thin mat is an air filter. A thicker, denser mat is cloth-like felt. A thicker and less dense mat (weaving large volumes of space together with fiber) is an effective absorbent. Formulation of non-wovens to optimize flow and strength criteria is an essential job requirement for researchers developing an non-woven products. Poultry processors do not need to produce that expertise,but need to understand the value of this fiber.

Feather fibers have an effective diameter of 6 μ. This is significantly smaller than 10-20 μ of wood pulp, and 20-30 μ of wool fiber. Synthetic fibers smaller than 10 μ are difficult and expensive to make. The smaller diameter means for any weight of fiber, there is much more surface area on feather fibers than on these other fibers.

Feather fibers also have good bulking properties. This means the space between the fibers does not readily collapse as occurs with less rigid fibers. These properties make the fiber a valuable material for use in air filters. The major technical advantage of rigid high surface area fibers is that one can formulate filters with comparable affinity to existing filters but at higher air flow rates.

The same properties which make feather fibers valuable in air filters also makes them valuable in adsorbents. Air filters remove dust particles. Adsorbents are designed to pick up, to immobilize and/or to concentrate molecular species. Examples of adsorbents range from diapers to floating boys for oil spills. A positive evaluation of absorbent filters made from feather powder has been reported (Kawaguchi, 1997). The feather powder they used, however, was a mixture of both fiber and quill components.

Fibers made from synthetic chemical utilize a valuable finite natural resource. Analogous to wood made from trees, because the supply of trees is limited and the price significant,for many applications, much modern wood furniture is made with expensive wood veneer outside, and lower cost composite pulp material inside. For those applications in which the surface properties of a fiber contain its value, feather fiber by design coated with a synthetic polymer would not have comparable surface properties to the fiber entirely made from synthetic fiber at lower cost.

Plastics including fibers can add to its bulk properties. Feather fiber is microcrystalline in structure; less expensive plastics are rather soft and pliable. The more valuable/expensive plastics are less amorphous/more rigid. Mixing microcrystalline compounds with amorphous ones results in a mixture which is more rigid. This hardens the plastic and can make it comparable in physical properties to that of more expensive plastics.

When the fiber has similar properties to that of a aplastic, composites can also be made with them. Instead of adding to the physical properties of the plastic, it then just adds to the volume of plastic. Feather fiber then acts as a filler and/or extender of the plastic already in use. The value of an inert fiber in a plastic mixture which adds no new properties to the end-product is in the volume of plastic it has replaced within the original end-product.

Examples of straightforward applied research is required to determine the fiber length/distribution which is best for that product. It requires further applied end-product research to formulate the optimum amount of fiber and the processing parameters required to assure that the original product quality is maintained. Reasonable formulations could take qualified individuals perhaps only several weeks to design and optimize.

Which of these paths is most promising has more to do with what is economically most reasonable rather than with what is most technically feasible. These uses can consume very significant amounts of fiber. A logical choice may be to match the market demand for the fiber at one location with the amount of fiber which is being produced at a particular poultry plant.

FURTHER ENHANCEMENTS IN FIBER VALUE

The rationale for the value of feather fiber discussed thus far has been to the use of this fiber in existing fiber processes, to improve existing products made from fiber. Each poultry processing plant in fact has a finite supply of feathers matched to its poultry production. The internal logic of this is that market forces will determine which commercial products are first made from feather fiber, and which remain the major users of feather fiber. Existing processes become more efficient, cost of end-products is reduced, value of end use products is refined/redefined.

The maximum value of feather fiber however is not in the fiber that it can replace, but in unique properties of the fiber which enable valuable new products to be created and for which existing fibers are inadequate. New markets, new products, new sales. Typically such products begin with a higher price for fiber but a lower volume in sales. A better design would perhaps be to decide upon/among the price distributions within a framework that maximizes production and sales.

Research requires an investment in personnel, time and money. It can be difficult to accurately predict who will succeed, when, and what the cost will be. Innovative product development research requires effective technical/business collaboration between those who produce the feathers, those who process the feathers into fiber, and those who design and manufacture new fiber products. The slow step is technical innovation can very often be the lack of effectively designed collaborative strategies.

Binding of heavy metal ions to fibers and filters from poultry feathers (Schmidt *et al.*, 1997) is an example of an application which can significantly enhance feather fiber value. Feather fiber has high affinity for specific heavy metals including copper, chromium andiron. Controlling the heavy metal levels released into water waste streams is different for each industrial process/plant because different metal ions are required for different processes. Feather fiber has the advantage of adsorbing heavy metals under faster flow rates than slow affinity adsorbents. A potentially promising strategy is to modify the surface properties of the fiber to increase its affinity for specific metals in specific clean up sites.

Successful innovative efforts could also be achieved with utilization of the quill fraction. One approach using the whole feather has been to grind it into a fine powder and under raised temperature and pressure to form a clear plastid sheet (Kawako *et al.*, 1974). Quill sample were sent to Dr. Attila Pavlath, USDA/ARS/Western Regional Research Center, Albany, CA to determine if sheet can be formed from only the quill fraction. Processing advantages to using only the quill fraction would result. It requires less energy to make a uniform powder and to form the resulting powder under higher temperature and pressure into a plastic sheet from the quill than from feather fiber. Again any successful innovation must link research to a mechanism through which conversion to practice is feasible.

CONCLUSIONS

Innovative strategies exist to lay down broad stroke directions, not to develop a blueprint which directs instructions. The area of innovation is uncharted, no adequate maps yet exist. It is the willingness to explore these unknown areas that is the real innovation.

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DISCHARGE PERMITTING OF NEW CHICKEN PROCESSING PLANTS

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I. APPLICATION REQUIREMENTS

A. Discharge Only
   1. Basic Facility Info (Location, Address, Contracts, Summary of Operations, etc.)
   2. Discharge information (Discharge Location, Receiving Stream, Flows, Sources of Discharge, Production, Treatment Systems, Effluent Characteristics, etc.)

B. Surface Impoundments/Septic Tanks as part of Treatment Systems
   1. Surface Impoundment/Septic Tank Info (Flows, Wastewater Sources & Descriptions, Impoundment/Tank Locations, Impoundment/Tank Dimensions/Holding Capacities, Liner System Info, Groundwater Info, etc.)

C. Land Application of Wastewater or Sludge
   1. Land Application Info (Wastewater/Sludge Sources & Characteristics, Land Application Site Locations, Soil type & Properties, Depth to Groundwater, Application Rates, Durations & Frequencies, Methods of Application/ Incorporation, Crop Info, etc.)

II. PERMITTING PROCESS

A. Minor Discharger.
   1. Submit application, publish notice of application in local paper
   2. Application reviewed by DEQ and determined complete/incomplete
      a) 60 day regulatory timeline

   b) Complete → Go to technical review/permit drafting
   c) Incomplete → Additional info requested
3. Technical review/permit drafting
   a) 60 day regulatory timeline (may be extended if additional info needed, or DEQ has to run wasteland allocation model)
   b) Draft permit prepared, with fact sheet/statement of basis explaining basis of permit conditions
4. Courtesy draft sent to facility for review (30 day review period, extensions may be granted)
5. Draft permit sent to public notice
   a) DEQ sends notice to mailing list
   b) Facility publishes notice in local paper
   c) Hold public meeting if requested
   d) Comment period ends 30 days after last notice (may be extended if requested), or after public meeting
6. No comments received → Issue final permit
7. Comments received → Respond to comments, DEQ publishes response, issues final permit

B. Major Discharger
1. Major/minor determination based on multiple factors, including discharge flow, receiving stream flow, conventional pollutant loading, toxic potential, etc.
2. Permitting process for majors is as for minors, with following additions:
   a) Process meeting held by DEQ at time of application submittal
   b) 90 day regulatory timeline for technical review
   c) If comments received on draft permit, applicant publishes newspaper notice of response and opportunity for administrative hearing.
   d) Administrative hearing held by DEQ if requested.

III. PERMIT LIMITS & CONDITIONS

A. Technology-based limits developed based on Best Professional Judgment, since EPA has not promulgated Effluent Limitations Guidelines for this type of facility
1. Total Suspended Solids: Typically 30 mg/1 avg, 45 mg/1 max

2. Oil & Grease: Typically 10 mg/1 avg, 15 gm/1 max
3. pH: Typically between 6-9 s.u.

B. Water-quality screens performed, may result in more stringent limits
   1. Oxygen-demanding substances (BOD, ammonia, DO, etc.): Limits vary based on results of wasteland allocation modeling
      a) Modeling may be done by DEQ, or may be done by facility/consultant and reviewed/approved by DEQ
      b) May involve field work to survey receiving stream
      c) Model based on complete mixing with receiving stream, steam flow, maximum 30-day average effluent flow
      d) Limits may be seasonal, may require equivalent of secondary or advanced treatment to maintain WQS
   2. Fecal coliform: Typically 400/100 ml max
   3. Nitrate: Additional limits may be necessary if receiving stream is Public & Private Water Supply
      a) Limits based on 10 mg/1 instream WQS
      b) Limits based on complete mixing with receiving stream, receiving steam flow, maximum 30-day average effluent flow
   4. Phosphorus: Additional limits may be necessary if receiving stream is nutrient-impacted (Typical limits 1 mg/1 avg, 1.5-2 mg/1 max)
   5. Other conservative substances (metals, organics, minerals)
      a) Water quality screening performed if parameters of concern identified
      b) May result in additional WQ-based limits
      c) Depending on applicable criteria, limits may be based on mixing zone or complete mixing, receiving stream flow, maximum 30-day average or effluent flow
   6. pH: For effluent-dominated streams, more stringent limits of between 6.5-9 s.u. may be required
   7. Biomonitoring (major dischargers only)
      a) May require acute testing, chronic testing or both
      b) Specific testing based on effluent/receiving stream flow ratio
         (1) Effluent-dominated → Chronic testing only

(2) Large receiving stream, lake → Acute testing only
(3) Intermediate → Both chronic and acute testing

c) Acute testing uses fathead minnow and D. pulex, 48-hour LC50, 100% effluent
d) Chronic testings uses fathead minnow, C. dubia, 7-day NOEC, dilution series

C. Mass loading limits based on concentration limits, maximum 30-day average effluent flow

D. Best Management Practices Plan requirements may be include as necessary.

E. Surface impoundment requirements may include minimum freeboard, liner type, and other construction, maintenance and operational requirements

F. Land application requirements may include hydraulic and/or agronomic loading limits

IMPORTANT FACTS ABOUT OPERATOR CERTIFICATION[1]

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General Information

1. State law requires that all operators of community wastewater systems be certified within ten (10) days of employment or appointment as an operator.

2. An operator is a person who performs work on, or determines the method of working on, wastewater works, or who changes water quality either directly, or by order. This includes a person who sets or removes meters, makes service connections, or repairs lines.

3. A community wastewater system is a public system which has at least ten (10) service connections or treats 5000 gallons or more of wastewater per day.

4. "Wastewater works" means all facilities used in the collection, transmission, storage, pumping, treatment, or disposal of liquid or waterborne waste.

5. Owners of wastewater works must give their operators reasonable opportunity to obtain the necessary hours of training for their required certification upgrades and renewals.

6. Owners shall furnish the necessary equipment and materials for adequate maintenance and operation of the treatment plant, laboratory, and supporting facilities.

7. It is the responsibility of the operator as well as the employer to see that his or her certification is the proper certification according to operator certification regulations.

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[1]This Information is Subject to Change.

8. Operators who have limited certification such as, wastewater collection, lagoon systems are restricted to work in only that type of system that they hold a certification, except that those with lagoon system certification may also operate the collection system.

9. Possible penalties for violation of the Operator Certification Act are loss (or denial) of certification, a fine, and/or a jail term.

Level of Certification Required

10. Operators who are not supervisors or superintendents may hold any level of current certification. All operators are encouraged to obtain the highest level of certification for which they qualify.

11. The superintendent must hold at least the same level of certification as the classification level of the wastewater works that he or she is responsible for.

12. A superintendent is the operator who is in direct responsible charge of an entire plant or collection system. This is true even if other official titles are sometimes assigned by employers.

13. Determinations concerning classification of wastewater works will be made by the Operator Certification Unit based on *system complexity* and *population served.* Population categories are:

Class "D"	1,500 or less
Class "C"	1,500 - 15,00
Class "B"	15,000 - 50,000
Class "A"	50,000 or more

14. All discharging wastewater works must be operated by a superintendent with at least a class "C" certification regardless of population served.

15. Superintendents of class "C", "B", or "A" facilities are not eligible for temporary certification.

16. Persons who supervise superintendents are required to have a certification level equal to or higher than that required for the superintendent if they give commands which can affect the quality of the wastewater.

17. The assistant superintendent shall be certified at no less than one certification level below that required for the superintendent.

18. Employers may require their employees to hold a higher certification level than is required by state law.

Temporary Certification

19. If permanent certification is not already held, temporary certification must be applied for within ten days of employment or appointment as an operator. These applications are available from Local department of Environmental Quality (DEQ) offices, or from the DEQ Operator Certification Unit.

20. Individuals who have temporary certificates must work under the general supervision of a permanently certified operator. Direct constant supervision is not required.

21. Temporary certificates expire one year after the date of the applicant's initial employment as an operator and cannot be renewed.

22. After receiving temporary certification, the operator should immediately begin to make plans to attend an DEQ approved entry level standard training course and an exam session in order to obtain at least class "D" certification before the temporary certificate expires.

Laboratory Technician Certification

23. All discharging wastewater facilities must have a properly certified designated laboratory technician.

24. The designated lab technician for wastewater facilities is required to give general supervision of all laboratory tests performed and is held responsible for all test results.

25. Certified laboratory technicians are authorized to work in laboratories only. They are not certified to operate or make decisions concerning the operation of the plant.

26. Owners of wastewater facilities that contract for laboratory services must notify the Operator Certification Unit within ten (10) days of the contract and state the analyses to be performed. Also, the contracting laboratory must notify the Operator Certification Unit within ten (10) days of the contract and state what analyses are performed by them.

27. The results of all laboratory analyses shall be recorded in a bound volume at the time of analysis. Each entry in this volume shall be signed and dated by the person who performed the analysis. These volumes will be kept on

file at the laboratory for the required number of years (three years for wastewater systems).

Qualifications for Certification Exams

28. All levels of certification will require a written examination (except temporary certification). The maximum value for each exam shall be 100 points. An examine must make 70% or more to pass.

29. A completed Wastewater Works Operator Examination Application must be complete for each examination taken. Exam applications (with instructions) are available from County Department of Environmental Quality (DEQ) offices, or from the DEQ Operator Certification Unit.

30. Exam applications must be received by the Operator Certification Unit at least two (2) weeks before the exam is to be taken.

31. A fee of $40.00 is charged for each examination taken. Payment must be made by check or money order made payable to DEQ. Payment must be submitted with the Exam application.

32. Reciprocity may be granted when the requirements for certification held in another state are equal to requirements for the certification in Oklahoma.

33. The Class "D" operations exam requires sixteen (16) hours of approved training.

34. The Class "C" operations exam requires thirty-six (36) hours of approved training and one (1) year of experience.

35. The Class "B" operations exam requires one hundred (100 hours of approved training and three (3) years of experience. One (1) of the years must be actual hands-on operating experience.

36. The Class "A" operations exam requires two hundred (200) hours of approved training and eight (8) years of experience. Three (3) of the years must be actual hands-on operating experience.

37. The Class "C" laboratory technician exam requires thirty-two (32) hours of approved laboratory training.

38. The Class "B" laboratory technician exam requires Class "C" laboratory technician certification, sixty-four (64) hours of approved laboratory training and three (3) years

of experience. Two (2) of the years must be actual hands-on laboratory experience.

39. The Class "A" laboratory technician exam requires Class "B" laboratory technician certification, a Bachelor of science degree in chemistry, or twenty (20) semester hours in higher education credit in chemistry, microbiology, or instrumental analysis. Also, eight (8) years of experience with at least three (3) years actual hands-on laboratory experience.

Training and Experience

40. Training credit will be granted only for those courses or workshops which are approved by the Operator Certification Unit in advance in writing.

41. All certified operators will periodically receive issues of the DEQ Certified Operator Newsletter. This publication provides information of concern to operators including listings of most approved training classes.

42. Unless there is an emergency, each person attending an approved training class should attend the entire class as it was approved. For example, if an approved class is to meet for 16 hours, all persons desiring training credit for the class should attend all 16 hours.

43. All approved training hours are cumulative. Although DEQ keeps copies of training records, all operators are also required to keep personal records of all approved training received.

44. Experience credit may only be granted for legal experience. Legal experience in the wastewater field includes only the work performed as a properly certified operator, Laboratory technician, or registered helper.

45. Partial credit for experience not directly connected with wastewater works operation will be approved if the experience involves tasks similar to what required for operation of wastewater works. One year of related experience cannot court more than one-half year of experience.

46. Training classes which directly relate to wastewater works may be counted as one year of experience for each 180 classroom hours. Training classes which are not directly related may be counted as one year of experience for every 360 classroom hours.

47. Training hours used as a substitution for experience cannot also be used as training credit.

48. All experience credit requests for classes in higher education must be accompanied with an official transcript.

Annual Renewal of Certificates

49. All certificates expire on June 20 of each year and must be renewed by that date to remain current.

50. Operators are responsible for renewal of their certificates regardless of notification.

51. Before renewing a certificate, the operator must have completed at least four (4) hours of approved training within the last fiscal year (July 1-June 30).

52. Renewal applications/invoices are mailed to all certified operators during late spring of each year. The application must be completed and then submitted with payment of fees. Please do not submit the application until the training requirement has been met.

53. Renewal fees are $30 per certificate. An additional $10 late fee must be paid for each certificate renewed after July 31.

54. Expired (delinquent) certificates may be reinstated within two (2) years after the expiration date. After two years, the examination must be re-taken to become certified.

55. If the operator failed to attend the required approved training during the previous fiscal year, the first four hours of training taken after June 30 is counted only as "makeup" training (it cannot be applied to the training requirement for the current fiscal year).

56. Any State approved training an operator receives during the year can be counted towards the required renewal training of his or her certification.

PARTNERSHIPS IN MANURE AND MORTALITY MANAGEMENT INDUSTRY PERSPECTIVE

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MANURE MANAGEMENT

Manure has traditionally belonged to the grower with him using it as a valuable fertilizer for crop and forage production Over time, the buildup of phosphorus on some of our growers fields has caused some concern. The companies must have the independent growers to produce birds. The ownership of manure will stay with the grower; however, the companies will be working with the producers to develop alternate uses for litter. Partnerships will be developed between growers and/or companies and growers to furnish a consistence supply and quality of litter to alternate uses as they are developed.

MORTALITY MANAGEMENT

Normal mortality is being handled very well today through composting, incineration, freezing, and other approved methods. Each farm should develop a plan in case of a catastrophic loss.

NATIONAL POULTRY DIALOGUE

A detailed plan for poultry litter and mortality management has been developed by the National Poultry Dialogue.

EQUAL PARTNERS

Ina Young
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It is my pleasure to be a part of this symposium and I thank Dr. Reynnells for inviting me. I am particularly pleased to be included in this session discussing partnerships. Growers are often told that they are equal partners in their alliance with the poultry companies, but many growers do not think there is equal sharing of risks, resources or responsibilities.

Before you conclude that my remarks are intended to place blame entirely on the companies, let me assure you they are not. Contract poultry production has saved many small farms, and sent many children to college in this state and others. I believe food produced on contract has a place at the production agriculture table now and in the future.

However, we are faced with serious problems of how we will dispose of the by-products of this industry. It is foolish to think growers and companies can come together with solutions without first coming together in honest open communication as befits equal partners.

Before we get to some solutions to this problem of disposal, let us look for a moment to see how we might have put a system in placed that causes communication difficulties between a company and its suppliers.

I believe some of the problem is caused by America's long held romantic idea that farming should not be a very profitable way of life. A couple of years ago I listened to a Canadian speaking at a farm meeting ask, "Where is it written in United States law that a farmer must be poor?"

When we recently incorporated our farm we found that this has only been an accepted practice since the late eighties. That is when accountants were told by their trade organization that the IRS had lost every case they took to the courts of farmers wanting to be considered a for-profit business. The law was there and had not be changed; farmers just had not challenged it. That image we farmers have had of being different from other business people is changing.

Historically poultry company fieldmen (and they have been mostly men) and other company employees have not included growers in the decision making process, but dictated how the growers must manage their business. However, as our image of ourselves is changing, growers are asking that companies recognize that they also have a bottom line. That they recognize their demands for sophisticated equipment in state-of-the-art buildings causes very real concerns about finances.

Perhaps we should look at some causes of the environmental problem from a broader angle before we point fingers at who should do what or pay for what.

We are told consumer demand drives the market in today's economy; that we only produce what consumers want. It seems tome that this can be an artificial demand brought on by companies telling us over and over in the media what we should want.

Certainly consumer demand is not driving the poultry market very well as production is continuing to be expanded in the face of the current oversupply. Let me quote Jerome Foods President, Jerry Jerome, speaking about the turkey industry a few months ago. He said, "It's difficult to shed capacity...we don't want to burn down building; many of us have our lives invested in turkey production and we're good at turkey production. As long as there is infrastructure to increase production and there is marginal return, the industry will increase production."

When, as a grower, I cannot make ends meet on current pay I must expand and that expansion can cause environmental degradation. The same process drives smaller companies as they dash to get bigger so they will not be eaten up by a larger company, pouring more and more waste from their processing plants into our streams as they put on more shifts.

Merger mania is upon us as companies insist they must meet the competition. My reply to that theory is that when you own or control a major portion of the market you **are** the competition.

Even our government policies encourage farmers to grow for an export market that does not have the money to buy our product.

We have been told that corporations must have no goal except to make money, but people in many fields are beginning to question long held assumptions about the rights of corporations. We all need to realize there are social consequences to doing business. That includes the consumer enjoying his buffalo wings while he watches a ballgame.

I am happy to see this conference includes all the partners; poultry companies, growers, consumers, environmentalists, government agencies and universities. People who have no input into policies that affect them feel pushed to the wall and can become cynical and even violent. This can happen to growers,caught between their desires to be good stewards of the land and save their farms; or owners trying to keep a small company alive; or citizens wanting to preserve their land value and protect the environment.

Companies **could** demand that growers institute environmentally sound practices, and they will get compliance because growers operate on short-term contracts. Or growers **could** drag their feet and continue environmentally damaging practices,knowing that states may not be able to enforce laws. Or growers and companies **could** join together to affect environmental legislation.

I received several calls this past year from Oklahoma growers who were told by company employees that they could lose their farms if they did not help defeat environmental legislation in that state. That reminds me of a grower symposium held this past spring in this very place. A professor spent the better part of an hour telling us how we could lose our farms when the HACCP inspection system comes to the farm. During the question and answer session, a very distressed grower asked what the government and companies would demand of her. The reply was, "Well, it might not get too bad."

We are facing national legislation, which usually is a one-size-fits-all proposition, because we cannot regulate ourselves. Many states where poultry waste is a problem do not have enough non-rural voters to hold state legislators' feed to the fire. Here, in my home state, poultry companies have such clout that I have heard there will be dead bodies before Arkansas has major regulations.

Why would a grower want legislation? Because the cost of protecting the environment could fall directly on growers, and we do not even own these birds.

Now, how do we start to become partners in managing mortality and manure? What if we give up our adversarial positions and just fix the problems?

What is we expected consumers to pay a few cents more to protect the environment? Surveys show they are willing to do so. In 1996 less than 11% of our household disposable income went for food. Why do we need such cheap food? So I can buy every little trinket from China that they sell at Wal-Mart? So I can buy tennis shoes made by children?

I know that will bring comments about having to compete with other countries or worse. As National Broiler Council spokesman, Bill Roenigk, said, "There is nothing in the Constitution that says we have to produce in the United States for the U.S. market." Please remember the United States is large enough to set the world price. The United States is "Boss Hog" in the marketplace.

Let us say we get a few more pennies for our product. How would we spend them?

Concentration of many poultry houses in a small area, particularly sensitive watersheds, is a major problem. With a little larger return on its investment, a company would not need the economy of scale of a huge feed mill with its many satellite farms and large processing plants.

Poultry companies could pay the growers enough to take care of some of the problems at the farm level. Pay enough so growers make a decent return on their investment and do not have to keep building chicken houses. Grower's investment is now twice that of the companies, according to testimony by a company official at an Oklahoma hearing this year.

How about reformulating feed to be more environmentally friendly? It is not right to tell growers that the problem of too much phosphorus is theirs alone to solve and pay for.

There has been any number of ideas put forth the past few days about what to do with dead birds and litter so I do not need to enumerate them. In fact, I just read about most of them in the report of the 1992 waste management symposium, and I am not sure we have made much progress implementing them since then.

Let me read a sentence from that report. "Environmental goals may be met if farmers are provided appropriate educational opportunities, sufficient and realistic time frames to comply with standards, financial assistance in the form of low interest loans, or technical assistance."

I do not need another loan, no matter what the interest rate. Besides the building loan, we are still paying for a $14,000 rooster feeder mandated three years ago, the new fluorescent lights in one of our buildings mandated this year, and will borrow money next year to complete that mandated addition to our lighting system. This is in a lighting system where we recently replaced all the mercury vapor lights in one of our buildings and changed from incandescent to high-pressure sodium lighting in the other building.

Our goal should be to assure that we do not merely pay lip service to this idea of equal partnership in disposal of litter and birds and then drop the financial burden on the grower.

Let us talk a moment about sharing the responsibility with our other partners. I lost confidence in universities being partners with growers in anything a few years ago when we had several suicides and other signs of hopelessness among growers. A plan to study grower stress was started at the University of Arkansas and then canceled. It seems to me that encouraging professors to be consultants to companies is unfair to growers.

What can our government partner do to help manage mortality and manure? I have certainly done my share of griping about a government which funds university research on another piece of equipment that the companies make growers purchase.

If the USDA supports programs for industrial agriculture and tosses a bone to small farming, then throws up its arms and says "may the best man win", guess who wins?

The present situation with the Miler and Harkin bills seems to pit the USDA and the EPA against each other in the area of enforcement. The better path to follow, it seems to me, is that of putting emphasis on encouragement of environmentally friendly policies not enforcement.

We growers used to joke about the birds belonging to the companies until they died and then they were ours. We kept hoping they could find a profitable use for them. On our farm we have used pits, an incinerator and now a freezer provided by Tyson. The dead birds accumulate in the freezer and then are hauled 20 miles to Tyson's animal by-products plant. This system works well unless we have a major bird loss. We produce hatching eggs so we deal with much larger birds than broiler growers do.

A few years ago we lost 750 hens one hot day. We had to hire a backhoe to bury the birds on our farm because the plant would not take them. During this past summer's intense heat wave, we lost 400 hens one day, and another day we lost 1,000 hens. We feel fortunate that Tyson has changed their policy and allowed us to take the dead birds to the by-products plant.

One strategy that comes to mind is tax breaks for companies to provide freezers for dead birds. Our government could continue providing research grants for uses for by-products and tax breaks for companies to build by-product plants.

Again, see contract agriculture as one of the ways to save small farms and the environment, but risks, responsibilities and resources must be shared. Just as farmers had to have a different image of themselves before they were able to incorporate as businesses, we have to step outside the Limited thinking that keeps us continuing to see poultry waste and mortality management as disconnected problems that can be solved separately.

Waste disposal affects and is affected by the global economy as well as many social issues. All of those involved need to be really heard, not just listened to. We are running short of time to solve these problems. There is simply no place among equal partners for less than the best we **ALL** have to offer.

DETERMINING PARTNERSHIPS IN MANURE AND MORTALITY MANAGEMENT-UNIVERSITY FOCUS

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Universities are suited for research and education activities, which compliment each other. A research base is needed for development of good education programs normally through Extension.

Poultry manure/litter has been used very successfully over the years as fertility sources in plant production systems. However, many have applied plant needs based on nitrogen (N) and not a limiting element such as phosphorus (P). Positive environmental and economic returns can be attained when farmers use poultry manure/litter as a crop nutrient source in conjunction with commercial fertilizers. The key to effective nutrient management is a knowledge of crop needs; soil fertility; fertilizer content of the nutrient source; and the application equipment. Many states are looking at nitrogen and phosphorus as limiting nutrients for nutrient management plans. Which nutrient will become the limiting nutrient will vary from region to region across the United States.

In 1998 Maryland passed legislation mandating nutrient management planning for commercial fertilizer, sludges and manures. The time frame for plan implementations are:

- Commercial Fertilizer N & P Based . December 31, 2002
- Sludges and Manures N Based . . . . December 31, 2002
- Sludges and Manures N & P Based . . . . . July 1, 2005

The legislation authorized cost share monies to re-distribute twenty percent (20%) of the broiler litter produced in the four Lower Eastern Shore Countries. This re-distribution is a voluntary four year pilot project with shared cost between the poultry industry and the State of Maryland. The Maryland

Department of Agriculture has the responsibility for implementation.

RESEARCH OPPORTUNITIES

There is an imbalance between N & P utilization in most cases where poultry litter is used for crop production. For example, in corn production, to satisfy the N requirement from poultry litter the application of P may be 3 to 4 times that needed. Over time P will increase in the soil and may cause environmental problems such as surface and ground water pollution with yearly or bi-yearly litter application. With the potential imbalance between N & P, there are research opportunities to address the nutrient issues. Some of the research opportunities are as follows:

Dietary Management for Poultry Waste Stream Reduction to include utilization of direct-fed enzymes, precision nutrition, and genetic alteration of feed ingredients and animals consuming the ingredients.

Mass Balance of Nutrients to include input nutrients verses output nutrients from an animal; evaluating animal units based on live weight verses evaluation based on the nutrient output of animals as affected by age, diet, and other factors; and genetic alteration of the animals and feedstuffs to better use the nutrients.

Water Quality degradation has a source(s). There are times a source is blamed for the degradation when it should be sources from a holistic approach. To assist in determining sources, quick DNA finger printing techniques need to be developed. Total maximum daily loading (TMDL) techniques need further research as well as the impact of litter additives on nutrient control. Research is need on runoff and ground water quality from stockpiled litter and other sources.

Re-distribution of Nutrients to include nutrient separation, composting, raw verses processed litter, effect of litter storage, threshold P values for nutrient plans, and marketing.

Public Health to include use of pharmaceuticals, airborne particulates, microorganisms, odor, and insect issues.

Combustion to include on and off the farm uses of the energy in poultry litter to supply supplemental energy for heating and electrical power.

CONCLUSION

Research opportunities presented will assist in dealing with N and P issues for nutrient management plans. Education programs can be developed to assist with the process of environmental protection based on research results.

DETERMINING PARTNERSHIPS IN MANURE AND MORTALITY MANAGEMENT

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There are two (2) major national initiatives that are under development that will impact how management of manure and dead birds will be addressed in the future. Each of these efforts recognize traditional partners but inherent in the need to sustain the poultry industry, additional partners that effectively coordinate and integrate both technical and financial resources, will help provide the needed environment for sustainability.

The National Poultry and Egg Environmental Dialogue is an industry-led approach to deal with the nutrient and other environmental problems associated with poultry production. It is led by the National Broiler Council and includes representatives from the broiler, turkey and egg industry,a nd stakeholder participation from the Farm Bureau, and state and federal agricultural, environmental and conservation agencies. One of the nine (9) work groups that comprise the Dialogue is the Manure/ By Product Management Work Group chaired by Dave Staples from United Egg Producers.

The second initiative being the Unified Animal Feeding Operation Strategy jointly developed by the USEPA and USDA also recognized that the proper disposal on manure and dead birds promotes a safer environment and helps to improve public health.

Another important area that has shown leadership comes from state legislative efforts. Several states, because of particular water quality incidents, general public sentiment, and the shear magnitude of poultry operations in certain geographic areas, have challenged the industry to design a reasonable pollution prevention program while recognizing growth for the industry.

Experts for the session will address the complex management issues associated with manure and dead bird disposal. An array of technical solutions are available. Developing comprehensive nutrient management plans should include components that ease the burden for the integrator/grower relationship.

Having the needed finances to support the expertise is currently an unresolved issue. Comprehensive nutrient management plans need to be developed or updated that include phosphorus requirements, transportation infrastructure needs to be fully evaluated, and effectively managing the residual products of poultry production as a valuable resource are at the heart of the issue.

Some financial support will be available, as in the past, from state and federal conservation cost sharing programs. Additionally, EPA through its Clean Water Revolving Grant/Loan Fund will be strongly encouraged to be used by landowners and farmers to assist with constructing management practices. Tax incentives that provide relief for environmental stewardship also helps and needs to expanded.

Yet with these sources of financial support, additional funds are needed to, in a timely fashion and to promote corporate responsibility, industry needs to also step up and implement a national program that helps the poultry industry sustain economic growth while recognizing that environmental stewardship is not just a secondary player but an equal part of sustainability.

POSTER PRESENTATIONS

NUTRIENT MANAGEMENT EDUCATIONAL MATERIAL AND WORKSHOPS FOR NORTH CAROLINA POULTRY PRODUCERS

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Revised regulations concerning land application of animal manure were put into effect in North Carolina during the 1990's. The revised regulations separated manure management systems into wet and dry systems with mandatory education for those operating wet manure systems. The state's poultry industry realized the need for a comprehensive educational program for the state's poultry growers and collaboratively worked with Cooperative Extension Service and other state agency personnel to conduct a voluntary educational program that will enable poultry growers across the state to comply with new non-point source regulations. In contrast to the mandated educational program for the wet systems which was funded by the state; educational materials for the voluntary dry poultry litter program were funded by the state's poultry companies, the North Carolina Poultry Federation and Farm Credit Associations.

This paper will discuss the revised regulations, how the specific educational needs were identified, organizing and conducting the program, measuring the success of the program and future programs that are underway to assure that the state's poultry industry will successfully remain environmentally friendly.

REVISED ENVIRONMENTAL REGULATIONS

0200 Revised Guidelines

After hearings throughout North Carolina, revised 0200 non point source guidelines were put into effect in 1993. These guidelines separated wet systems (mainly lagoon waste management systems) from dry systems (mainly broiler and turkey litter) and set up criteria for each type system. Under the 0200 guidelines, operators of wet systems had to attend mandatory training and had to have their nutrient management plans certified. The dry systems were to quantify the litter removed from their poultry facilities, document how the litter was utilized and verify that when litter was land applied it was applied at "agronomic nitrogen rates". In addition, litter was not to be land applied within 25 feet of a perennial stream.

Senate Bill 1217

In June of 1996 further regulations known as Senate Bill 1217 (S.B.1217) were ratified. This legislation, while continuing specific compliance procedure for dry poultry litter, added compliance stipulations including mandatory soil testing, litter testing, liming, stockpiling setback and monitoring of phosphorus, copper and zinc levels in the soil. In addition, more detailed record keeping is required that verifies agronomic application rates. Part of the record keeping will be a nutrient management plan for all land application of poultry litter which should be kept on the farm, but does not have to be certified.

ORGANIZING THE EDUCATIONAL PROGRAM

Program Need Identification

As soon as S.B. 1217 was ratified, communication began among extension and industry personnel about the need for an educational program that would give poultry growers the information they needed to comply with the newest environmental regulations. A need for a comprehensive educational program was evident and in October 1997 the N.C. Poultry Federation was approached to obtain their input into if and how the educational effort should proceed. The Poultry Federation endorsed the concept of a statewide workshop for poultry growers and company personnel. Board members suggested that each poultry company in the state be contacted to see if they would financially support the educational materials for the poultry farmers with whom they contract production and work collaboratively to set up workshop sites.

There was support from almost all the poultry companies for the in-depth workshop concept. Communication with grower committees of the N.C. Poultry Federation and N.C. Farm Bureau indicated that they also were supportive of the educational effort.

Organizing the Workshop Program

A steering committee made up of Extension Specialists from the Departments of Poultry Science, Soil Science, Biological and Agriculture Engineering, and Area Poultry Agents, and County Extension Agents was organized. The steering committee decided on subject matter that needed to be included in the workshop. It was decided that the nucleus of the material should be based on the material that was being developed by the Interagency Committee that was charged by the state Senate to interpret how the stipulations in the bill should be applied in the field. The steering committee also decided to begin the program with "train the trainer" sessions for Extension Agents, NRCS Technicians, N.C. Department of Agriculture personnel, and Poultry Company personnel to not only educate these individuals but also to identify a pool of instructors that would be willing to teach the workshops that would be held later for contract growers.

The Interagency Committee released a draft of their work addressing poultry nutrient management in late December of 1996. An *ad hoc* industry committee made up of company personnel, commercial operators, and poultry farmers met with the Interagency Committee in April 1997 to request changes in the guidelines that would facilitate good nutrient management. The Interagency Committee revised the guidelines and published them in May of 1997.

Developing the Educational Materials for the Workshop

A team of campus based Cooperative Extension Service specialists and locally based agents developed educational materials in a notebook format. The notebook was designed to not only contain information needed for the instruction of a four hour workshop, but also to be used as a reference and as a place to organize necessary records. An initial notebook printing was published for the "train the trainer" sessions and then revised for the poultry farmers workshop using the comments from the training workshops.

The notebook was organized into the following sections: Summary of Regulations, Soil and Litter Sampling, Nutrient Management, Agencies and Assistance, and an Appendix which contained additional Best Management Practices (BMP's). The Nutrient Management section which contained the information and record forms to do a nutrient management plan contained the following material: a check list of what should be included in a nutrient management plan, a farm information sheet, a work sheet to determine quantity of litter being generated, a crop nutrient requirement table, nitrogen fertilization guideline, a table of state wide average nutrient content of litter for different types of poultry, litter removal and field application record forms.

Several sets of visuals(slides, overheads and a case study) were developed for use by instructors to conduct the workshops

Conducting the Educational Workshops

Four "train the trainer" workshops were conducted in June and July of 1997 by NCSU Extension Specialists in Biological Agricultural Engineering, Poultry Science, and Soil Science. The 216 County Extension Agents, NRCS Technicians, Poultry Company Personnel, Private Consultants and other participants who took the training course were asked to critique the training. Those comments were utilized to revise the notebook for grower workshops.

The revised notebooks were printed in September and October, 1997 and workshops were conducted with the poultry companies arranging for the meeting site and trained instructors teaching the workshop. Meeting times and other logistics which enabled growers to attend workshops were mutually agreed upon. Companies provided meals and/or refreshments for the growers to encourage attendance. Instructors often worked in teams so that one person did not have to teach the entire four hour workshop.

Measuring Impact of Workshops

One hundred twenty five workshops were conducted across the state from late October 1997 until June 1998. Thirty instructors were involved in the teaching the workshops. The 2,910 growers who completed the workshop represented 123 million bird capacity on their farms. The state's poultry companies, N.C. Poultry Federation, Farm Credit Associations provided financial support of over $23,000 for the notebooks and other workshop educational materials. Pre- and post-quizzes were given to the workshop participants to document the learning that took place during the workshop. Workshop participants scored higher on the post quiz for all quiz questions indicating a good learning experience. Figures 1, 2 and 3 show the pre- and post-scores of three quiz questions. Perhaps the strongest area of learning was in the nutrient management area. Only 30% of the participants thought they knew how to determine agronomic rates of litter application in the pre-quiz while 83% answered yes to the question in the post-quiz (Figure 2).

Future Programming

Over 50% of the poultry litter is cleaned out of N.C. poultry houses by Commercial Operators. A training program is currently being conducted for those individuals who provide an important clean out and field application service for poultry producers and crop farmers. With a goal of having all nutrient management plans completed by 1/1/2000 work continues with individual assistance to poultry producers.

Fig.1 Pre and Post Quiz

Question:

- Poultry Producers generating dry litter must comply with what regulations and who can write your nutrient management plans? Possible 3 correct (+) answers

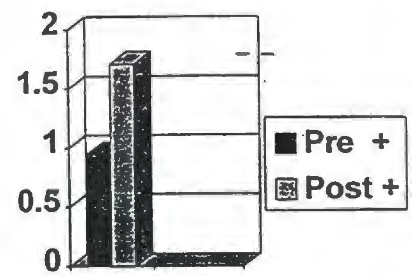


Fig. 2 Pre and Post Quiz

Question:

- Do you currently know how to determine agronomic rates of poultry litter to apply to different crops , Yes or No ?

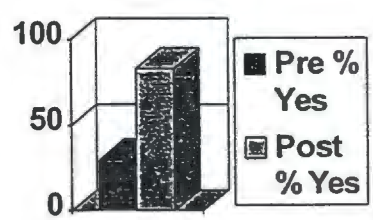
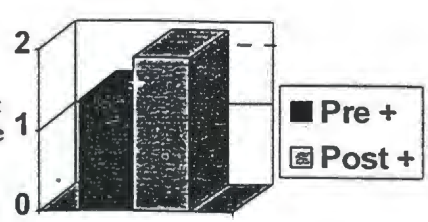


Fig. 3 Pre and Post Quiz

Question:

- Where can you find assistance with your nutrient management plan.? Possible 3 correct (+) answers.



A COST COMPARISON OF COMPOSTING AND INCINERATION AS METHODS FOR MORTALITY DISPOSAL

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All poultry production operations have to determine how they will deal with the issue of disposal of mortality which is inherent in an operation. There are numerous methods used to dispose of the mortality and the method selected should be based upon the situation of each particular farm and by restrictions placed upon them by regulatory agencies. Generally, these restrictions are based upon the method's impact upon disease control, air, and water quality.

The most common methods of disposal are burial (several different variations), rendering, composting, and incineration. Additionally, there are carcass preservation processes utilized on the farm to store for rendering later, but these methods are used little because of the investment in labor and equipment. Currently, these methods include fermentation, refrigeration, and acid preservation. Extrusion is another method being investigated that transforms the carcass to a value-added feedstuff but, due to economics, is currently used by very little.

Composting is a recent procedure developed for the disposal of poultry mortality. The method uses naturally occurring microorganisms (Bacteria and fungi) to convert mortality and litter into a product which can be used as a soil amendment on the farm. It is important to note that the final composition of the compost can be highly variable depending upon the management of the process. Incineration is a biologically safe method since it reduces the carcasses to ash using very high temperatures. Additionally, there is no threat to water quality, is safe from the threat of spreading disease, and will not promote problems with insects or vermin. There may be some concern for air quality if the incinerators are not properly designed or if they are improperly managed.

The criteria a person must use to determine the most suitable disposal method needs to include the economics of each method, the reliability of the procedure, the degree of biosecurity and method offers, and how the method will fit into one's particular operation. The cost of labor, the availability of needed equipment and the amount of mortality which needs to be disposed of all have to be considered in the disposal assessment. The pattern of mortality is also important. Carcass mass is rather consistent in a breeder or layer operation but a growout operation will have increasing volumes as body size increases with age. Catastrophic losses can create havoc with any disposal method and alternative procedures should be in place in case of a severe disease outbreak or a management problem such as ventilation failure which may cause high losses. When evaluating the disposal methods, one should examine carefully the most recent information available. Technology has been changing rapidly and sound management decisions should not be made from inappropriate or outdated information data.

OBJECTIVE

To determine the cost of disposing of poultry mortality on typical broiler, broiler breeder, and commercial layer farm using incineration and composting. Most information to date on the efficiency of incineration is based upon the older styles of incinerators and not the newer designs. The newer designs utilize an improved single burner in combination with a redesigned fire box which enhances combustion. Composting of mortality was developed as an alternative to disposal pits because of the concern with potential of ground water contamination in areas of high water tables. Composting requires the monitoring of the compost temperature as an indicator of the microbial activity within the bin. The compost bin must be aerated by physically turning the compost material when the compost temperature declines, introducing oxygen which initiates another heat cycle. Previous work by the authors with forced aeration of the compost bin demonstrated that mechanical turning of the compost is essential for proper composting. Apparently, the mechanical turning helps to mix the compost material and eliminates micro environments established in the bins. This makes having a front-end loader essential for operation of a composter. The composting carcasses need to go through three heat cycles to insure complete decomposition and destruction of potential pathogens.

MATERIALS AND METHODS

The incineration efficiency studies used carcasses from 3 week-old broilers, 7 week-old broilers, 65 week-old broiler breeders, 72 week-old commercial layers, and 18 week-old turkey toms. A new style incinerator[1] was used having a capacity of 250 pounds for the smaller carcasses and 200 pounds for the larger carcasses. Five loads for each class of birds were conducted. There were no differences noted in fuel efficiency between the first burn and subsequent burns. The results are calculated on a carcass mass of at least 1000 pounds. It was evident from the data gathered that carcass fat supplemented as a fuel which increased the efficiency of the incinerator and subsequently reduced incineration cost. the broilers which were incinerated when 3 weeks-old, had little or no carcass fat, while the 7 week-old broilers, the broiler breeders, commercial layers, and turkeys had substantial body fat. The labor inputs required to properly mange the composer and incinerator were recorded. A comparison of the newer style incinerator[1] with the older two-burner incinerators[2] was also conducted with 3 week-old broilers and 72 week-old commercial layers. Results are recorded in Table 1.

Calculation for determination of cost of mortality disposal required the use of certain assumptions. These assumptions are explained as follows.

Incineration and composting were compared as mortality disposal methods in this study for three types of poultry (broilers, broiler breeders, and commercial layers). It is inappropriate to use the same cost efficiencies of a particular method for all types of poultry as different body compositions exist. The cost analysis is based upon data collected for each poultry type with regards to fuel consumption, composter capacities needed, and labor evaluations. Additional assumptions were made with regards to the amount of mortality and some fixed and variable costs that are specific for a farm. It is imperative that a front-end loader be used to turn the compost bin at the appropriate time to insure proper composting. Labor criteria will not include the cost of gathering carcasses but rather the cost of moving them from the house and disposing by the indicated method. Composting trials were conducted concurrently with the incineration trials to assess the labor costs to properly compost carcasses. The size of the incinerator purchased and composter built is varied to best suit a farm based upon the type of poultry and the mortality expected.

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[1]New design incinerator used in the trials was a Shenandoah A-10.

[2]Older design incinerator used in the trials was the two burner Shenandoah A-4.

Commercial Layers

Assumptions will be to use a 100,000 hen production unit and an expected death rate of 0.5% per month. An average weight of 3.75 pounds will result in approximately 62 pounds per day or 22,500 pounds per year. The assumption for incineration uses a Shenandoah A-6 Incinerator (200 pounds capacity), and assuming fuel usage of 31.1 pounds of commercial layer carcass mass per gallon of propane which was arrived at through the work outlined above of Wineland *et al.* (1995). An inexpensive shed with only a roof needs to be constructed to protect the incinerator from the weather and prolong the life expectancy. Labor is calculated at 20 minutes per day to load and clean the incinerator. The assumptions for composting used a composter having a bin capacity (primary and secondary) as per Composting Poultry Mortality. Poultry Science and Technology Guide No. 47, North Carolina Cooperative Extension Service. Costs of the composting facility are from current costs utilized by industry constructed composters. Labor is assumed to be 30 minutes daily with an additional 3/4 hour to turn the compost bin and 1½ hours to empty and spread the compost material on a field. The cost of a front-end loader will be charge at the rate of $20/hour with an average use of 1½ hours per week including turning use. The litter used in the composter is charged a value of $200 a year as litter is not available in a commercial layer operation and sawdust will need to be purchased.

Broiler Breeders

The assumptions will be to use a 10,000 breeder facility with an average mortality for the hens of 0.35%/week and 1.5%/week for males. This results in approximately 32 hens/week (8 lbs.) and 15 males/week (11.5 lb.) for a total of 434 pounds of carcass mass (62 pounds per day) per week for 45 weeks (315 days) during the year (19,530 pounds). The assumptions for incineration utilize a Shenandoah A-6 Incinerator (200 pounds capacity), assuming fuel usage of 28 pounds of broiler breeder carcass mass per gallon of propane (Table 1). In inexpensive shed with roof only is constructed to protect the incinerator from the weather and prolong the life expectancy. Labor is assumed to be 20 minutes daily to load and clean out the incinerator. The assumptions for composting used a composter having a bin capacity (primary and secondary) per Composting Poultry Mortality. Poultry Science and Technology guide No. 47, North Carolina Cooperative Extension Service constructed at costs current in industry. Labor is assumed to be 30 minutes daily with an additional 3/4 hour to turn the compost bin and 1½ hours to empty and spread the compost material on a field. The cost of a front-end loader will be charged at the rate of $20/hour with an average use of 1¼ hour per week.

The litter used in the composter is not assigned a value as it will be negated by the value of the compost material.

Broilers

The assumptions will be to use a broiler farm having a capacity of 100,000 broilers, raised to 7 weeks of age and having six flocks per year. A broiler operation with a capacity of 100,000 may demonstrate a mortality profile such as calculated in Table 2.

It is apparent that with increasing bird age, disposal becomes more time consuming. Because of the variability in a grow out operation, disposal method must be adequate to handle the maximum mortality. The assumptions for incinerators used a Shenandoah A-15 Incinerator (500 pounds capacity), fuel usage is assumed to be 15.4 pounds of broiler carcass per gallon of propane through 4 weeks of age and 25.1 pounds of carcass per gallon of propane from 5 through 7 weeks of age. This assumption is based upon the data above produced by Wineland *et al.* (1995). An inexpensive shed with roof only is constructed to protect the incinerator from the weather and prolong the life expectancy. Labor for incineration will vary also with age of flock. It is assumed that the daily labor input will be 10, 20, 25, 30, 30, 45, and 75 minutes for weeks 1 through 7, respectively. The last week will require multiple loading of the incinerator. The assumptions for composting are to use a composter having a bin capacity (primary and secondary) as per Composting Poultry Mortality. Poultry Science and Technology Guide No. 47, North Carolina Cooperative Extension Service constructed at costs current in industry. Labor is assumed to be 20, 25, 30, 35, 40, 55, and 75 minutes daily for weeks 1 through 7, respectively. An additional 3/4 hour to turn the compost bin and 1½ hour to empty and spread the compost material on a field is assumed for each bin. The cost of a front-end loader will be charged at the rate of $20/hour with an average use of 1¼ hours per week. The litter used in the composter is not assigned a value as it will be negated by the value of the compost material.

RESULTS AND DISCUSSION

The estimated annual cost for commercial layers is shown in Table 3. Estimated cost of composting is $507 more or 29% greater than incineration using the assumptions outlined.

The estimated annual cost for broiler breeders is shown in Table 4. Estimated cost of composting is $364 more or 22% greater than incineration using the assumptions outlined.

The estimated annual cost for broilers is shown in Table 5. Estimated cost of composting is $90 more or 2% greater than incineration using the assumptions outlined.

the results of this study indicate that incineration of poultry mortality can be a viable alternative for an operation. It is true that a case could be made to alter the assumptions made in our study for either incineration or composting, but the assumptions were made based upon actual costs experienced in a poultry operations. The actual decision as to which method is best for a particular farm should be based upon the individual circumstances on each farm and the restrictions they must adhere to. One of the first steps in developing information from which to make an informed decision is to develop a budget similar to the ones presented, using a producer's own cost information.

Table 1. Efficiency of the Different Designs of Incinerations.

Species	Newer Design Incinerator Pounds of Carcass/Gallon Propane	Older Design Incinerator Pounds of Carcass/Gallon Propane
3 week old broiler	15.4	9.9
7 week old broiler	25.1	N/A
Broiler Breeder	28.0	N/A
Commercial Layer	31.1	11.1
Turkey	27.7	N/A

Table 2. Profile of Broiler Mortality.

Age (weeks)	1	2	3	4	5	6	7
Total Mortality	0.972%	0.628%	0.484%	0.46%	0.476%	0.58%	0.904%
Carcass Mass (lb)	332	532	744	1092	1584	2536	4876

Table 3. Estimated Annual Cost of Incineration and Composting of Commercial Layers.

	Incinerator		Composting
Capital Investment			
Incinerator cost (Shenandoah A-6	$2000		---
Shed and base slab cost or composter	$ 500		$1250
Water service	---		$ 150
Total	$2500		$1400
Annual Fixed Costs			
Building and/or incinerator (10 year life expectancy)	$ 250		$ 140
Interest on investment (10% interest rate, one-half of investment at 10%)	$ 125		$ 70
Maintenance and repair	$ 50		$ 80
Insurance (0.5% of investment)	$ 13		$ 7
Annual Variable Costs			
Fuel 724 gallons @ .70/gal	$ 507		---
Electricity	$ 55		---
Labor (20 min a day @ $6/hr - 365 days)	$ 730	(215 hr @ $6/hr)	$1290
Machinery	---	(32.5 hr @ $20/hr)	$ 650
Total	$1730		$2237

Table 4. Estimated Annual Cost of Incineration and Composting of Broiler Breeders.

	Incinerator		Composting
Capital Investment			
Incinerator cost (Shenandoah A-6	$2000.00		---
Shed and base slab cost or composter	$ 500.00		$1250.00
Water service	---		$ 150.00
Total	$2500.00		$1400.00
Annual Fixed Costs			
Building and/or incinerator (10 year life expectancy)	$ 250.00		$ 140.00
Interest on investment (10% interest rate, one-half of investment at 10%)	$ 125.00		$ 70.00
Maintenance and repair	$ 50.00		$ 80.00
Insurance (0.5% of investment)	$ 13.00		$ 7.00
Annual Variable Costs			
Fuel 698 gallons @ .70/gal	$ 489.00		---
Electricity	$ 55.00		---
Labor (20 min a day @ $6/hr - 315 days)	$ 630.00	(185.75 hr @ $6/hr)	$1114.50
Machinery	---	(28.25 hr @ $20/hr)	$ 565.00
Total	$1612.00		$2976.50

Table 5. Estimated Annual Cost of Incineration and Composting of Broiler.

	Incinerator		Composting
Capital Investment			
Incinerator cost (Shenandoah A-6	$3000.00		---
Shed and base slab cost or composter	$ 500.00		$3600.00
Water service	---		$ 150.00
Total	$3500.00		$3750.00
Annual Fixed Costs			
Building and/or incinerator (10 year life expectancy)	$ 350.00		$ 140.00
Interest on investment (10% interest rate, one-half of investment at 10%)	$ 175.00		$ 70.00
Maintenance and repair	$ 55.00		$ 80.00
Insurance (0.5% of investment)	$ 17.50		$ 7.00
Annual Variable Costs			
Fuel 3202 gallons @ .70/gal	$2241.00		---
Electricity	$ 175.00		---
Labor (27.5 hrs per flock @ $6/hr for 6 flocks/yr)	$ 990.00	(277 hr @ $6/hr)	$1662.50
Machinery	---	(51 hr @ $20/hr)	$1620.00
Total	$4003.50		$4093.50

EFFECT OF ALUM-TREATED POULTRY LITTER, NORMAL LITTER AND AMMONIUM NITRATE ON ALUMINUM AVAILABILITY AND UPTAKE BY PLANTS

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Aluminum (Al) is one of the most abundant elements on the earth's surface. The Al content varies in soils from about 1 to 30%, with an average of about 7% for soils in the U.S. (Lindsay, 1979). Hence, in an acre furrow slice of soil (top 6"), the average soil contains about 140,000 pounds of Al per acre. Most of this Al is unavailable to plants, since it is bound in mineral forms. Aluminum solubility in soils is regulated by soil pH (Lindsay, 1979). Normally the mineral governing Al solubility is an aluminum hydroxide compound like gibbsite or a similar mineral (Lindsay *et al.*, 1959; Richburg and Adams, 1970). As pH decreases, these compounds are solubilized and release Al^{3+}, which is held by negatively charged clay minerals. The total amount of Al in soils does not affect Al availability (Al uptake by plants, exchangeble Al in soils or Al in runoff water), since almost all Al in soils is in a mineral form, it is the soluble Al that controls Al availability and, as mentioned before, Al solubility is regulated by soil pH.

Poultry producers throughout the country have begun using aluminum sulfate (alum) to improve poultry production and reduce the negative effects of litter on the environment. Research has shown that alum applications to poultry litter control ammonia volatilization and reduce phosphorus runoff from land fertilized with litter (Moore *et al.*, 1995; Moore *et al.*, 1996; Moore *et al.*, 1997; Shreve *et al.*, 1995). Since alum-treated litter does contain additional Al, concerns have been expressed that this Al will be more available than Al already present in soils. The objectives of this research were to determine the effects of alum-treated litter, normal litter and ammonium nitrate on Al uptake by plants, Al runoff, and Al availability in soils.

MATERIALS AND METHODS

This study was initiated in 1995 using 52 small plots (1.52 x 3.05 m) located at the University of Arkansas on a Captina silt loam soil, which had been in continuous tall fescue for two years. There were a total of 13 treatments; four rates of alum-treated poultry litter, four rates of normal poultry litter, four rates of ammonium nitrate, and one control. Litter application rates were 2.24, 4.49, 6.73, and 8.98 Mg ha^{-1} (1, 2, 3, and 4 tons $acre^{-1}$). Ammonium nitrate application rates were 65, 130, 195, and 260 kg N ha^{-1}. There were four replications per treatment in a randomized block design. The poultry litter utilized for this study was obtained from six commercial broiler houses located in NW Arkansas. These houses have been part of a study on the effects of alum on ammonia volatilization and poultry production. In 1995, rainfall simulators were used to provide 5 cm per hour precipitation events immediately after litter application and 7 days later. Rainfall was simulated for a sufficient duration to allow 30 minutes of continuous runoff from each plot. Runoff samples were collected during each event at 2.5, 7.5, 12.5, 17.5, 22.5 and 27.5 min after continuous runoff was observed. Runoff samples were collected in 1-L plastic containers. The six water samples from each plot were composited into one sample, based on runoff volumes on a flow-weighted basis. A portion of each runoff water sample was filtered through a 0.45-um membrane, acidified to pH 2 with concentrated HCl and frozen for soluble metal analysis. Metals (Al, As, B, Ca, Cd, Co, Cr, Cu, Fe, K, Mg, Mo, Mn, Na, Pb, Ni, Se, Ti, and Zn) were determined using a Spectro Model D ICP. Fescue was harvested from a $1m^2$ area, when needed, by cutting to a height of 10 cm with a bagger-mower. After the samples were weighed, a sub-sample was taken for moisture content and metal analyses. Metal analyses were conducted on a ICP after digestion with nitric acid and hydrogen peroxide. Soil pH and exchangeable Al were measured after three years of annual applications.

RESULTS AND DISCUSSION

Soil pH

One of the concerns that has been expressed over the use of alum in litter is that it will result in soil acidification. Soil pH data from the three fertilizer types is shown in Figure 1A. These data indicate that the pH of soils fertilized with alum-treated litter is slightly higher than the control (unfertilized) soils. The pH of plots fertilized with normal litter were the highest, as would be expected, because alum-treated and normal poultry litter both contain sufficient buffering materials (carbonates) to counteract the acidity formed during nitrification. However, since ammonium nitrate is unbuffered, it has a net acidifying effect on the soil. This is not new information. Soil fertility textbooks have long recognized that the use of ammoniacal fertilizers, such ammonium nitrate, acidify the soil, making lime a necessity (Tisdale *et al.*, 1985).

Soil Aluminum

Exchangeable Al in soil is shown in Figure 1B. Exchangeable Al was highest in the plots fertilized with ammonium nitrate, as would be expected due to the lower pH caused by this fertilizer. Exchangeable Al was almost identical in the plots fertilized with normal and alum-treated litter, indicating the alum had no effect on available Al in the soil.

Alum-treated litter, like normal litter, contains only trace quantities of soluble Al. The Al is precipitated either as $Al(OH)_3$ (aluminum hydroxide) or $AlPO_4$ (aluminum phosphate); both of which are very insoluble minerals. Alum-treated litter applications will, over the long term (hundreds of years) gradually increase total soil Al levels; however, this should not affect Al availability since the Al will not be soluble. The total amount of Al in soil has no direct relationship to the amount of Al that is soluble or bioavailable. Rather it is chemistry (pH, redox potential, ionic strength, microbial activity, and presence or absence of other minerals) that determines availability. Because ammonium nitrate applications result in the lowest pH (Figure 1A), then this treatment would have the greatest potential to result in high levels of Al in plants.

Plant Aluminum

Plant Al concentrations are shown in Figures 2A, 2B, and 2C. Aluminum levels in the plants were generally in the 50-100 mg Al/kg range. There were no significant differences due to fertilizer type on Al levels in the plants. Although the type of fertilizer used had no significant effect on Al levels in the plants, the highest Al values observed were found in plants fertilized with ammonium nitrate. This is expected since the soil pH was the lowest and exchangeable Al highest for these plots.

Aluminum Runoff

Aluminum concentrations in runoff from control plots was 0.129 and 0.136 mg Al L^{-1} for the first and second runoff event, respectively (Fig. 3A and 3B). Aluminum concentrations increased as litter application rates increased and tended to be higher in runoff from untreated litter, although the effects of litter application rate and litter type were not as

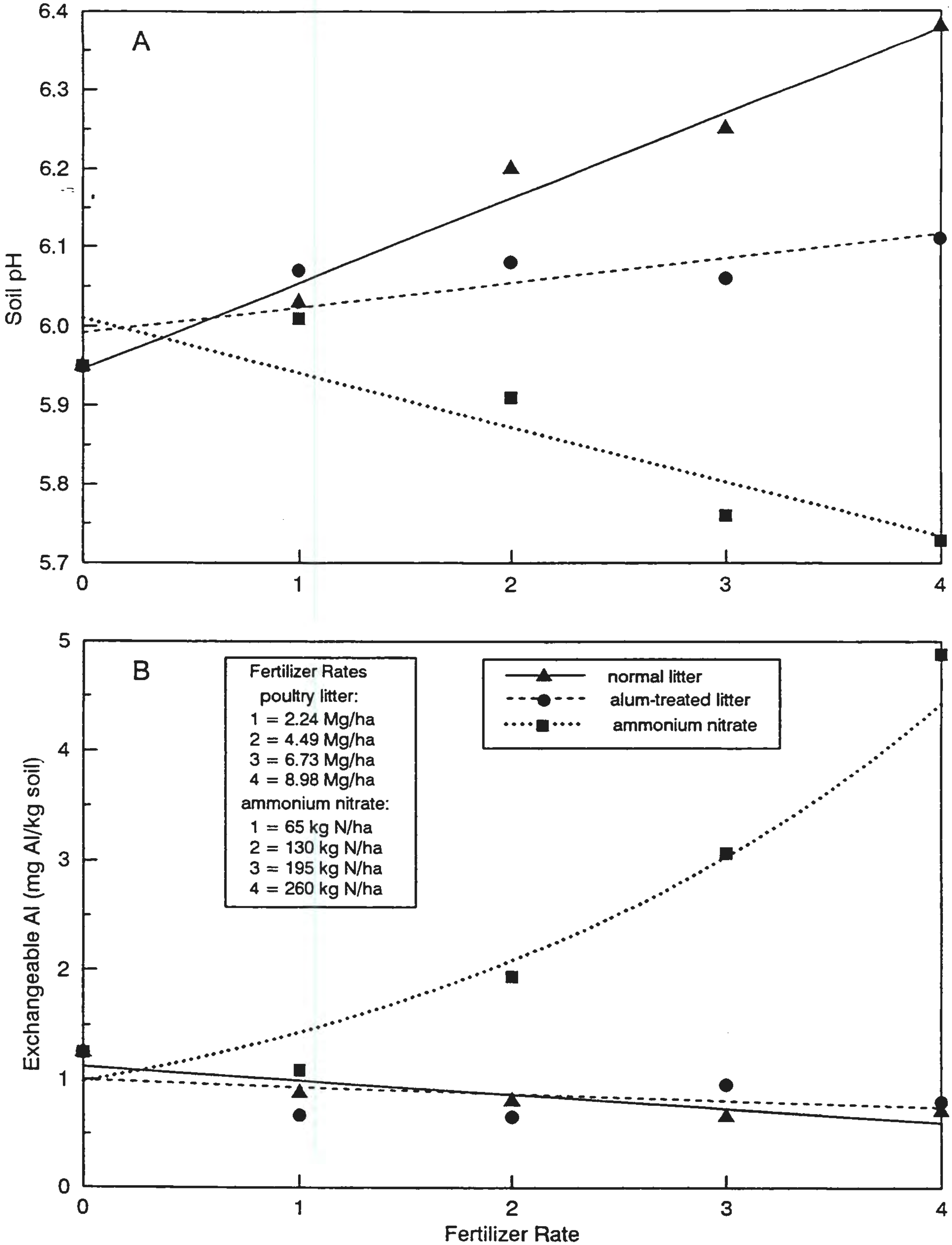

Figure 1. Effect of Fertilizer Treatments on; (1) Soil pH and (b) Exchangeable Aluminum.

pronounced on Al concentrations as they were for As, Cu and Zn (Moore *et al.*, 1998). The highest litter application rates resulted in Al concentrations of 0.23 and 0.25 mg Al L^{-1} for the first runoff event, for alum-treated and untreated litter, respectively. These data indicate that alum is unlikely to cause any problems with respect to Al runoff into the aquatic environment.

CONCLUSIONS

- Aluminum is one of the most abundant elements in soils, ranging in concentration from 1-30%. The average Al content in soils of the U.S. is 7%. There are two million pounds of soil in an acre furrow slice (the top 6 inches in an acre); hence, the Al content for average soils is 140,000 pounds per acre furrow slice.

- Aluminum sulfate (alum) contains about 9% Al. When alum is added to poultry litter at a rate of 10% by weight (250 lbs per 1,000 ft^2), the Al content of the litter is about 1%. Fertilizing an acre of land with 2.5 tons of alum-treated litter results in about 50 pounds of Al being applied.

- To increase the Al content of soils from 7 to 8% would require 20,000 pounds of Al, which would take 400 years of heavy (2.5 ton/acre/year) applications of alum-treated litter each year. Increasing the total Al content of soil should have no effect on available Al if the form added is not soluble, such as $Al(OH)_3$ or $AlPO_4$.

- Soluble Al in soils is regulated by soil pH. Alum-treated litter increases soil pH, as does normal litter, although such increases occur at a slower rate with alum-treated litter. Since alum-treated litter increases pH, it will actually lower soluble Al in soils.

- Exchangeable Al was highest in soils fertilized with ammonium nitrate, due to low pH.

- Aluminum uptake by plants was not affected by alum-treated litter.

- Aluminum runoff was not affected by alum-treated litter.

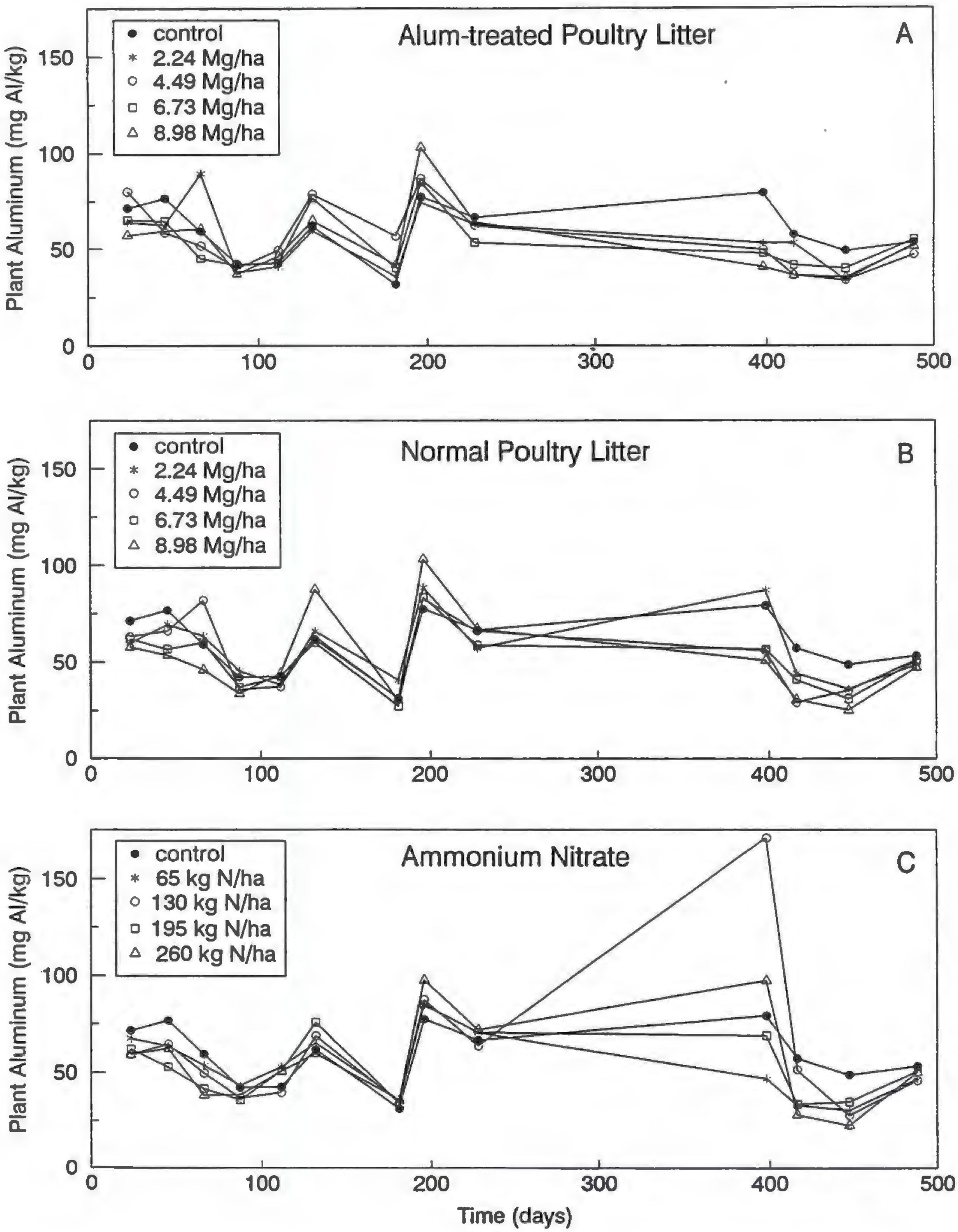

Figure 2. Plant Aluminum Concentrations as a Funciton of Time from Plots Fertilized with (A)Alum-Treated Litter, (B) Normal Litter, and (C) Ammonium Nitrate.

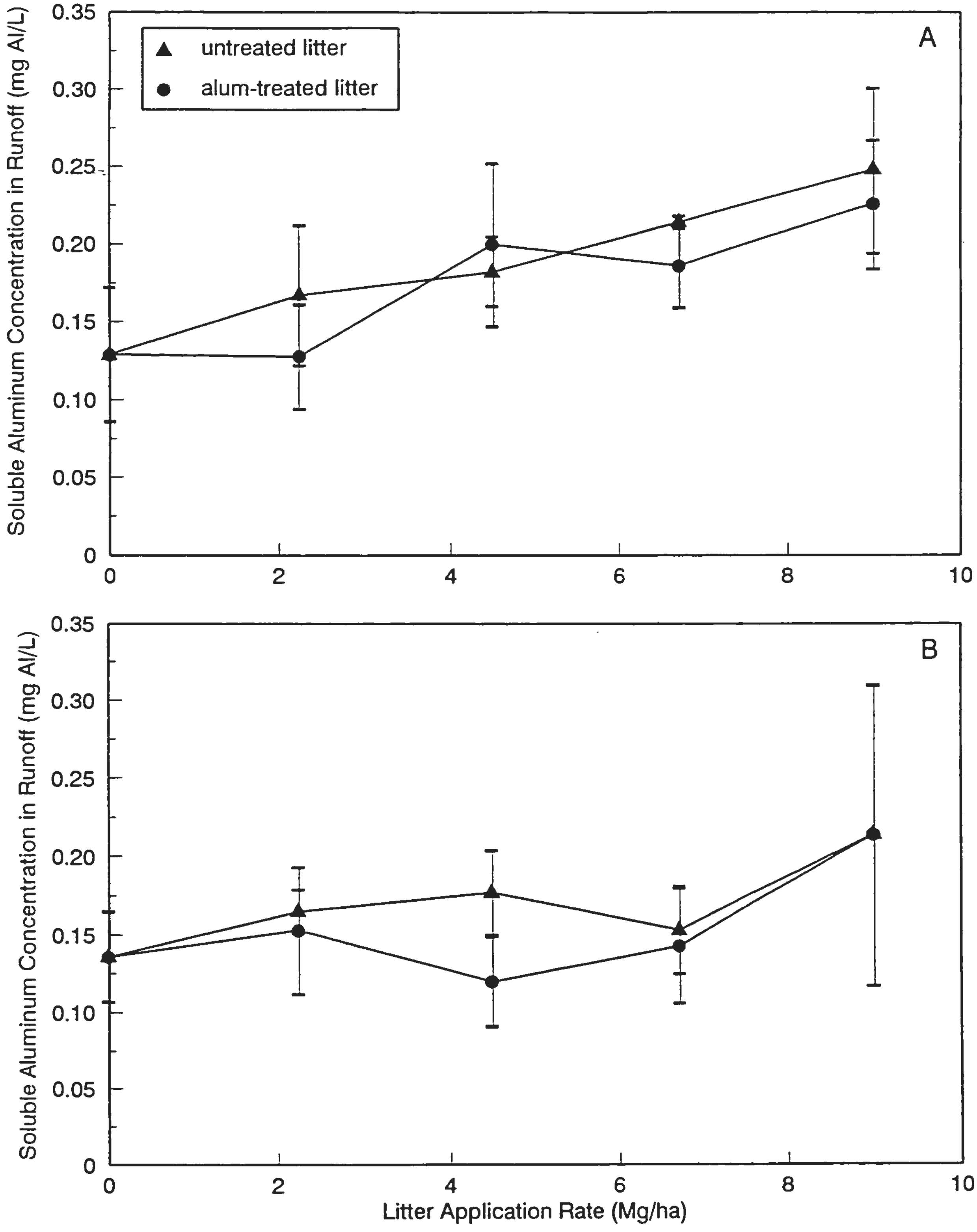

Figure 3. Effect of Poultry Litter on Soluble Aluminum Concentrations in Runoff Water from (A) the DAy of Application, and (B) 7 days later.

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EFFECT OF pH ON THE SOLUBILITY OF PHOSPHATE MINERALS

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Phosphorus availability in soils is normally governed by the solubility of aluminum, calcium and iron phosphate minerals. Based on this, we have attempted to regulate P solubility in poultry litter with the addition of Al, Ca, and Fe compounds in an attempt to precipitate P minerals (Moore and Miller, 1994; Moore *et al.*, 1995). Although we found that P solubility could be lowered with the addition of various compounds to litter, information on the stability of these minerals under various conditions is lacking.

The most promising litter amendment for reducing soluble P levels is aluminum sulfate (alum). Research has shown that alum additions to poultry litter can reduce P concentrations in runoff from small plots by 87% (Shreve *et al.*, 1995) and from field-scale watersheds by 75% (Moore *et al.*, 1997). Alum additions to litter also greatly reduce ammonia volatilization, result in improved poultry production and reduce energy use (Moore *et al.*, 1995; Moore *et al.*, 1996; Moore *et al.*, 1997), making this practice very cost effective.

One uncertainty that arises concerning the use of alum or other chemical amendments to poultry litter is whether the phosphate mineral that forms will later dissolve if the soil becomes acidic. Although this would not be expected to occur for aluminum phosphate minerals, because they are theoretically less soluble under somewhat acidic conditions, it may occur for calcium phosphate minerals.

The objectives of this study were to: (1) determine the effect of pH on phosphorus solubility from aluminum and calcium phosphate minerals, and (2) determine the solubility products of phosphate minerals.

MATERIALS AND METHODS

Aluminum and calcium phosphate minerals were purchased from Minerals Unlimited or obtained from the Smithsonian Institute. The minerals were ground with a mortar and pestle and passed through a 50 um sieve. The minerals were then examined using a Philips X-ray diffractometer with a CuLa source and a curved-crystal graphite monochrometer, to verify mineralogy.

Two grams of each phosphate mineral were weighed out into 250 ml polyethylene bottles containing 200 ml of DDI water. Various amounts of HCl were added to insure a wide range of pH conditions. The samples were then sealed and placed on a reciprocating shaker for 8 months at ambient temperatures (20-25°C). Periodically throughout the incubation, samples were withdrawn and analyzed for pH, electrical conductivity, alkalinity, and metals. Metals (Al, As, B, Ca, Cd, Co, Cr, Cu, Fe, K, Mg, Mo, Mn, Na, P, Pb, Ni, S, Se, Ti, and Zn) were determined using a Spectro Model D ICP.

Soilchem (Sposito and Coves, 1988) was used to calculate ion activities. The total concentrations of metals and ligands and the pHs of the solutions were used as input data. Activities were calculated by multiplying free ion concentrations with activity coefficients using the Davies equation.

RESULTS AND DISCUSSION

Effect of pH on Phosphorus Solubility

The effect of solution pH on phosphorus solubility is shown in Figure 1. Calcium phosphate minerals were found to be much more soluble than aluminum phosphates at low pHs, as would be expected. At pHs around 5.0, the calcium phosphate minerals all yielded P concentrations >100 mg P/L, whereas the P concentrations noted at this pH range for the aluminum phosphate minerals was on the order of 1 mg P/L.

The most soluble phosphate mineral studied was dicalcium phosphate. This mineral is undoubtably present in poultry litter, since it is normally the inorganic P supplement used in poultry diets. It is obvious from Figure 1 why nutritionists use this mineral; it is extremely soluble, particularly at relatively low pHs.

Tricalcium phosphate was the second most soluble phosphate mineral studied. Moore *et al.* (1991) and Moore and Reddy (1994) indicated that ß-tricalcium phosphate was potentially the mineral forming in alkaline lakes in Florida, based on the solubility products of the sediment porewater. Fixen *et al.*

(1983) also reported near equilibrium with respect to ß-tricalcium phosphate and suggested that whitlockite, a mineral with the composition $Ca_{18}(Mg,Fe)H_2(PO_4)_{14}$, may be forming in calcareous soils. Moore and Reddy (1994) showed that whatever the mineral phase was, it was extremely soluble at slightly acidic pHs (pH 5.5).

The two least soluble calcium phosphate minerals were hydroxyapatite and fluorapatite. Although these minerals are less soluble than the other calcium phosphates, they are still far more soluble that aluminum phosphates. It should be noted that it is highly unlikely that either one of these compounds would form when calcium amendments, such as calcium sulfate, are added to poultry litter, because apatite precipitation is inhibited by the presence of organic acids, magnesium, and bicarbonate; all of which are found in high concentrations in litter (Brown, 1981; Innskeep and Silvertooth, 1988; Moore and Miller, 1994).

The most insoluble phosphate minerals studied were the aluminum phosphates. Appreciable quantities of P in solution were not detectable until the pH had been dropped to below pH 3. Since these pHs are not encountered in soils, aluminum phosphates can be considered geologically stable, at least in the pH range of 4-8, which covers most soils worldwide.

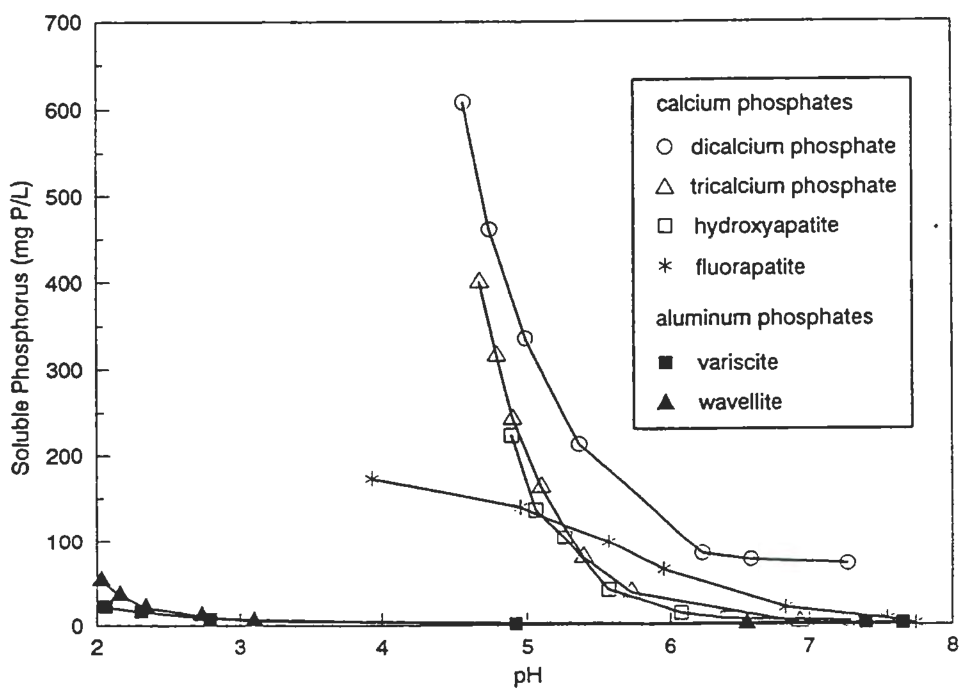

Figure 1. Effect of pH on Phosphorus Solubility in Various Phosphate Minerals.

These data have important implications. Although soluble P can be precipitated with a variety of compounds, it is obvious that the end product should not be a calcium phosphate mineral, since these minerals are very soluble in slightly acidic to acidic conditions. Most poultry production occurs in the southeastern U.S., where soils are generally acidic in nature. Under these conditions the least soluble of the phosphate minerals would be the aluminum phosphates, like variscite and wavellite. Hence, alum appears to be the best additive for reducing P solubility in poultry litter.

Ion Activity Products

Equilibria calculations can help determine if a mineral would be expected to precipitate or dissolve under a certain set of conditions. Many of the solubility products for phosphate minerals that we now use were determined in the 1950's or 1960's. Because of the advancements in technology and equipment, we are far better suited to determine solubility products now. The negative log of the ion activity products (IAPs) for the minerals studied are shown in table 1. These values are relatively close to values that had been used in past, with the exception of wavellite. The previously reported value for wavellite was -79.0, which is far higher than -82.53, which was found in this study. The value of -79.0 was estimated by Nriagu (1976) using thermodynamic calculations alone, which probably led to the overestimation.

Table 1. Measured and reference ion activity products for phosphate minerals.

Mineral	Measured log IAP	Reference log IAP	Reference
dicalcium phosphate $CaHPO_4 2H_2O$	-6.61	-6.56	Moreno *et al.*, 1960
tricalcium phosphate $Ca_3(PO_4)_2$	-30.74	-28.92	Gregory *et al.*, 1974
hydroxyapatite $Ca_{10}(PO_4)_6(OH)_2$	-56.02	-58.20	Avinimelech *et al.*, 1973
fluorapatite $Ca_{10}(PO_4)_6(F)_2$	-58.13	-58.89	Lindsay, 1979
variscite $AlPO_4 2H_2O$	-22.39	-22.52	Taylor and Gurney, 1964
wavellite $Al_3(PO_4)_2(OH)_3 5H_2O$	-82.53	-79.00	Nriagu, 1976

CONCLUSIONS

Calcium phosphate minerals, such as dical, trical and apatite, are very soluble under slightly acidic to acidic conditions. Aluminum phosphates, such as variscite and wavellite are not soluble until pHs of less than 3 are reached. Because soil pHs in the poultry producing areas of the U.S. are generally acidic, the formation of aluminum phosphate minerals in poultry litter would be far more preferable than the formation of calcium phosphates, since the latter would be expected to dissolve with time.

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EFFECTS OF CHEMICAL AND MICROBIAL AMENDMENTS ON PHOSPHORUS RUNOFF FROM COMPOSTED POULTRY LITTER

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Two of the biggest environmental problems with animal manures are ammonia volatilization and phosphorus (P) runoff. Ammonia volatilization decreases nitrogen levels in litter and P runoff leads to eutrophication in nearby water bodies. Research has shown that aluminum sulfate (alum) and phosphoric acid greatly reduce ammonia volatilization and affect P availability in fresh poultry litter. However, no studies have yet reported the effects of these amendments on composting litter.

Composting has received increasing interest as a method for handling various types of wastes. The major advantage of composting is the production of a stabilized product that can be stored or spread with little odor or fly breeding potential. Composting stabilizes organic matter, improves materials handling characteristics, preserves nutrients, and reduces product odors (Sweeten, 1988). The most negative impact of composting animal manures is the loss of nitrogen (N) via ammonia volatilization.

Ammonia volatilization increases with an increase of pH, moisture content, wind speed, NH_3 concentration, or temperature (Reddy *et al.*, 1979). High moisture contents (up to 60%), increasing pH and temperatures are characteristic of composting and therefore results in enhanced volatilization rates. Ammonia volatilization during manure handling and storage reduces the agronomic value of the end product, as well as making a significant contribution to environmental pollution (Witter and Kirchmann, 1989). Henry and White (1993) found that N concentrations decreased significantly due to composting. Eghball *et al.* (1997) reported as much as 40% of total manure N can be lost during composting, while

Kirchmann and Witter (1989) reported 44% of the initial N present was lost via ammonia volatilization.

Once poultry litter is land applied, there is potential for P loss via runoff. Because poultry litter is usually applied based on N needs, P is over-applied and soil P levels increase. This build-up of P results in excessive P concentrations in runoff. Soluble reactive P (SRP) is very important due to its direct bioavailability to aquatic plants; whereas, particulate P is bioavailable only through conversions to inorganic phosphate (Sonzongi *et al.*, 1982). Up to 90% of runoff P from fresh poultry litter has been reported as SRP (Edwards and Daniel, 1993).

Alum and phosphoric acid have both been shown to greatly reduce ammonia volatilization from poultry litter (Moore *et al.*, 1996). Moore *et al.* (1995) found that the addition of alum results in the doubling of N concentrations in the litter which would greatly increase the value of poultry litter as a fertilizer source. Due to ammonia losses, N is more deficient for plant uptake. Studies have shown non-composted manure and fertilizer application resulted in significantly greater grain yield than composed manure (Eghball and Power, 1995). Shreve *et al.* (1995) showed that total-yields for fescue had the greatest response to applications of litter amended with alum. Alum additions also have been shown to greatly reduce water soluble P concentrations (Moore and Miller, 1994). Shreve *et al.* (1995) reported that amending poultry litter with alum resulted in an 87% reduction in the SRP concentrations compared with non-treated litter alone.

The objectives of this study were to measure P runoff, yields, and N uptake from fescue fertilized with composted and fresh poultry litter. Litter was treated with alum, phosphoric acid, or a microbial mixture prior to composting.

MATERIALS AND METHODS

The composting procedure was conducted at EarthCare Technologies, Inc. in Lincoln, Arkansas. This was conducted to determine whether alum and phosphoric acid should be surface applied or incorporated into the litter prior to composting and to determine the most effective rate of application. Poultry litter was obtained by EarthCare and windowed into twelve rows, with each windrow weighing four tons. The composting litter was monitored daily and each individual row was turned with a 2°F drop in the temperature was noted and/or the moisture content dropped below 30%. Once the compost trial was completed, compost of selected treatments were collected for use in the runoff study.

Litter samples were taken from each treatment and composited for analysis. Water soluble P was determined by extracting a 20 gram sub-sample of litter with 200 ml of deionized water. The sample was shaken for two hours, centrifuged at 8,000 RPM, filtered through a 0.45 um millipore membrane, and acidified to pH 2 with HCl. Soluble reactive P (SRP) was determined using the ascorbic acid technique with an auto-analyzer (American Public Health Association, 1992). Total P was determined by digesting oven dried (60°C) litter with HNO_3, and analyzing the sample using ICP (Zarcinas *et al.*, 1987). Litter samples were also analyzed for total N using a LECO CNS-2000 elemental analyzer.

The runoff study was conducted on 28 plots (1.52 x 5.96 m) at the University of Arkansas Agricultural Research Station. The plots consist of a Captina silt loam soil and have been in continuous tall fescue for six years. There were seven treatments: (1) unfertilized control, (2) normal composted litter (no amendment), (3) litter composted with alum (10% by weight), (4) litter composted with phosphoric acid (2% by weight), (5) litter composted with a microbial mixture, (6) litter composted with 5% alum/microbial mixture, and (7) fresh poultry litter. Litter was collected from the beginning of the study and kept frozen until the runoff study (fresh litter). The microbial mixture was developed by EarthCare Technologies, Inc. and applied based on their recommendations. Litter was applied at rates equivalent to 8.98 Mg ha^{-1} (4 tons/acre). There are four replications of each treatment in a randomized block design.

Immediately after applying each treatment, rainfall simulators were used to provide a 5 cm hr^{-1} storm sufficient in length to cause 30 minutes of continuous runoff. Runoff samples were collected at 2.5, 7.5, 12.5, 17.5, 22.5, and 27.5 minutes after initial runoff. Composited samples were analyzed for total P and SRP. Composited runoff water samples were filtered through a 0.45-um membrane and acidified to pH 2 with concentrated HCl. SRP concentrations were determined colorimetrically on the filtered, acidified samples, using the automated ascorbic acid reduction method (APHA, 1992). Unfiltered, acidified samples were analyzed for total P with a spectro Model D ICP after digestion with nitric acid according to APHA Method 3030E (APHA, 1992).

Nitrogen uptake and total yield from each fescue plot was also evaluated. The plots were mowed prior to the application of any treatments. Each plot was mowed with a bagger-mower to a height of 10 cm every two weeks for six weeks after the rainfall simulation. Wet weights were determined and subsamples were taken for dry matter determinations and N analysis. After drying, the plants were ground using a Wiley

Mill with a 2mm mesh screen. Total N was determined using a LECO CNS-2000 elemental analyzer.

RESULTS AND DISCUSSION

Soluble reactive P and total P concentrations in the various composted litter are listed in Table 1. Fresh litter had the lowest total P concentrations. This is due to volume reduction and retained P during the composting process. Alum amended compost had the lowest SRP concentrations. SRP and total P concentrations in the runoff water are presented in Table 2. Analysis of the runoff water showed that SRP concentrations were significantly lower in the alum-treated compost than the other treatments except the unfertilized control. Amending composting litter with alum resulted in a 78% reduction in the SRP concentrations compared with fresh litter and an 84% reduction compared to the microbial treated compost. Runoff from the unfertilized control was significantly lower than the other treatments except the alum-amended composted litter. The composted litter amended with alum and alum/microbial mixture were lower than the rest of the treatments. Although not significantly higher, SRP and total P runoff concentrations were highest from microbial treated compost.

Total N concentrations in the various composted litter are listed in Table 1. Forage yields and nitrogen uptake were increased by all treatments over the unfertilized control for the individual harvests, total yield and total nitrogen uptake (Table 3). Total yields and total nitrogen uptake showed the greatest response to the non-composted litter. This response is most likely due to a decrease in available N resulting from ammonia volatilization during the composting process. Fresh litter applications resulted in significantly higher total yields than other treatments except the alum-amended compost. These results are similar to those found by Eghball and Power (1995). Nitrogen uptake was significantly higher than all other treatments from fresh litter applications.

CONCLUSIONS

Composting poultry litter amended with alum greatly reduced SRP and total P concentrations in runoff water. Composting with alum from this aspect showed promise as a new best management practice. However, fresh litter applications resulted in greater yields and N uptake levels than all composted poultry litter due to ammonia losses during composting. The combination of increasing P concentrations and ammonia volatilization during the composting process actually decreases the N:P ratio. Therefore, composting with chemical amendments such as alum may be necessary to limit decreasing N:P rations. More studies are currently underway to determine if composting with chemical amendments is economically feasible.

Table 1. SRP, Total P, and Total N Concentrations in Applied Litter.

Treatment	SRP	Total P	Total N
	Constituent		
	-mg/kg-	--g/kg--	--mg/g--
Compost + Alum	94.6	30.6	44.6
Compost + Alum/Microbial	313	33.4	42.1
Fresh Litter	1244	25.7	49.3
Compost + Phosphoric Acid	2285	44.8	41.2
Compost + Microbial	1336	33.5	35.2
Compost (no amendment)	1635	34.5	36.4

Table 2. SRP and Total P Concentrations in Runoff Water.

Treatment	Constituent SRP	Total P
	--------- mg L^{-1}	--------
Compost + Alum	3.8	10.6
Compost + Alum/Microbial	10.4	17.9
Fresh Litter	17.3	27.2
Compost + Phosphoric Acid	17.3	29.6
Compost + Microbial	23.7	31.2
Compost (no amendment)	12.8	20.4
Unfertilized Control	0.9	1.1
LSD (0.05)	6.5	10.9

Table 3. Fescue Yields and Nitrogen Uptake Concentrations.

Treatment	Forage Yield First Harvest	Second Harvest	Third Harvest	Total
	---------- kg ha^{-1}	----------		
Fresh Litter	1233	969	394	2596
Compost + Alum	1095	924	298	2317
Compost + Alum/Microbial	965	767	269	2001
Compost + Microbial	879	613	227	1719
Compost + Phosphoric Acid	839	619	230	1688
Compost (no amendment)	772	611	241	1624
Unfertilized Control	652	324	122	1098
LSD (0.05)	277	143	76	443
	Nitrogen Uptake			
	---------- kg ha^{-1}	----------		
Fresh Litter	52	43	16	111
Compost + Alum	42	36	10	88
Compost + Alum/Microbial	36	28	9.3	73.3
Compost + Microbial	29	21	7.3	57.3
Compost + Phosphoric Acid	28	22	7.5	57.5
Compost (no amendment)	26	21	8.0	55.0
Unfertilized Control	17	10	3.6	30.6
LSD (0.05)	11	6.8	3.1	19.2

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USE OF ALUMINUM SULFATE TO REDUCE SOIL TEST PHOSPHORUS LEVELS IN SOILS FERTILIZED WITH POULTRY LITTER

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Surface application of poultry litter to pastures can result in high concentrations of phosphorus (P) in runoff (Edwards and Daniel, 1993). Runoff of phosphorus (P) from fields receiving poultry litter has been speculated to be a principal factor affecting water quality in regions where the poultry production industry is concentrated. Many studies have linked increased total P concentrations in lake water to accelerated eutrophication (Vollenweider, 1975; Effler *et al.*, 1985).

Recent studies my Moore and Miller (1994) have demonstrated that the addition of aluminum sulfate (alum) to poultry litter converts P to nonsoluble forms. Shreve *et al.* (1995) found that P runoff from fescue plots fertilized with alum-amended litter was 87% lower than plots fertilized with normal litter. However, there is little information about the effects alum-treated litter additions have on the availability of P in the soil. The objective of this study was to compare soil P levels (Mehlich III extractable and water soluble P) in tall fescue plots treated with alum-amended litter, untreated poultry litter, and ammonium nitrate.

MATERIALS AND METHODS

The study was conducted using 52 small plots (1.52 by 3.05 m, with 5% slope) located at the Main Agricultural Experiment Station of the University of Arkansas on a Captina silt loam soil (fine-silty, siliceous, mesic Typic Fragiudult). The plots had been in continuous tall fescue production for 2 years. There were a total of 13 treatments; four rates of alum-treated poultry litter, four rates of untreated poultry litter, four rates of ammonium nitrate, and one unfertilized control. Litter application rates were 2.24, 4.49, 6.73, and

8.98 Mg ha^{-1} (1, 2, 3, and 4 tons $acre^{-1}$. These treatments were applied annually in the spring of the year for 34 consecutive years (1995, 1996, and 1997). There were four replications of each treatment in a completely randomized design. The poultry litter used for this study was collected from six commercial broiler houses in northwest Arkansas that had been used in a prior study to examine the effects of alum on ammonia volatilization (Moore *et al.*, 1997). Alum had been applied to half of the houses at a 1816 kg $house^{-1}$ rate after each growout. Alum was applied and mixed into the litter using a litter "decaker". This resulted in the alum-treated litter being approximately 10% alum by weight.

Soil samples (0-5 cm) were taken from each plot (10 cores/plot) periodically throughout the study. Mehlich III soil test P (Mehlich, 1984), and water soluble soil P (modification of Pote *et al.* (1996), with a 1:10 as opposed to a 1:25 dilution factor) were determined.

RESULTS AND DISCUSSION

Water Soluble Phosphorus

One year after the initial fertilizer treatment, plots that received the 8.97 Mg ha^{-1} untreated poultry little application had significantly higher water soluble P values than plots treated with the 8.97 Mg ha^{-1} alum-amended litter treatment (32.5 vs 23.5 mg P kg^{-1}). During the second study year, water soluble P values for plots treated with the 6.73 and 8.97 Mg ha^{-1} untreated litter applications were significantly higher than plots treated with the 6.73 and 8.97 Mg ha^{-1} alum-amended litter. Results from the third year of the study followed the same pattern, with the soil water soluble P values being higher in the untreated litter plots compared to equivalently treated alum-amended litter plots.

The most significant differences between treatments occurred during the third study year (Fig. 1). As application rates for the untreated litter increased, water soluble P concentrations increased. However, there were no significant differences in water soluble P values between unfertilized control plots and the plots fertilized with the four rates of alum. There were also no differences in water soluble P values between the unfertilized control and plots treated with NH_4NO_3.

Mehlich III Phosphorus

Mehlich III P values in the plots treated with untreated poultry litter increased significantly with an increasing application rate during the third study year (Fig. 1).

However, there were no significant differences in Mehlich III P values between the plots treated with the 4.48, 6.73, and 8.97 Mg ha^{-1} applications of alum-amended poultry litter. The unfertilized control and plots treated with NH_4NO_3 had the lowest Mehlich III P values.

CONCLUSIONS

After three years of treating tall fescue grass plots with alum-amended poultry litter, there were no significant differences in soil water soluble P values when compared to the unfertilized control. However, water soluble P levels in plots receiving untreated poultry litter increased each year, particularly at the higher rates of application. Alum-amended litter plots had significantly lower Mehlich III P values compared to equivalently managed untreated litter plots after two years of litter applications. This study is being continued to observe the long term effects of untreated poultry litter and alum-amended litter on P levels in the soil.

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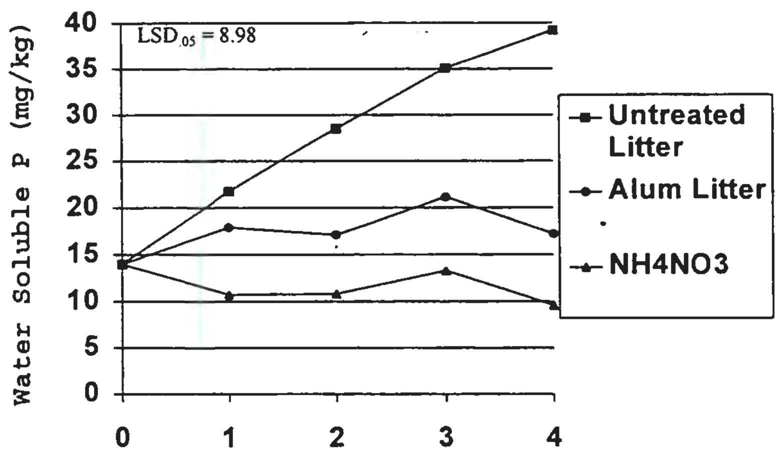

Litter Application	NH4NO3 Application
1 = 2.24 Mg/ha	1 = 65 kg N/ha
2 = 4.48 Mg/ha	2 = 130 kg N/ha
3 = 6.73 Mg/ha	3 = 195 kg N/ha
4 = 8.97 Mg/ha	4 = 260 kg N/ha

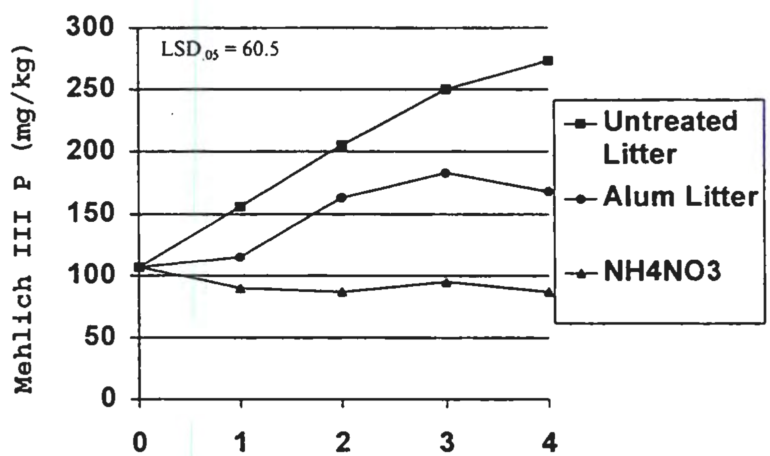

Figure 1. Soil Water Soluble P and Mehlich III P, June 1997.

USE OF HIGH AVAILABLE PHOSPHORUS CORN AND PHYTASE ENZYME ADDITIONS TO BROILER DIETS TO LOWER PHOSPHORUS LEVELS IN POULTRY LITTER

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Most of the phosphorus in corn and soybeans is phytate P, which is unavailable to poultry because these species lack phytase enzymes. As a result, broiler diets are heavily supplemented with dicalcium phosphate in order to meet the dietary needs of the birds. This addition of inorganic P results in high levels of P in manures and can ultimately result in elevated levels of P in runoff from pastures fertilized with the manure. Two methods of reducing the level of inorganic P fed to these animals are: (1) adding phytase enzyme to the feed to break down phytate P, and (2) feeding corn and soybeans which have relatively low amounts of phytate P and high amounts of animal-available P.

The idea of reducing mineral phosphate levels in poultry diets by adding phytase enzymes was demonstrated thirty years ago by Nelson *et al.* (1968). Since that time, many different studies have been conducted which have shown that inorganic P levels can be reduced in both poultry and swine by adding phytase enzymes to the diet (Nelson *et al.*, 1971; Jongbloed and Kemme, 1990; Beers and Jongbloed, 1992).

Another method that has been used to lower the amount of mineral phosphate supplements needed in poultry diets is the use of grains in which a greater proportion of the P exists as available (non-phytate) P. Recently, a low phytate corn variety has been developed by USDA-ARS (Raboy *et al.*, 1994), which was licensed by Pioneer Seed. This corn has only about 10% of the P tied up as phytate, rather than the 65% common in non-HAP corn. Pioneer Seed refers to this new corn variety as HAP corn (High available P corn).

Although phytase enzyme addition and HAP corn show promise in reducing P runoff from animal manure, runoff studies have not been conducted using this technology. Production data from a companion study indicate that P levels can be reduced in the diet without any negative effects on productivity (Huff *et al.*, 1998). The objective of this study was to evaluate the effects of reducing inorganic P levels in poultry diets (through the use of phytase enzyme additions and HAP corn) on P runoff from tall fescue (*Festuca arundinacea, L.*) plots fertilized with poultry litter.

MATERIALS AND METHODS

There were two phases of this study: (1) a broiler production study to evaluate the effects of various diets on soluble and total P in the litter; and (2) a runoff study using rainfall simulators to evaluate P runoff.

Broiler Production Study

Two consecutive growouts were conducted with male broilers (Cobb x Cobb) which were fed four different diets from one day of age to 49 days of age. The four diets were: (1) a control diet (normal commercial diet); (2) a diet using HAP corn which had 11% less total P than the control diet; (3) a diet supplemented with phytase enzyme which had 15% less total P than the control diet; and (4) a diet using HAP corn and supplemented with phytase enzymes which had 25% less total P than the control diet. The HAP corn used for this study was provided by Pioneer Seed (Pioneer Hi-Bred International, Inc., Johnston, IA). The enzyme used for this study was Natuphos, which was provided by BASF (Mount Olive, NJ). Phytase was added in sufficient quantities to provide an activity of 500 U/kg in the feed.

Each dietary treatment was fed to six pens of broilers, with 50 broilers per pen. Both feed and water were provided ad libitum. Starter diets were fed from 1 to 21 days, feeder diets from 21 to 42 days, and finisher diets from 42 to 49 days. For specific details concerning diet composition and formulas, see Huff *et al.* (1988).

Poultry litter samples were collected at day 21, day 42, and day 49 which corresponded to the end of each diet. After the birds were removed at day 49, the litter was tilled to insure good mixing of the bedding material (pine shavings) with the manure.

Ten litter samples were taken from each pen and composited for analysis. Water soluble P was determined by extracting a 20 gram sub-sample of litter with 200 ml of deionized water. The sample was shaken for two hours, centrifuged at 6,000 RPM, filtered through a 0.45 um filter, and acidified to pH 2 with HCl. Soluble reactive P (SRP) was determined using the ascorbic acid technique with an auto-analyzer (APHA, 1992). Total P was determined by digesting oven dried (60°C) litter with HNO_3, and analyzing the sample using ICP (Zarcinas *et al.*, 1987).

Phosphorus Runoff Study

This study was conducted on 1.52 x 6.1 m plots located at the Main Agricultural Experiment Station of the University of Arkansas on a Captina silt loam soil (fine-silty, siliceous, mesic Typic Fragiudult). The plots had been in continuous fescue for six years. The experimental design was a randomized block design, with four replications of five treatments consisting of a control (no litter applied to plots), normal litter (commercial diet), litter from birds fed a diet with HAP corn, litter from birds fed a diet with phytase enzyme added, and litter from birds fed a diet with both phytase enzyme and HAP corn. Litter application rates were equivalent to 6.73 Mg/ha (3 tons/acre).

Rainfall simulators (Edwards *et al.*, 1992) were used to provide 5 cm h^{-1} precipitation events immediately after litter application and 7 days later. Rainfall was simulated for a sufficient duration to allow 30 minutes of continuous runoff from each plot. Runoff samples were collected during each event at 2.5, 7.5, 12.5, 22.5, and 27.5 min after continuous runoff was observed. Samples from each plot were composted. A portion of each runoff sample was filtered through a 0.45-um membrane and acidified to pH 2 with concentrated HCl for SRPP analysis. Unfiltered samples were used for pH, electrical conductivity, alkalinity, and total P determination. Soluble reactive P was analyzed as above. Total P was determined using an ICP after digestion with nitric acid according to APHA Method 3030E (American Public Health Association, 1992).

RESULTS AND DISCUSSION

Litter Phosphorus Content

For the first growout, the only significant differences in soluble P content of the poultry litter occurred at day 42 (Table 1). At this time, the phytase diet resulted in significantly higher soluble P than the other diets. The cause for this is unknown. Soluble P contents in litter from the second growout are also shown in Table 1. At day 21, the phytase and phytase plus HAP corn diets resulted in significantly lower soluble P in the litter when compared to the normal feed. At day 42, the HAP corn diet had significantly lower soluble P that the normal diet, with the HAP corn plus phytase diet having the lowest soluble P in litter. At day 49, only the phytase plus HAP corn diet was significantly lower in soluble P than the normal diet.

Total P concentrations in the litter during the first growout are shown in Table 1. At day 21, the HAP corn plus phytase diet resulted in significantly lower total P than the normal diet. At day 42, all the diets were significantly lower in total P, with the HAP corn plus phytase being the lowest. Total P content of the litter during the second growout is shown in Table 1. Day 21 showed the only treatment differences, with the HAP corn plus phytase being the lowest.

Phosphorus Runoff

There were no significant differences in soluble reactive P concentrations in the runoff among litter types for either of the runoff events (Figures 1a and 1b). Total P concentrations followed the same trend, with all litter treatments being significantly higher than the unfertilized control, but no significant differences among litter types. Although the differences were not statistically significant, the data showed that the HAP corn and HAP corn plus phytase diets lowered P runoff by 22 and 26% respectively during the first runoff event.

CONCLUSIONS

Poultry performance data from a companion study indicate that P contents of broiler diets can be reduced utilizing HAP corn and/or phytase enzymes without any negative effects on bird performance (Huff *et al.*, 1998). However, results from this study showed that these treatments did not result in a statistically significant reduction in P runoff, although the data showed that HAP corn and HAP corn plus phytase lowered P runoff by 2 and 26%, respectively. Reducing total P in broiler diets should logically be an important tool in reducing environmental P loading. However, the data from this study suggest indicate that diet manipulation alone may not be sufficient to solve this problem.

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Table 1. Soluble P and Total P Content in Poultry Litter for Both Growouts.

Time	Diet	Constituent (mg kg^{-1}) SRP	TP
First growout - 21 days	Normal	577[a]	2987[a]
	HAP	564[a]	2293[ab]
	Phytase	536[a]	2329[ab]
	HAP+Phytase	520[a]	1876[b]
42 days	Normal	828[b]	6347[a]
	HAP	727[b]	5239[bc]
	Phytase	1018[a]	5582[b]
	HAP+Phytas e	661[b]	4765[c]
49 days	Normal	654[a]	6836[a]
	HAP	591[a]	4979[a]
	Phytase	640[a]	6004[a]
	HAP+Phytase	430[a]	6033[a]
Second growout - 21 days	Normal	1224[a]	5330[a]
	HAP	1151[ab]	5350[a]
	Phytase	1048[b]	4630[ab]
	HAP+Phytase	987[b]	3237[b]
42 days	Normal	842[a]	9813[a]
	HAP	601[cd]	9092[a]
	Phytase	707[ab]	9683[a]
	HAP+Phytase	485[c]	8011[a]
49 days	Normal	1127[a]	7868[a]
	NAP	913[ab]	6410[a]
	Phytase	944[ab]	8068[a]
	HAP+Phytase	724[b]	5928[a]

[a,b,c]Means with different letters represent significance at the 5% probability level between diets within a sampling date.

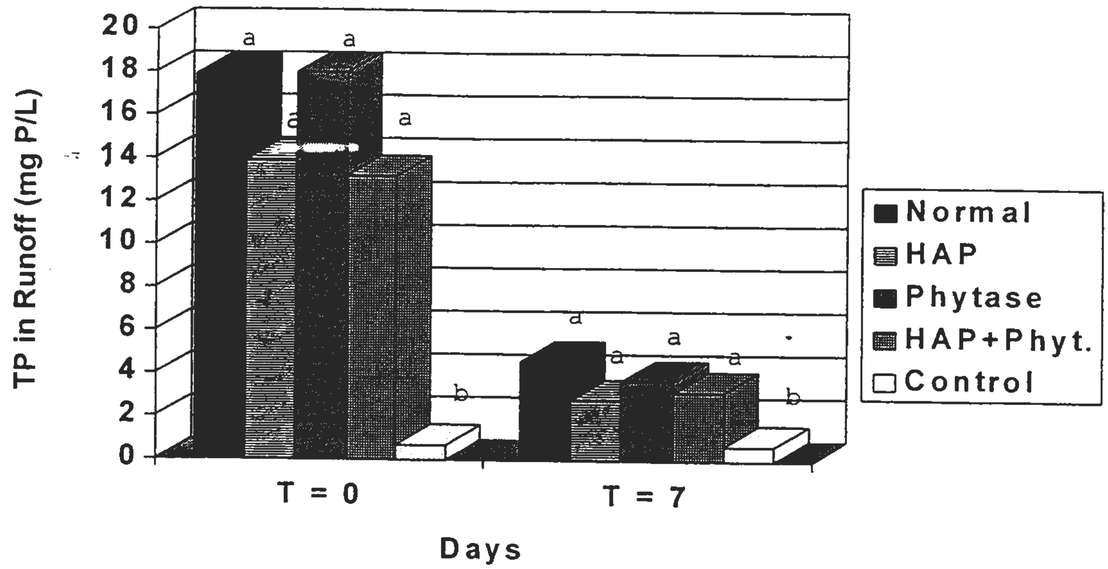

Figure 1a. Total P in Runoff.

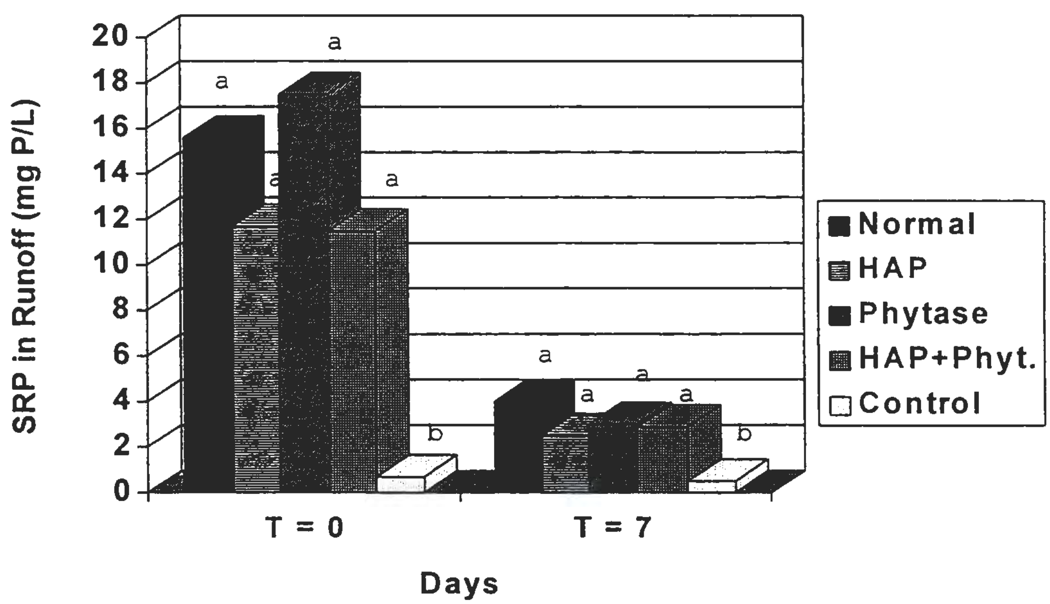

Figure 1b. Soluble P in Runoff.

[a,b]Means with different letters represent significance at the 5% probability level between diets within a sampling date.

EFFECT OF FORAGE SPECIES AND CANOPY HEIGHT ON RUNOFF QUALITY FROM POULTRY LITTER-AMENDED SOILS

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One of the major uses of poultry litter in Northwest Arkansas is surface application to pastures. In the past, application rates of poultry litter have been based only on the nitrogen (N) requirements of the forage, resulting in excessive phosphorus (P) buildup in the soil. Huneycutt *et al.* (1988) reported that poultry litter applications to tall fescue grass (*Festuca arundinacea Schreb.*) based on N requirements resulted in an excess of 40 kg/ha of P.

When poultry litter is surface applied to pastures there is a potential for runoff and nutrient loss from these systems. Edwards and Daniel (1993) reported that when broiler litter was surface applied to tall fescue grass 2.2 to 7.3% of total P was lost in runoff, with 80% or more of P in runoff in the dissolved form. It is well documented that increased P levels in runoff can adversely impact surface waters by accelerating the eutrophication process (Effler *et al.*, 1985; Sharpley and Menzel, 1987; Pote *et al.*, 1996).

There is increasing emphasis in federal conservation programs on using native plant species as opposed to introduced species. Native warm-season grasses are touted for their deep, extensive rooting and nonaggressive (nonweedy) growth habit and are widely used in lower rainfall regions of the U.S. (Sharp *et al.*, 1995). Two such grasses receiving attention are the tall bunch grasses switchgrass (*Panicum virgatum L.*) and eastern gamagrass (*Tripsacum dactyloides L.*). It has been hypothesized that these grasses allow greater water infiltration into the soil profile than introduced grasses, thus reducing runoff and nutrient loss (ARS/NRCS Gamagrass Workshop, Atlanta, GA, 1996). However, data on the effects of various forage species on hydrology are lacking.

Many recent studies have focused on methods to reduce the problems associated with nutrient runoff from agricultural land and its impact on the environment (Edwards and Daniel, 1993; Shreve *et al.*, 1995; Pote *et al.*, 1996; Moore *et al.*, 1997). Much of the work on P runoff; however, has dealt with only one forage species, tall fescue, which is an introduced, cool-season, perennial grass having minimal summer growth. Tall fescue is widely used for pasture in the principal poultry-producing areas of the U.S. and has a semi-bunchy growth form (Sleper and West, 1996). Other commonly grown, introduced pasture species include the warm-season grasses bermudagrass (*Cynodon dactylon (L.) Pers.*), a dense sod-former, and caucasian bluestem (*Bothriochloa caucasia (Trin.)* C.E. Hubb.), a medium-bunch type. These introduced grasses form lower-growing, denser canopies and are more tolerant of abusive grazing than the taller-growing, native grasses, switchgrass and eastern gamagrass.

Canopy height and density may impact the rate of infiltration and runoff from pastures in that the leaves intercept rain drops and conduct the water slowly to the soil surface. Data are also lacking on the effect of leaf area on runoff using various species.

The objective of this study was to compare the five grasses described above for runoff volume, infiltration rate, total N removal in the forage, runoff nutrient content and, runoff nutrient load at two canopy heights when poultry litter is used as the nutrient source.

MATERIALS AND METHODS

The study was conducted at the Main Agricultural Experiment Station of the University of Arkansas on a Captina silt loam (fine-silty, siliceous, mesic Typic Fragiudult). The design was a split plot randomized block design. There were 25 split plots (6.1m x 6.1m, with 5% slope) separated by a 25 cm metal frame for a total of 50 (3.05m x 6.1m) plots. Each plot contained one of five forage species; Pete eastern gamagrass, Alamo switchgrass, Caucasian bluestem, Greenfield bermudagrass, and Kentucky-31 tall fescue. Each forage species represented a treatment. The split plot treatment was canopy height; forage on one-half of the plot was cut one week prior to simulated runoff, the other side had six weeks growth (full canopy cover). Canopy height averages and percent ground cover measurements were taken for each plot using the line transect method. Each plot was treated with poultry litter on 30 April 1997 at (9 Mg/ha).

A rainfall simulation was conducted in October 1997, after approximately 14 months of forage establishment. The simulator used for the study is described by Edwards *et al.* (1992). The plot was rained on at an intensity of 5.0 cm/hr for a sufficient time to cause 30 min of continuous runoff. Runoff samples were taken at 2.5, 7.5, 12.5, 17.5, 22.5, and 27.5 min after continuous runoff was observed. Time to runoff was recorded for each plot, and collection time and volume of runoff per unit time were recorded for each runoff sample. Total runoff volumes and rates were then calculated from these parameters. A portion of each runoff water sample was filtered through a 4.45-um membrane and acidified to pH 2 with concentrated HCl. Soluble reactive P (SRP) concentrations were determined colorimetrically in the filtered, acidified samples, using the automated ascorbic acid reduction method (American Public Health Association, 1992). Phosphorus loss from each plot was calculated from P concentration and runoff rate. Unfiltered aliquots of each sample were digested for total N (TKN) and total P (TP) (USEPA, 1983). Soil cores (0-5 cm) were taken within 24-hr of the rainfall simulation, and analyzed for water soluble P (Pote *et al.*, 1996).

Plots were harvested at six week intervals to calculate annual biomass yield for the 1997 growing season only. Tall fescue was harvested four times during the season (April, June, July, October); whereas, the other forages were harvested three times (June, July, October). Forage samples were retained from each plot for determination of moisture and nutrient content, and forage yield was corrected to dry weight basis. Dried plant samples (60°C for 48 h) were ground in a Wiley mill to pass a 1-mm screen. Total N was determined using a LECO CNS-2000 elemental analyzer. Dry matter yield and N concentration were used to calculate total N uptake for 1997.

RESULTS AND DISCUSSION

Runoff volumes calculated from the rainfall simulation showed that plots covered in tall fescue had significantly lower runoff volumes compared to all other forage species (Figure 1). There were no significant differences in runoff volumes between the other four grass species. Infiltration also followed the same trend, with tall fescue plots having the highest rates compared to the other forage species (data now shown).

There were no significant differences in runoff volumes between canopy height differences within a species. Although not significant, the native grasses with a bunch-type growth (switchgrass and eastern gamagrass) that had only one-week growth post-harvest had the highest runoff volumes. These two native grasses have strongly defined bunch habits and are more widely spaced than the three introduced grass species. Transect data (not shown) indicated that the clipped native grasses had 20% bare ground area; whereas, the clipped introduced grasses had less than 1% bare area.

Analysis of runoff water indicated that there were no significant differences in soluble reactive P (SRP), total P (TP), or total N (TKN) concentrations between the different forage species. However, when nutrient loads were calculated, tall fescue plots had significantly lower SRP, TP, and TKN loads leaving the field. Figure 2 shows the differences in SRP and TP leads calculated from the runoff. Values for the SRP and TP loads leaving the tall fescue plots are almost 50% of the load values for the other species. There were no differences in soil water soluble P between any of the grass species.

Switchgrass had the largest annual biomass yield with 17.3 Mg/ha. There were no differences among tall fescue, gamagrass, caucasian bluestem, and bermudagrass, which yielded 13.2, 13.1, 12.4, and 17.7 Mg/ha, respectively. Tall fescue removed the most N, 570 kg ha^{-1}, during the 1997 growing season. Gamagrass, switchgrass, bermudagrass, and caucasian bluestem removed 486.6, 484.2, 446.7, and 340.6 kg N ha^{-1}, respectively.

CONCLUSIONS

The lower runoff volume and higher infiltration rate for tall fescue compared to the other grass species explained the lower N and P nutrient loading from tall fescue, since nutrient concentrations in the runoff were the same across species. Clipping the grasses one week before rainfall simulation had no effect on runoff. There was evidence, however, that the relatively large amount of bare ground area caused by the sparse, bunchy habit of the native grasses resulted in more runoff than from the more densely populated introduced grasses. These results are considered preliminary since they were taken from the first full year's growth after planting and, therefore the plants were still establishing their crowns and root systems. Measurements will continue in subsequent years when the stands are fully established.

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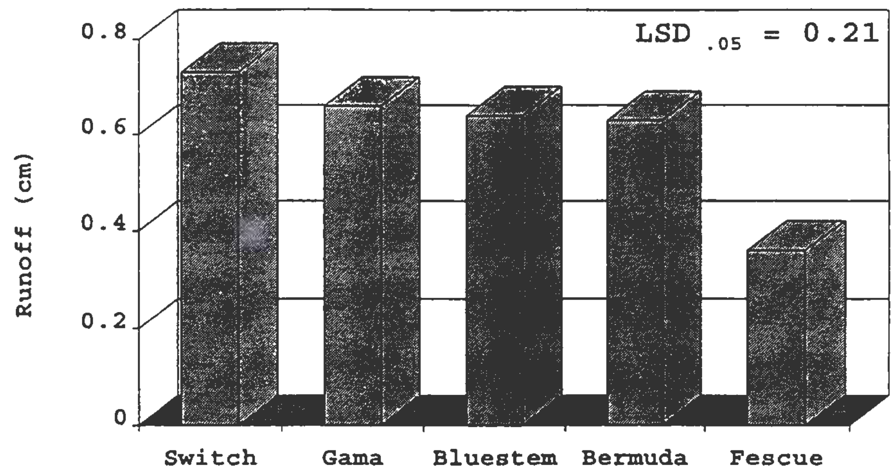

Figure 1. Runoff Volume for Each Forage Species, Averaged Over Two Canopy Heights, October 1997.

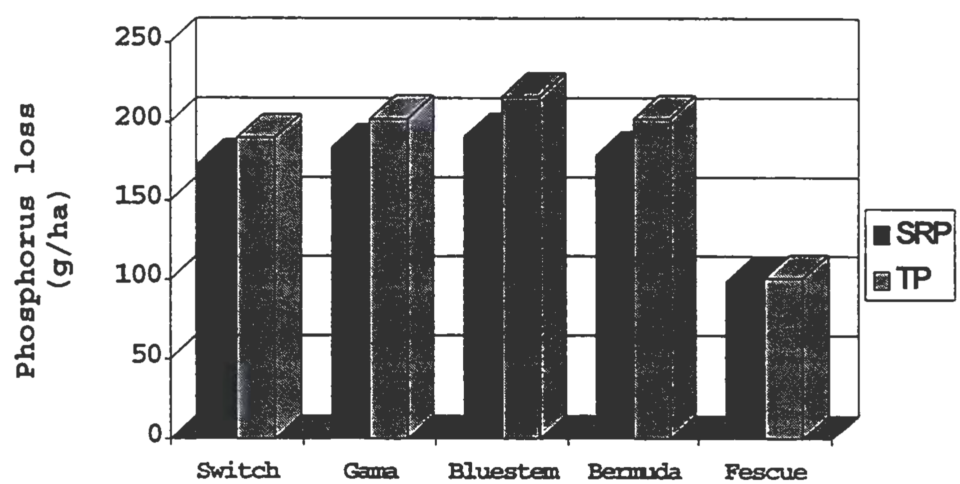

Figure 2. Soluble Reactive P and Total P Loads for Each Forage Species, Averaged Over Two Canopy Heights, October 1997.

CONSTRUCTED WETLANDS FOR ANIMAL MANURE TREATMENT AND ODOR CONTROL

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Liquid manure management systems associated with confined animal operations typically use lagoons as temporary wastewater storage structures. In fact, lagoons have been used for animal waste treatment and storage for over 20 years in the U.S. particularly with swine facilities. Objectionable odors and water contamination are potential weaknesses of these systems. Lagoons eventually fill and require the wastewater to be irrigated onto pasture or cropland to prevent the lagoons from overflowing. During high rainfall events, large scale lagoon spills have occurred causing potential pollution of adjoining rivers and streams. The North Carolina lagoon spill episode in 1995 due to excessive rainfall during a three-week period attracted national attention. Odors associated with irrigation of lagoon wastewater are offensive to nearby homeowners, both perceived and real, and some livestock producers have been forced to use alternative methods of managing lagoon effluent to avoid offending their neighbors. Constructed wetlands are being explored as secondary treatment systems to reduce the impact of livestock wastewaters on the environment. They were first used in Europe and Scandinavia as an affordable alternative to municipal wastewater treatment systems. The technology has been proven to be highly successful for treatment of municipal wastewaters, and this has stimulated interest to adopt this technology for the treatment of lagooned manures. Constructed wetlands are shallow earthen detention ponds planted with emergent aquatic plants, such as cattail and bulrush, that serve as physical barriers and attachment sites for microorganisms that aid in wastewater treatment. Constructed wetlands usually perform more efficiently than natural wetlands because system components are manipulated to provide optimum treatment efficiency and to minimize maintenance and labor associated with the system.

MATERIALS AND METHODS

Constructed Wetland Design: A free surface flow wetland was constructed at the Sand Mountain Agricultural Station (SMSS), Crossville, AL, in 1988 to evaluate the efficiency of constructed wetlands to treat the waste generated by a 500 pig/year (farrow to finish) operation. On a daily basis this amounts to the BOD_5 loading contributed by 160, 200 lb pigs; 40, 1000 lb dairy cows or 4,390, 4 lb layer hens. A two-stage anaerobic lagoon system serves as a temporary wastewater storage structure. The effluent from the secondary lagoon flows continuously through a shallow mixing pond and then into a two-tiered constructed wetland consisting of five upper cells and five lower cells. Each cell is 26 x 164 ft (0.1 acre) with an operating wastewater depth of 0.5 ft and a bottom slope of less than 1% grade. The total treatment area of the wetland cells including both upper and lower tiers is 1 acre (Figure 1).

Treatments: The wetland was operated at a loading rate of 5.95 kg BOD_5 (biochemical oxygen demand)/ha/day (5.3 lbs/acre/day) and 5.61 kg total Kjeldahl nitrogen (TKN)/ha/day (5.0 lbs.acre/day). The BOD_5 loading rate was well below the Tennessee Valley Authority (TVA) recommended rate of less than 70 kg/ha/day while TKN loading rate was above the TVA rate which is 3 kg/ha/day (Hammer, 1994). The theoretical hydraulic detention time including both tiers was approximately 18 days which was higher than the original USDA/Natural Resources Conservation Service (NRCS) (1991) guideline of 12 days for constructed wetlands treating livestock wastewaters. In the spring of 1989, emergent aquatic plants were planted in the wetland cells. Species included broadleaf cattail (*Typha latifolia*), soft stemmed bulrush (*Scirpus validus*), and rush (*Juncus effusus*). Common reed (*Phragmites australus*), giant cutgrass (*Zizaniopsis miliacea*), giant bulrush (*Scirpus californicus*), bull-tongue (*Sagittaria lancifolia*) and narrowleaf cattail (*Typha angustifolia*) were planted in early 1990. The wetland cells were kept moist with pond water for two growing seasons to allow the plants to become established before wastewater was introduced into the wetlands in November 1990.

RESULTS AND DISCUSSION

Data collected over a 57-month period substantiate that the constructed wetlands are highly efficient for treating lagoon effluent. The TKN of the wetland inflow was reduced from 74 to 12 mg/L after treatment, an 84% reduction (Table 1). The total ammonia-nitrogen (TAN) represented 75% of the wetland inflow TKN and was reduced 85%. Total phosphorus (TP), BOD_5, chemical oxygen demand (COD) and total suspended solids (TSS) were reduced 76%, 90%, 80% and 89%, respectively. After treatment the wetland effluent contained the following concentrations of analytes (mg/L) TP, 6.8; BOD_5, 7.9; COD, 64.2; TSS, 15.5; TKN, 12.2; TAN, 8.6 and NO_3-N <1 (Table 1). The upper tier of cells alone provided sufficient treatment to meet the USDA/NRCS wetland effluent criteria for BOD_5 and TSS (<30 mg/L), but both the upper and lower tier of cells were required to meet the recommended effluent criterion for TAN (<10 mg/L).

Significant reductions occurred for all parameters in the upper tiers. The highest removal was for TSS (86%) followed by BOD_5 (78%). Total suspended solids are commonly removed from wastewater in the first 20% of the flow distance in wetland cells due to low water velocity (Reed *et al.*, 1995). With a water-marsh-pond system treating municipal wastewater in Arcata, California, solids removal occurred in the initial 12-20% of the cell area (Gearheart *et al.*, 1983). After 5 years of continuous operation, the SMSS wetland has met or exceeded the suggested USDA/NRCS (1991) wetland effluent criteria (mg/L) for BOD_5 <30, TAN <10 and TSS <30 (Table 2). However, TAN did not meet the TAN effluent guidelines of 5 mg/L for constructed wetlands treating municipal sewage in Georgia during the Spring and Summer (Georgia Department of Natural Resources, 1995) nor the effluent TAN guideline of 1 to 5 mg/L for a poultry processor in Texas (Vernon, 1992).

The effluent TP concentration exceeded the annual average for Duplin county, North Carolina (<2 mg/L; Humenik *et al.*, 1997) for livestock wastewater effluent and the Danish guidelines of 1.5 mg/L for constructed wetlands treating municipal sewage (Brix and Schierup, 1989). Water quality standards are common to more states governed by the US EPA but individual states can mandate most stringent standards and criteria. Livestock producers are required to comply with effluent guidelines, but fecal coliform bacteria guidelines might be difficult to meet on a continuous basis. The fecal coliform count for the SMSS wetland effluent was reduced 95% of the influent count but the effluent count of 6500/100 ml was about 33 times higher than the EPA criterion for full body contact (<200/100 ml) (Table 1). Additional treatment would be required to meet fecal coliform limitations of most streams and lakes. Odors were not measured directly, however criteria such as the blackish-green color of wastewater associated with odorous lagoon wastewater were used as a crude measure (Barth et a., 1990). The lagoon water entering the wetlands was blackish and odorous, and after treatment the wetland effluent was odorless and nearly colorless.

CONCLUSION

A 57-month study has demonstrated that constructed wetland treating animal manure lagoon effluent has successfully reduced wastewater nutrient concentrations to meet BOD_5 and TSS discharge criteria for wetlands treating municipal sewage. However, not all discharge criteria were consistently met such as TAN, TP and fecal coliform bacteria. The final effluent was odorless indicating that the wetland system was highly efficient in eliminating manure odors.

State, county and city governments have authority to mandate water quality standards so producers should take into account these guidelines depending on where their operations are located. One of the inherent problems associated with animal wastewater is the extreme variability in analyte concentrations and constructed wetlands cannot be a fool proof technology to ensure compliance. Some investigators view constructed wetlands as a treatment system to maximize the removal of pollutants irrespective of the final effluent concentrations and suggest that wetlands should be incorporated into an animal wastewater management program to reduce costs and land requirements. However, the objective of this study was to achieve effluent criteria required for discharge of wetland treated municipal sewage.

Wetland loading should be optimized to achieve wetland effluent that is sufficiently clean so as to recycle and use to flush manure from animal production facilities because wetland effluents cannot be legally discharged. There is also no guarantee that lagoon wastewater will be fully contained during high rainfall events. To ensure containment of the wetland effluent, a detention pond was constructed. The treated wastewater in the detention pond was pumped as required to a storage pond (referred to as recycle pond; Fig. 1) located upgrade of the constructed wetlands system. The recycle water has been used to flush manure from the animal production facilities.

The analyte concentrations of recycle water were determined at two-week interval for one year and contained the following concentrations of analytes (mg/L) TKN, 6.5; TAN, 1.6; BOD_5, 12.0; TSS, 24.9; TP, 6.2 and fecal coliform count of 312/100 mL. The analyte concentrations met the USDA/NRCS minimum guidelines of BOD_5, TAN and TSS for treating animal lagoon wastewater and also Georgia criteria for effluent from wetlands treating municipal sewage (Table 2). However, the fecal coliform count for the recycle water (312/100 mL) exceeded the EPA criterion for full body contact (<200/100 mL) (Table 1). Additional treatment would be necessary to comply with the EPA standard.

SUMMARY

A two-tiered, 0.4 hectare (1 acre) free surface flow wetland system operated at a loading rate of 5.95 kg BOD_5/ha/day (5.3 lbs BOD_5/acre/day), which is equivalent to the waste produced by 4,390, 4 lb layer hens, consistently met the effluent discharge criteria for BOD_5, TAN and TSS for constructed wetlands treating municipal sewage and after the treatment the wetland effluent was odorless and colorless. Because effluent from the animal facilities cannot be discharged, a recycle system was built to re-use the final wastewater to flush the animal production facilities. The recycle system further reduced fecal coliform count from 6,500/100 mL to 312/100 mL. The results clearly indicate that constructed wetland system is a viable alternative for the treatment of animal manures that controls odors and meets effluent discharge guidelines for wetlands treating municipal sewage.

Table 1. Mean concentrations of wastewater analytes and treatment efficiencies for constructed wetlands treating lagoon effluent[1].

	Wetland Upper Tier			Wetland Lower Tier		Overall
	Influent	Effluent	Reduction	Effluent	Reduction	Reduction
	mg/L	mg/L	%	mg/L	%	%
TKN	73.7	27.1	63.2	12.2	55.0	84.0
TAN	55.6	20.7	62.8	8.6	58.5	84.5
NO_3-N	<1	<1	-	<1	-	-
BOD_5	76.6	16.8	78.1	7.9	53.0	89.7
COD	319.9	107.7	66.3	64.2	40.4	80.0
TP	28.4	12.7	55.3	6.8	46.5	76.1
TSS	135.7	19.1	85.9	15.5	18.8	88.6
FCB[2], (#/100 mL)	1.2X10^{5}	1.3X10^{4}	89.2	6.5X10^{3}	50.0	94.6

[1] Triplicate analyses were conducted at 2-week intervals for 57 consecutive months.
[2] Fecal coliform bacteria.

Table 2. Comparisons of effluent quality from wetlands treating animal and municipal wastewaters.

	Constructed Wetland Effluent					
	Animal Waste			Municipal Sewage		Rain Water Field Runoff[6]
Components	57-Month Study SMSS[1]	NRCS Criteria[2]	Poultry Processor Plant[3]	Georgia Criteria[4]	Danish Criteria[5]	
BOD_5, mg/L	7.9	30	5-15	20	15-20	11
TAN, mg/L	8.6	10	1-5	5	-	2
TP, mg/L	6.8	-	-	-	1.5	1
TSS, mg/L	15.5	30	15-30	30	-	-
FC (#/100 mL)	6,500[7]	-	-	-	-	11

[1]Mean final analyte concentrations for wetlands treating lagoon wastewater over 57-month at the Auburn University, Sand Mountain Substation.
[2]USDA/NRCS minimum effluent guidelines for wetlands treating animal lagoon wastewater.
[3]Texas state discharge regulations for poultry processor.
[4]Georgia Department of Natural Resources criteria for effluent from wetland treating municipal sewage.
[5]Danish discharge criteria for sewage treatment by constructed wetlands.
[6]Mean analyte concentration of rainfall runoff from non-manured field over a two-year period.
[7]Criteria for "full body contact" water classification is 200/100 mL.

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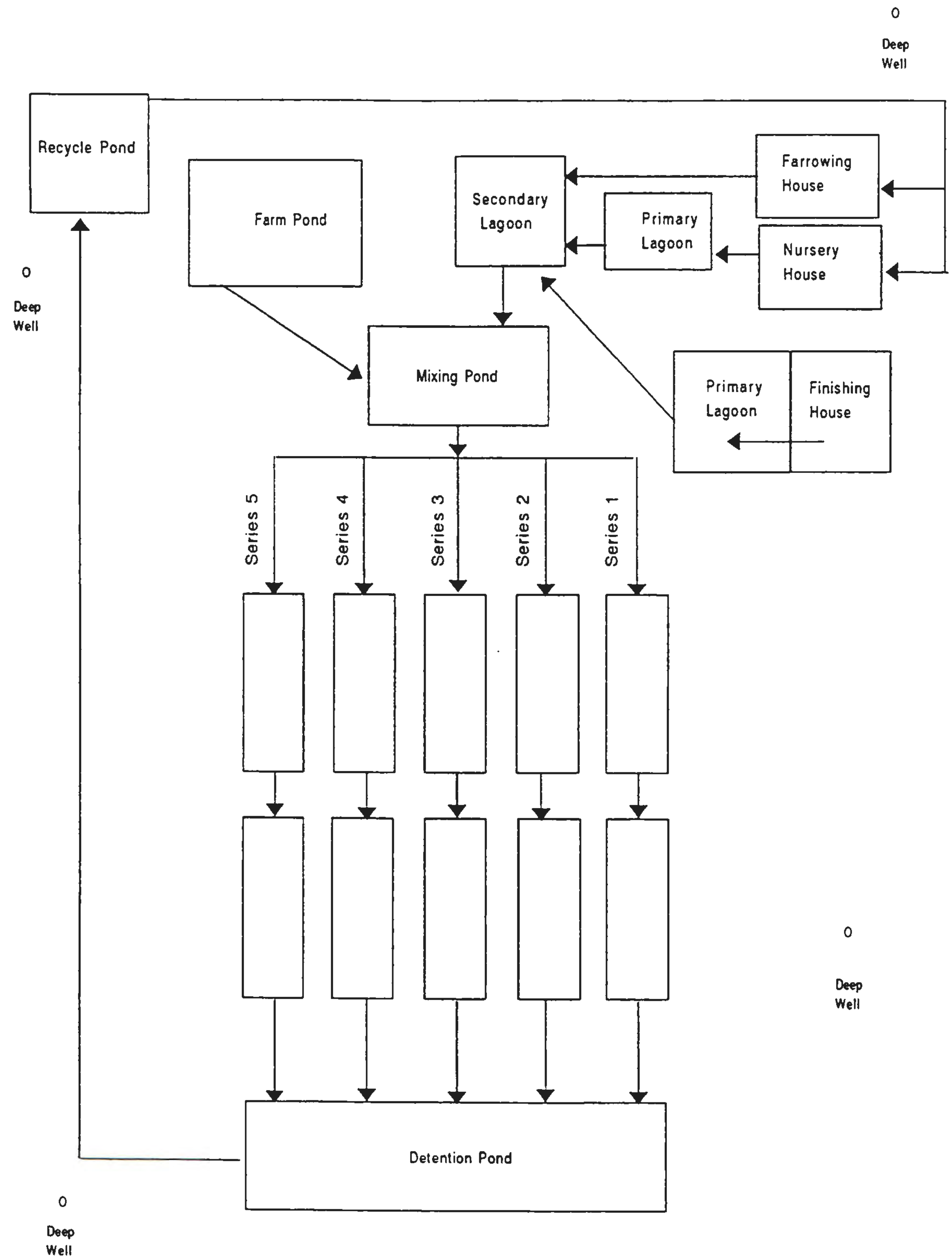

Figure 1. Constructed Wetland System for Treatment and Recycle of Lagoon Effluent.

SELENIUM IN BROILER LITTER: SOLUBILITY IN SOILS AND AVAILABILITY FOR GROWING PLANTS[1]

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Upon reviewing the 1987 amendment (52 FR 10887) of the food additive regulation that had increased the maximum amount of selenium (Se) supplementation to poultry feeds to 0.3 parts per million (ppm) in 1993, the Food and Drug Administration (FDA) ruled that insufficient information had been presented for the finding of a no significant impact on the environment due to using higher level of Se in diets. One of the concerns of the FDA was to know more about the fate of Se in poultry manure on the environment surrounding intensive animal production facilities. Therefore, the studies described below were initiated. The objectives were: 1) to determine the partitioning of added Se in broiler litter between soil and water in order to find out whether added Se is vulnerable to leaching or runoff to ground and surface waters; 2) to determine the bioavailability of added Se in litter for growing plants; and 3) to examine cycling of litter Se in field production or corn and soybeans.

SOIL INCUBATION STUDY

A laboratory experiment was conducted to determine the solubility of Se in ten Kentucky soils representative of the landscapes receiving litter. Bulk topsoil (0-20 cm) and subsoil (20-40 cm) horizon samples, including both upland and

[1]Research funded by the U.S. Poultry & Egg Association.

creek-bottom soils, were taken from unmanured field sites. Duplicate portions (500 g) of each soil horizon in the incubation study were subjected to three treatments; broiler litter (as an organic source of Se), sodium selenite (as an inorganic source of Se), and an unamended control. The litter contained 0.87 ppm Se and was applied at a rate of equivalent to 8 metric tons dry matter per hectare (3.6 English tons dry matter per acre). Sodium selenite provided the same amount of Se as the litter (~7 g per hectare). Soils were moistened to, and maintained at, field capacity and then incubated at room temperature for 16 weeks. Aliquots of soil were taken at 24 hours, and 4, 8 and 16 weeks. Soil aliquots were air-dried, crushed to pass a 2 mm sieve opening, and then subjected to extraction for water-soluble Se. A 10 g aliquot of soil was placed into a 50 mL centrifuge tube with 10 mL of deionized water and mechanically shaken for 20 minutes. Suspensions were centrifuged and the filtered supernatants were analyzed for Se by graphite furnace atomic absorption spectroscopy in the presence of palladium and magnesium modifiers.

levels of water soluble Se in the supernatants never exceeded the analytical detection limit (0.005 μg). Though there were occasionally detectable "traces" of Se, these "hits" followed no predictable pattern in relation to soil or treatment.

SOIL-CORN GREENHOUSE STUDY

A greenhouse study was conducted to determine the bioavailability of Se to corn grown on four Kentucky top soils under controlled environmental conditions. Bulk soil samples were taken from the 0-20 cm depth interval at four unmanured field sites across the state. A factorial combination of treatments, consisting of four rates of each of two sources of Se, were imposed, in triplicate, on each soil. Poultry litter was applied at rates of 0, 7, 14 and 21 g per pot (equivalent to 0, 4, 8 and 12 metric tons DM per hectare, respectively) and sodium selenite was applied at rates to give equivalent amounts of Se (0, 6, 12 and 18 μg Se per pot). The source of the litter was the same as that used in the laboratory incubation study. The litter was dried and ground to pass a 1 mm sieve opening prior to soil amendment. Soils were air-dried, crushed to pass a 5 mm sieve, and then weighed 2 kg portions were placed in pots fitted with plastic liners to prevent leaching. Litter or sodium selenite, and other fertilizer amendments were added to the soil, mixed, and the soils were then moistened to 75% of field capacity.

Following 10 days of incubation, each pot was planted with 8 seeds of corn cultivar B73xFR27rhm. Pots were covered with 300 g blasting sand to slow water evaporation and again watered to 75% of field capacity. The pots were thinned to three uniform plants per pot 9 days after planting. Thinned plant tissue was returned to each pot. The remaining plants were grown for a total of 27 days after seeding. Watering was done each day and pots were rotated on the bench to minimize location effects within the greenhouse environment. The three plants per pot were cut at 2.5 cm above the soil surface, composited, dried at 60°C, weighed and ground to pass a 1 mm sieve. The blasting sand was removed and the pots were then air-dried in the greenhouse for 2 weeks. After the remaining sand was removed from the surface, the soil in the pot removed, completely air-dried and crushed to pass a 2 mm sieve.

Soil samples were subjected to extraction for water soluble Se as described earlier in the laboratory incubation study. Corn tissue samples were analyzed for Se using fluorescence detection following digestion in nitric and perchloric acids and reaction with diaminonaphthalene.

Uptake of Se by corn (Table 1) was calculated by multiplying the tissue dry matter production per pot by the tissue Se concentration. The Huntington soil caused by significant reduction in Se uptake. This wa due, in large part, to a significant reduction in dry matter production on this soil. Neither Se source was associated with greater bioavailability of Se. The addition of Se with either source failed to increase the uptake of Se by the plants.

Table 1. Effects of Soil, Source and Application Rate of Selenium on Selenium Uptake by Corn in Greenhouse Experiment.

Main Effect	Selenium Uptake (μg/pot)
<u>Soil</u>	
Huntington	0.26[b]
Pope	0.41[a]
Vicksburg	0.49[a]
Zanesville	0.55[a]
<u>Selenium Source</u>	
Sodium selenite	0.42
Broiler litter	0.43
Selenium Application Rate (μg/pot)	
0	0.49
6	0.41
12	0.37
18	0.43

[a,b]Means followed by difficult superscripts are significantly different ($P<0.05$).

As in the laboratory incubation study, levels of water soluble Se in the greenhouse soils never exceeded the analytical detection limit. Unlike the laboratory greenhouse study, there was a pattern to the detectable "traces" of Se found in those extracts (Table 2). The Huntington soil gave significantly fewer trace detections of water soluble Se than the other soils, while the Pope gave significantly more of those trace detections. Poultry litter did not result in significantly more detections of water soluble Se than sodium selenite. The unamended controls resulted in a lesser number of trace Se detections, but there was no trend for greater detections with greater rates of added Se.

Table 2. Effects of Soil, Source and Application Rate of Selenium on Occurrence of Trace Detections of Water Soluble Selenium in Soil Samples from the Greenhouse Experiment.

Main Effect	Fraction of Samples with "Trace" Detections
Soil	
Huntington	0.08[c]
Pope	0.75[a]
Vicksburg	0.54[b]
Zanesville	0.58[b]
Selenium Source	
Sodium selenite	0.51
Broiler litter	0.46
Selenium Application Rate (μg/pot)	
0	0.21[b]
6	0.58[a]
12	0.58[a]
18	0.58[a]

[a,b]Means followed by difficult superscripts are significantly different (P<0.05).

LYSIMETER STUDY

Lysimeter pans were installed in 12 plots in a water quality study. Six pans were under plots receiving poultry litter at a rate of 20 metric tons DM per hectare on an annual basis. Six pans were located under plots that were not litter amended. Lysimeter pans (61 cm x 61 cm) were constructed of stainless steel and were installed under undisturbed soil at an average depth of 70 cm, which is where the soil root zone ends and the underlying rock (aquifer) begins. Though grown to a cover crop in each winter, no plant material was harvested and no crop was actively growing over the course of the summer season. Essentially, this gave a "worst case scenario", where there were maximal amounts of water for leachate production, with minimal transpiration of water and Se uptake for lack of a growing crop. Pans were sampled subsequent to every precipitation event sufficient to cause leaching.

Samples were analyzed for Se by graphite furnace atomic absorption spectroscopy. Selenium was not found in waters under either the amended or unamended soils. "Trace" detections were few and followed no discernable pattern.

FIELD CORN AND SOYBEAN STUDIES

Field studies were initiated to determine the bioavailability of SE in broiler litter to field grown corn and soybean, and to measure the amount of Se moving past the root zone in percolate waters. Corn (1995) and soybeans (1996) were grown at each of two sites, one on a Pope silt loam, and the second on a Tilsit silt loam. At each of the two sites, there were seven replications of each of two treatments: litter amendment at a rate of 8 metric tons DM per hectare, and an unamended control. Inorganic fertilizer N, P and K were added to the unamended plots in amounts equivalent to that found in the poultry litter. Individual plot size was 9.1 m by 3.0 m on the Pope soil and 10.7 m by 3.0 m on the Tilsit soil. Corn was planted using no-tillage techniques in the third week in May of 1995. Soybeans were planted between middle and late May in 1996. Litter applications were not repeated in 1996. Herbicides were used to control emerged vegetation and prevent germination of additional weeds.

Prior to grain harvest, several other types of plant tissue were taken from the corn and soybean crops. Corn ear leaf samples were taken at 50% silking (the onset of reproductive growth). Both corn grain and stover samples were taken at harvest. In soybeans, the topmost, fully expanded, trifoliate leaves were taken at the onset of flowering. Whole soybean plants were cut when the crop was at growth stage R5 (mid-podfill). Soybean grain was sampled at harvest. All tissues were dried at 60°C and ground to pass a 1 mm sieve prior to wet acid digestion for Se determination by the fluorometric procedure.

Soil samples were taken at depths of 0 to 7.5 and 7.5 to 15 cm prior to litter application in early April, 1995. Soil samples were again taken at depths of 0 to 7.5 and 7.5 to 15 cm in March of 1996 to determine the water solubility of any

Se remaining after the 1995 corn production season. Soil samples were prepared as described previously.

Prior to litter and fertilizer amendment in 1995, both soils evidenced moderate (Pope) to low Tilsit) acidity, and low levels of plant available P and K. Water soluble Se was below the detection limit in all soil samples, at both sampling depths, in both years. "Trace" detections of Se were few, and without discernable pattern.

Litter application did not influence the leaf Se concentration on the Pope soil, but significantly raised it on the Tilsit soil (o.03 vs. 0.01 ppm). Litter amendment failed to affect the Se concentration in corn stover on either soil and the Se level in grain grown on the Pope soil. However, it significantly increased the Se concentration in grain grown on the Tilsit soil (0.038 vs. 0.025 ppm).

Soybeans, grown in 1996, responded to litter application on the Pope soil. At this location, litter application increased both whole plant dry matter production at mid-podfill (7740 vs. 5120 lb/acre) and grain yield (51.5 vs. 44.5 bu/acre). There were no such effects ont he Tilsit soil. Tissue Se, whether trifoliate leaf at early flowering, whole plant at mid-podfill, or grain at harvest, was not significantly affected by litter application at either locations.

CONCLUSIONS

Following application of broiler litter to soil, Se levels in soil extracts and plant tissues from both greenhouse and field studies and in leachates from a field lysimeter study were, in most cases, indistinguishable from background levels. This indicates that the Se in this litter, which was derived from commercial broilers fed diets containing supplemental sodium selenite, has very low solubility and has low availability for plants.

INFLUENCE OF SOURCE AND LEVEL OF DIETARY SELENIUM ON EXCRETION, CONCENTRATION AND SOLUBILITY OF SELENIUM IN BROILER LITTER AND LAYER MANURE[1]

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In 1993, the Food and Drug Administration (FDA) stayed the 1987 amendment (52 FR 10887) of its food additive regulation that had increased the maximum amount of selenium (Se) supplementation to poultry feeds to 0.3 parts per million (ppm). FDA ruled that insufficient information had been presented for the finding of no significant impact on the environment due to the use of the higher level of Se supplementation (0.3 ppm) in animal feeds. It became evident that new data on the environmental impact of feeding Se to poultry was needed. There were some fundamental questions that we believed needed to be addressed. First, how much Se is excreted by poultry fed different feedstuffs and different levels of supplemental Se? It is known that Se retention will vary depending on both the level of naturally occurring Se as well as the level of supplemental Se (Scott and Thompson, 1971; Cantor and Scott, 1975; Latshaw and Osman, 1975). It was also important to determine how much of the Se in the manure and litter is water-extractable to help assess the impact of feeding Se on ground and surface waters. The studies described below were undertaken to examine Se excretion and the concentrations and properties of Se in poultry excreta using a wide array of dietary conditions.

[1]Research funded by the U.S. Poultry & Egg Association

MATERIALS AND METHODS

Day-old broiler chicks were fed one of 12 series of practical starter and grower diets. The 12 dietary series consisted of three different basal diets supplemented with 0, 0.1, 0.2 or 0.3 ppm Se (as sodium selenite) in a 3 x 4 factorial arrangement. The first type of basal starter diet (Weeks 1-3) and grower diet (Weeks 4-6) contained corn and soybean meal obtained in Kentucky and was designed to be relatively low in naturally occurring Se. The second type contained high-Se soybean meal from Minnesota in place of the local soybean meal. The third type contained 6% menhaden fish meal, a high-Se ingredient, with locally obtained corn and soybean meal. The Se concentrations (means $\pm$ SD) of the major ingredients used were: corn, 0.038 $\pm$ .003; local soybean meal, 0.132 $\pm$ .001; high-Se soybean meal, 0.672 $\pm$ 0.014; menhaden meal, 2.77 $\pm$ 0.05; and dehydrated alfalfa meal, 0.321 $\pm$ 0.030.

Starting with 1152 day-old chicks, each of the 12 series of diets were fed to two groups of 24 males and two groups of 24 females for 42 days. Each group of chicks was housed in a floor pen (1.2 x 1.6 m) equipped with one automatic bell-type drinker and one tube feeder. At the start of the first trial, an amount of wood shavings (mostly pine) sufficient to provide a bed of approximately 15 cm (6 in.) was weighed and placed on the concrete floor. One week after the first trial ended, another flock of chicks with the same allotment of treatments to pens was grown. At the start of the second trial, the old litter was top-dressed with a weighed amount of wood shavings sufficient to provide approximately 5 cm (2 in.). At the end of the second trial, the litter in each pen was thoroughly mixed (manually) and weighed. Then, eight samples of approximately 0.5 kg were taken from the mixed litter and manually mixed. Then a sub-sample of approximately 1 kg was taken, freeze dried and ground for analysis.

A total of 360 Single Comb White Leghorn hens of a commercial strain were assigned to 12 dietary treatments for an 8-week trial. The treatments were similar to those used in the broiler trials, i.e., a factorial arrangement of three basal diets and four levels of supplemental Se, but diets were formulated to meet the requirements of laying hens. Each diet was fed to three replicate groups of 10 hens, housed two per cage. Each cage (25 x 41 cm) was equipped with a nipple drinker and a feed trough. The cages were arranged in a full stair-step design, which allowed the manure to fall directly into a concrete shallow pit below the cages. Empty cages between replicate groups prevented cross contamination. At the end of the trial, the total amount of manure for each of the 36 groups was weighed and manually mixed. Then, a sample of approximately 1 kg was taken, freeze dried and ground for analysis.

The fluorometric procedure of Olson *et al.* (1975), as modified by Cantor and Tarino (1982), was used to measure Se in samples of ingredients, feeds, litter and manure samples. To determine the solubility of Se in broiler litter and layer manure, air-dried, ground samples, weighing 1 g, were mixed with 10 ml of simulated rain water (10^{-4} M HCl) in 50 ml culture tubes. The mixture was shaken for 10 minutes and then centrifuged at 3000 x g for 10 minutes. The supernatant was then filtered through a 1 micron filter and analyzed for Se. Solubility of Se was calculated as follows:

% Solubility = (total Se extracted from the sample)/ (total Se in Sample) x 100

RESULTS

The concentration of Se in the broiler and layer diets is presented in Table 1. The Se concentrations ranged from 0.06 ppm to 0.66 ppm in broiler diets and from 0.05 ppm 0.48 ppm in layer diets.

Table 1. Concentration of Selenium in Experimental Diets[a].

		Diet		
Basal Diet	Added Se, mg/kg	Broiler Starter	Broiler Grower	Layer
Local soy	0	0.06	0.06	0.05
	0.1	0.19	0.15	0.11
	0.2	0.31	0.26	0.21
	0.3	0.40	0.35	0.30
High-Se soy	0	0.33	0.24	0.17
	0.1	0.45	0.37	0.27
	0.2	0.56	0.46	0.39
	0.3	0.66	0.56	0.48
Fish meal	0	0.24	0.23	0.18
	0.1	0.34	0.30	0.25
	0.2	0.50	0.38	0.38
	0.3	0.59	0.47	0.48

[a]Determined by analysis.

Dietary treatments did not affect growth performance parameters in the broiler studies. Overall averages for the variable measured were as follows: body weight at 6 weeks, 2.04 kg; feed intake for Weeks 1-3, 0.97 kg; feed intake for Weeks 4-6, 2.76 kg; and feed/body weight, 1.82.

Values for the amount of Se consumed and excreted per bird during the 6-week growing period and the percentage of Se intake excreted are shown in Table 2. The amount of Se consumed and excreted both reflected dietary Se concentrations and were significantly increased by supplemental Se and the use of high Se soybean meal or fish meal. Litter Se levels after two flocks, which were similarly affected by treatments, ranged from 0.13 to 1.34 mg/kg dry matter. Total Se excreted per bird was less than 1 mg with the highest dietary Se levels. The percentage of Se intake excreted by broilers, which was unaffected by treatments, ranged from 36 to 47% with an average of 41%. The lack of a treatment effect and the small range of values in percentage of Se excreted indicate that a value of approximately 41% can be used to calculate Se excretion.

Table 2. Effect of Broiler Diets on Selenium Intake and Excretion (amount per broiler during 6 weeks).

Basal Diet	Added Se, mg/kg	Se consumed[a] mg	Se excreted[a] mg	Excreted Se as % of intake
Local soy	0	0.21	0.09	41
	0.1	0.59	0.22	37
	0.2	1.00	0.38	38
	0.3	1.33	0.58	43
High-Se soy	0	1.00	0.38	38
	0.1	1.46	0.58	40
	0.2	1.80	0.74	41
	0.3	2.19	0.91	42
Fish meal	0	0.85	0.31	36
	0.1	1.16	0.50	43
	0.2	1.52	0.64	42
	0.3	1.87	0.88	47

[a]Significant effect of basal diet and Se supplement.

Dietary treatments did not affect feed intake, egg production, and egg weight of laying hens. During the 8-week period, the following average values were obtained: feed intake, 105 g per day; hen-day egg production rate, 72%; egg weight, 66 g; and manure excreted, 1.3 kg dry matter.

Values for total Se intake and excretion and percentage of Se intake excreted during the 8-week layer trial are shown in Table 3. The amount of Se consumed and excreted closely reflected dietary Se levels and were significantly affected by treatments, while the percentage of Se intake excreted was relatively constant, regardless of treatment. The highest amount of Se excreted during 8 weeks was 1.56 mg/hen for hens fed the fish meal diet with 0.3 ppm supplemental Se. The concentration of Se in layer manure ranged from 0.14 mg/kg dry matter for hens fed the unsupplemented basal diet with local soybean meal or fishmeal plus 0.3 ppm supplemental Se. The percentage of Se intake excreted ranged from 49 to 66% with an average of 55%. As seen in the broiler trial, this parameter was unrelated to the nature of the dietary Se source. Thus, a value of 55% appears to be reasonable for estimating the percentage of dietary Se excreted by laying hens.

Table 3. Effect of Layer Diets on Total Selenium Intake and Excretion (amount per hen during 8 weeks).

Basal Diet	Added Se, mg/kg	Se consumed[a] mg	Se excreted[a] mg	Excreted Se as % of intake
Local soy	0	0.26	0.19	66
	0.1	0.64	0.38	59
	0.2	1.24	0.70	56
	0.3	1.78	1.07	60
High-Se soy	0	0.96	0.47	49
	0.1	1.63	0.82	51
	0.2	2.28	1.21	53
	0.3	2.78	1.45	52
Fish meal	0	1.04	0.56	54
	0.1	1.53	0.85	56
	0.2	2.16	1.07	50
	0.3	2.75	1.56	57

[a]Significant effect of basal diet and Se supplement.

The solubility of Se in both broiler litter and manure samples was not affected by dietary treatment. The percentage of Se extracted from the broiler litter samples had an average of 25% with a range of 22 to 28%, while the respective average for layer manure was 34% with a range of 26 to 42%. Similar to our findings on the percentage of Se excreted, the results on extractability or solubility permit generalizations to be made to facilitate the prediction of the environmental impact of feeding supplemental Se.

CONCLUSIONS

Se concentrations in broiler litter and layer manure closely reflected dietary Se levels. The nature of the basal diet and the level of supplemental Se did not influence the percentage of dietary Se excreted nor the solubility of the Se in the Excreta. Broilers excreted approximately 41% of the dietary Se, of which 25% was soluble. Laying hens excreted an average of 55% of dietary Se, of which 34% was soluble.

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McCLENDON'S CREEK WATERSHED DEMONSTRATION PROJECT -- POULTRY OVERVIEW

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An EPA project was awarded, under federal Clean Water Act, Sec. 319 funding, to an interagency group lead by the North Carolina Cooperative Extension Service (NCCES). The interagency group consists of representatives of the USDA-Natural Resource Conservation Service, Moore County Soil and Water Conservation District, NC Division of Environmental Management, and the NC Division of Soil and Water Conservation, as well as the representatives from the NCCES. This project was approved for fiscal years 1996-98, with an extension possibly through 1999.

The project location was to be focused on the McClendon's Creek watershed of the Deep River tributary of the Cape Fear River System. This watershed was chosen because of the size and diversity of enterprises within its drainage area, and also because the entire watershed was contained within one governmental (county) unit, in North Carolina.

The McClendon's Creek watershed covers over 67 thousand acres in Moore County, North Carolina. Agricultural land uses consist of 3,000 acres of cropland (corn, small grains, soybeans, and tobacco) and 3,200 acres of pasture. Animal operations include more than ten poultry operations, one swine operation, and more than 20 beef pasture operations. Urban land uses include the communities of Seven Lakes and Carthage. Best Management Practices (BMP's) to be installed and evaluated through this project are intended to reduce nutrient and sediment runoff from these land uses and to prevent stream bank erosion. Water quality goals include a reduction in nutrients of 50% and a reduction in sediment of 40%.

Educational meetings, field days, demonstrations and newsletters were all specified as means of promoting BMP implementation.

POULTRY PROJECT OVERVIEW

With ten poultry operations in the watershed, each with several houses, the potential for nutrient overloading to McClendon's Creek from this portion of the agricultural industry is significant. Poultry involvement in the project included teaching farmers BMP's for correct litter handling, and aid in the establishment of a litter collection facility aimed at transporting litter out of the watershed. Operations to be included in the project were evaluated against a set of criteria (Figure 1), with the steering committee valuating the operation and judging its appropriateness. If farming operations met the intended criteria for inclusion in the project, they still were expected to carry out certain functions as a measure of their involvement (Figure 2).

Figure 1. Selection Criteria for Cooperators--McClendon's Creek Project.

- Potential for improved management
- Willingness to cooperate and serve as demonstration site
- Represent different poultry companies
- Different size operations
- Ease of measurement of water quality improvement
- Visible to farm and non-farm audiences
- Different soil and crop characteristics

Figure 2. Expectations of Cooperating Farms--McClendon's Creek Project.

- Soil, waste and tissue sampling
- Water Sampling
- Crop inventory including types of crops, fertilizer applications, and pasture quality for two years before selection for participation in the project
- Use of waste storage and application facilities and equipment
- Whole farm nutrient management planning
- Availability of farm for use as demonstration facilities and for use as tour stops, and for field days

BMP's for Poultry Operations

In the education of farmers from poultry operations on the correct BMP's that apply in managing their manure, a holistic approach was taken in total farm management. Since most farmers use litter on their crops or pastures, correct manure management for controlling nutrient loss, involves a number of procedures. Farmers were taught the importance of soil and litter testing, the importance of applying manure at agronomic rates, the importance of timing application to the growing period of the crop, and the importance of streambank setbacks for litter spreading and storage. Streambank restoration and fencing to keep cattle out of streams were used as a means of controlling sediment and nutrient loss.

Litter Collection Facility

The original intention of the steering committee was to establish a central point for the accumulation of poultry litter in order to facilitate the movement of litter to points outside of the McClendon's Creek watershed. It became obvious that the expense and labor involved with handling the litter twice,made this unacceptable. The committee agreed to look for an end user for a substantial amount of litter, and coordinate the delivery of a large amount of litter to that end user.

The committee selected a company with a national marketing system in place, for mulch and compost products. This company expressed an interest in composting poultry litter and making the compost an addition to its product marketing mix. Working with this company fit nicely with the committee's initial thoughts of reducing nutrient excesses within the watershed, by moving a significant amount of the manure production to areas where the nutrients were needed.

About 300 tons of litter has been delivered to the company. The product has been placed in three windows, one treated with an enzyme to aid in composting, one with litter mixed one:one with pine bark "fines", and one with only poultry litter. The company has assumed responsibility for daily temperature monitoring, and periodic turning of the windrows. NCCES personnel have assumed responsibility for periodic compost sampling for nutrients and weight. NCCES personnel will make a final judgment of the quality of the compost made, in each of the three windrow samples.

Findings to Date

Because of delays in starting, the project is only a little more than 50% completed. Cooperating farmers have been designated, and a number of BMP's have been implemented. Data is being collected on nutrient and sediment loading, both up- and down-stream of these sites. Preliminary analysis of the data shows changes to loading rates of streams.

Neither data on the quality of compost, nor its acceptability by the public, has yet been obtained. The company, on the other hand, is very interested in this project and very interested in making the product available to its customers.

EVALUATION OF SOIL COVER AS A MEANS OF CONTROLLING FLIES IN FIELD APPLIED MANURE

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Experiments were conducted to evaluate the effectiveness of soil cover in controlling field emergence of flies. A laboratory experiment using soil columns was developed using a factorial design to evaluate four factors, each at four levels. The four factors were soil type, depth of soil cover, soil moisture, and soil compaction.

The soil types were Hagerstown silt loam, Bucks silt loam, Rumford sandy loam and pure sand. The soil depths evaluated were 0, 5.1, 10.1, and 20.3 cm. The soil moisture levels evaluated were 8, 10, 12, and 14%. The compaction levels investigated were bulk densities of 1.35, 1.45, 1.55, and 1.75 gm/cm^3. There are 256 different possible combinations of these factors when each is considered at four different levels. Each of these 256 different combinations were replicated three times.

The fly emergence data was evaluated for all soil types as emergence counts and as percent emergence (For Bucks and Hagerstown soils only). The emergence count means ranged from 9.1-16.1 (out of a possible 20) for 0 cm. soil cover, 0-1.6 for 5.1 cm.soil cover, 0-4 for 10.2 cm soil cover, and 0-1.6 for 20.3 cm. of cover. Analysis of the emergence data using the mixed procedure technique in the SAS program indicated that each soil type yielded significantly different results. Soil type was significant at the 0.001 level. However, the differences between the Bucks and Hagerstown soils were small. Since the initial evaluation determined that each soil type reacted differently, additional evaluations were done by individual soil type. Soil depth was a significant variable for all soil types (0.001 level). The significance of moisture and compaction varied by soil type. With the Rumford soil; moisture (0.001 level), compaction (0.001 level), and moisture by depth interaction (0.001 level) were all significant. Compaction (0.0029 level) was the only significant term other than depth for the sand.

This data demonstrates that complete control of fly emergence can be obtained with as little as 7.1 cm. soil cover of Bucks or Hagerstown soil. This control was achieved with a bulk density of 1.35 gm/cm^3 and a uniform soil cover. In order to increase the bulk density of the soil to 1.35 gm/cm^3 after primary tillage, multiple secondary tillage trips would be required. This would increase the bulk density and result in improved fly control, this would also increase the risk of soil erosion. Therefore it may be necessary to use another method to control the flies in the manure before it is taken to the field which has less environmental impact than tillage.

EVALUATION OF DEEP STACKED TURKEY LITTER (DSTL) AS AN ALTERNATIVE FEED FOR GROWING AND FINISHING STEERS

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ABSTRACT

The objective of this study was to evaluate Deep Stacked Turkey Litter (DSTL) as an alternative feed for growing and finishing beef cattle. A total of 150 steers with a mean initial weight of 377 kg were randomly divided into three ration groups of 0 (control), 20 or 40% DSTL for a period of 294 days. DSTL was analyzed for microbial pathogens, pesticides, heavy metals, and nutritive value. Mean daily gains did not differ between the three treatments and averaged 1.14 kg/day. The mean dressing percentage (x=58.5%) of the control group tended to be somewhat greater ($P<.01$) than the mean dressing percentages for the two DSTL groups (x=57.8%). The mean backfat thickness of 8.8mm in the control group was significantly greater than the 7.6mm for the 40% DSTL group ($P<0.5$). Yield grades differed significantly ($P<0.01$) between all groups with the control group exceeding the two other groups. Based on five samples from each of the three treatment groups, mean blood urea nitrogen of the control and 20% DSTL group exceeded ($P<.05$) that of the 40% DSTL group. Pesticide and heavy metal concentrations in the diets were within FDA guidelines. Microbial pathogens were not detected. Feed cost per kg of weight gain were $1.43, $1.10 and $1.01, respectively. These results suggest that utilizing DSTL as an alternative feed would be economically beneficial to both beef and turkey producers and would have potential for reducing environmental pollution.

INTRODUCTION

Currently Michigan produces over 300,000 tons of turkey litter annually from growing houses. Disposal of litter as fertilizer is difficult due to nutrient management concerns. Processed poultry litter has been used in the past as an alternative feedstuff for cattle due to its nutritive value.

Reviews on feeding animal wastes include that of Bhattacharya and Taylor (1975), Smith and Wheeler (1979), and Fontenot (1991). Reviews concerning health aspects of feeding animals wastes were published by Fontenot and Webb (1975) and McCaskey and Anthony (1979).

No extensive research on turkey litter as an alternative feedstuff is seen in the literature. However, there are a few reports indicating its use as a feedstuff. Cross (1976) used turkey litter to feed replacement dairy heifers while Kirk and Fontenot (1987), McClure and Fontenot (1987, 1988 and 1989), and Harvey *et al.* (1994) used turkey litter to feed beef cattle. Most of these reports were made in research reports or as an abstract. Since there are limited studies, the purpose of this work was to conduct a more detailed study of the economics, toxicology, growth performance and carcass evaluation of steers fed deep stacked turkey litter (DSTL) as an alternative feed. In addition, the livestock industry is very interested in alternative feedstuffs since the cost of feed ingredients is very high at present.

MATERIALS AND METHODS

The Michigan State University feeding trial was conducted at a modern feedlot farm in Ottawa County. The producer annually raises over one thousand beef cattle at this facility. At the same time he had a partnership with the adjacent turkey farm which grows over 200,000 turkeys annually. Thus, he was confronted with disposal of animal waste from both species.

In March 1995, approximately 100 tons of turkey litter from turkey grower houses was brought to the cattle facility and deep stacked with a heavy tractor on concrete. Samples of the litter were analyzed for its microbial pathogens, pesticides and heavy metals at appropriate laboratories of Michigan State University. The nutrient analyses of DSTL were carried out at the Northeast DHI Forage Laboratory, Ithaca, New York.

One hundred and fifty Holstein steers having a mean weight of 377 kg were assigned to three treatment groups. Each animal was individually tagged and weighed. Fat biopsies were taken at random on steers from each group prior to feeding the experimental rations. The three treatment levels were as follows:

Treatment - I	0% - DSTL (control)
Treatment - II	10-20% - DSTL
Treatment - III	20-40% - DSTL

The feeding trial began on November 1, 1995. The first 20 days were an adapting period to cattle in groups two and three. The diets for the cattle included: corn silage, high moisture corn, protein and mineral supplements. DSTL replaced protein supplement for two groups.

After an initial growth period, the cattle manager insisted on doubling the quantity of DSTL used in treatments two and three. Hence the levels of DSTL changed to 20 and 40% for these two groups, respectively, as of January 1, 1996.

The cattle were individually weighed initially and at the end of the trial. Group weighing of cattle was done on a monthly basis. Similarly, feed intake was also tabulated on a monthly basis. Prior to the end of the trial, blood samples and fat biopsies were taken at random from cattle in each of the treatment groups. Fifteen days prior to slaughter, DSTL was removed from the diets of groups two and three and then all cattle received the conventional ration. All cattle were weighed to get the final weight prior to slaughter.

At slaughter, data was collected on carcass characteristics such as side weight, dressing percentage, yield grade, quality grade, and backfat thickness. Tissue and fat samples were taken for the analysis of pesticides.

Because a one-way completely randomized design with quantitive response variables was utilized, ANOVA along with pairwise t-tests on treatment group means were used to infer upon the treatment effects.

RESULTS AND DISCUSSION

The cattle in all treatments readily consumed the diets. No associated apparent physical problems were observed. However, two cattle were removed from the group fed 40% DSTL and one from the 20% DSTL group due to lameness. No mortality occurred during the trial. DSTL temperature in the stack ranged from 95 to 100 degrees F. This could be attributed to thorough packing with heavy tractor as well as due to high moisture of the litter. DSTL was analyzed for microbial pathogens, such as *Campylobacter jejuni*, salmonella, coliform and clostridia species as well as heavy metals and pesticides. The results showed that all of the above were neither present or only in negligible levels (within FDA guidelines).

Nutrient analyses of DSTL is presented in Table 1. DSTL is a good source of crude protein, calcium and phosphorus. The ash level present in DSTL indicated that it is safe to use as a feedstuff for cattle. Nutrient analyses of feed ingredients for all treatments are presented in Table 2. Crude protein for treatments II and III was provided totally from DSTL. Available protein from the DSTL group diets were sufficient.

Table 1. Nutrient Analysis of DSTL (% of DM).

	Average	Range
Crude Protein	33.7	31.2 - 26.0
Available Protein	30.7	28.5 - 33.5
Calcium	2.7	2.0 - 3.3
Phosphorus	1.8	1.3 - 2.2
Ash	17.0	16.8 - 17.4

Table 2. Nutrient Analysis of Diets Containing Deep Stacked Turkey Litter (% of DM) Fed to Growing and Finishing Steers.

Nutrient	Control	10% DSTL	20% DSTL	40% DSTL
% Sample Dry Matter	49.6	52.4	40.5	48.4
% Crude Protein	11.5	12.5	18.2	18.7
% Available Protein	11.2	12	16.9	17.6
% Unavailable Protein	0.3	.5	1.3	1.1
% Adjusted Crude Protein	11.5	12.5	18.2	18.7
% Acid Detergent Fiber	9.5	9.5	13.8	12.8
% Neutral Detergent Fiber	19.4	18.1	14.1	22.1
% TDN	87	87	83	84
% Calcium	.50	.58	1.78	1.37
% Phosphorus	.27	.42	.87	.82
% Magnesium	.16	.18	.30	.27
% Potassium	.66	.84	1.34	1.30
% Sodium	.145	.169	.383	.334
PPM Iron	159	150	543	381
PPM Zinc	38	74	195	178
PPM Cooper	10	21	73	72
PPM Manganese	35	62	191	168
PPM Molybdenum	1.8	1.5	4.6	42

Usage of corn in the experimental diets were considerably reduced compared to the control diet. The cost per Kg of gain and cost per ton of feed with DSTL valued at a zero price as well as cattle performance is presented in Table 3. Cattle performance is measured by dry matter intake, feed efficiency and average daily gain. Feed efficiency for the three groups on DM basis were 8.89, 9.09 and 8.99, respectively, for the control, 20% and 40% DSTL groups. Mean daily gain did not differ significantly between the three treatment groups and averaged 1.14 kg/day.

Table 3. Performance Summary of Growing and Finishing Steers Fed DSTL Diets.

Item	Treatment		
	Control	20% DSTL	40% DSTL
Number of Animals	50	49	48
Days of Feed	294	294	294
Final Weight (kg)	651.7	647.2	656.2
Avg. Daily Gain (kg)	1.15	1.12	1.16
Feed Efficiency	8.89	9.09	8.89
Feed Cost/kg Gain	\$1.43	\$1.10	\$1.01
Feed Cost/Ton	\$105.00	\$73.00	\$67.00

The final mean weight of the steers were 651.7, 647.2 and 656.2 Kgs, respectively, for the 0, 20 and 40% DSTL fed groups. Feed cost per Kg gain was \$1.43, \$1.10 and \$1.10, respectively, for the three groups. A significant cost saving of 34% was made by the producer by feeding DSTL at the 40% level.

Pesticide levels of body fat prior to feeding and after feeding for six months, in carcass fat and in liver tissue were analyzed. These levels were within the limits recommended by the Food and Drug Administration, DVM. Blood samples taken from 5 steers at random from each of the three groups for evaluating serum nitrogen showed that its concentration was higher in the control group than with the groups of cattle fed 40% DSTL. The levels were 14.8, 8.6 and 13.4 mg/dl, respectively, for cattle fed 0, 20 and 40% DSTL. The serum nitrogen from cattle fed 20% DSTL was significantly lower ($P<.05$) than that of the control suggesting that the nitrogen source of DSTL was likely from true protein sources rather than from non-protein nitrogen (NPN). The serum nitrogen from cattle fed 20% DSTL was also lower ($P<.05$) than the 40% DSTL. Further, it suggests that in the control ration the protein source could be from urea. The carcass characteristics of steers slaughtered from the three groups are listed in Table 4. The dressing percentage of cattle from the control group was 58.4% and were both 57.8% for the two groups fed DSTL. The mean dressing percentage for both DSTL fed groups were lower (P<.01) from the cattle fed the control diet. There were no significant difference among side weights of carcasses of the three treatments. Backfat thickness on carcasses of the three treatments were as follows: Treatment-I = 8.89 mm, Treatment-II = 8.38 mm and Treatment-III = 7.62 mm. The mean backfat thickness on carcasses of cattle fed 40% DSTL was significantly lower (P<.05) than that of the control diet. This finding is very significant since the cattle industry in recent years has been spending large sums of money in research to find a way to reduce fat in carcasses due to consumer demands and for health reasons.

Table 4. Effects on Carcass Characteristics of Feeding Deep Stacked Turkey Litter (DSTL) to Growing and Finishing Steers.

	Treatment		
Characteristic	Control	20% DSTL	40% DSTL
Side Weight (kg)	188.9 (7.7%)	187.4 (7.6%)	188.4 (9.7%)
Dressing Percentage	58.1 (4.1%)	57.4 (3.3%)	57.4 (2.5%)
Backfat Thickness (mm)	8.89 (28.1%)	8.38 (27.4%)	7.62 (33.4%)
Yield Grade Score	3.2 (20.5%)	2.7 (14.2%)	2.2 (31.6%)
Quality Grade	35 Head	40 head	39 head
Prime	8.6%	2.5%	0.0%
Choice	88.6%	97.5%	74.4%
Select	2.8%	0.0%	25.6%

*Numbers in Parenthesis are Coefficients of Variation (CV)

Yield grades were significantly different between all treatments (P<.01). Cattle fed the control diet had better yield grades than cattle fed DSTL diets. As the percentage of DSTL increased in the diet the yield grade deteriorated. Quality grade was lowest for the 40% DSTL fed group with 25% of cattle in this treatment grading "Select". This was probably due to the lower dietary energy level in this group. To alleviate this problem producers may want to reduce the level of DSTL in the diet and increase the energy level accordingly during the finishing stage of the cattle.

An imputed value for DSTL as a feed ingredient developed from this trial is presented in Table 5. However, in this trial, no dollar value was assigned to DSTL since the producer had this available to him free.

IMPLICATIONS

The results of this study suggests that protein sources in the diet from expensive sources such as soybean meal can be completely replaced by feeding DSTL. In addition to protein, a portion of corn used for energy and minerals such as calcium and phosphorus may be substituted by feeding DSTL ration to growing and finishing cattle. DSTL, as an alternative feed can provide cattle producers relief in the cost of production, especially when the feed prices go up very drastically. The producer saved 34% of cost by using DSTL at 40% level in the diet.

This study also suggests that DSTL when used as an alternative feedstuff for cattle, the turkey producer could make more profit when compared to selling it for fertilizer. DSTL may also be used for replacement dairy heifers. Another important implication of this approach of using DSTL as an alternative feedstuff is that it also reduces the pollution in the environment.

Table 5. Imputed Values of DSTL Based on Field Trial Performance Data.

Imputed 20% DSTL Values

Corn & Silage Price		Protein & Rumensin Kg Price			
Corn/Mg	Silage/Mg	$ 0.176	$ .220	$ 0.26	$ 0.30
$ 78.74	$20.94	$ 63.93	$ 74.13	$ 84.33	$ 94.52
$ 98.42	$24.53	$ 77.99	$ 88.18	$ 98.38	$108.58
$118.10	$28.11	$ 90.32	$102.51	$112.71	$122.91
$126.76	$29.68	$ 98.38	$108.57	$118.77	$128.97
$137.79	$31.69	$106.37	$116.57	$126.76	$136.96

*Price of Other Feedstuffs Held Constant.

Imputed 40% DSTL Values

Corn & Silage Price		Protein & Rumensin Kg Price			
Corn/Mg	Silage/Mg	$ 0.176	$ .20	$ 0.26	$ 0.30
$ 78.74	$20.94	$ 47.40	$ 52.91	$ 59.25	$ 64.21
$ 98.42	$24.53	$ 56.77	$ 62.27	$ 67.79	$ 73.03
$118.10	$28.11	$ 66.14	$ 71.10	$ 76.61	$ 82.12
$126.76	$29.68	$ 69.72	$ 75.23	$ 80.47	$ 85.98
$137.79	$31.69	$ 74.68	$ 80.19	$ 85.70	$ 90.94

*Price of Other Feedstuffs Held Constant.

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RECYCLING HEN MORTALITIES BY USING A FEATHER DIGESTING ENZYME OR SODIUM HYDROXIDE TREATMENT AND FERMENTATION

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Commercial practice would suggest that 7.5% hen mortality is an annual average that require proper disposal or recycling. However, simple disposal of these mortalities would mean the loss of valuable agricultural nutrients. Therefore, many researchers have tried to recycle poultry mortalities into animal feed ingredients by rendering or extrusion. However, feathers on mortalities may affect the quality of end-product meals because of their poor digestibility and constitute approximately 10% of the body on dry weight basis (Webster, 1997). Thus, a feather digesting enzyme or chemical pretreatment of feathers on mortalities might improve the quality of the end-product meal. Therefore, the objectives of this research were; 1) to determine the effect of enzyme or sodium hydroxide treated hen mortalities with lactic acid fermentation for preserving nutrients and eliminating pathogenic microorganism; 2) to determine the nutritional composition and protein quality of enzyme or sodium hydroxide treated and fermented hen mortalities.

MATERIALS AND METHODS

Ninety commercial SCWL hybrid hens 65 wk old were used for this study. There were two dead bird treatments (Insta-pro enzyme and NaOH) and one control (non-treated group). The enzyme contained: protease, dried B. Subtillis fermentation extract, amylase, gumase, sodium bicarbonate, sodium sulfate, sodium sulfite, potassium chloride. The enzyme treatment included 10 dead birds treated with 1.204 g of feather digesting enzyme per 1kg of dead birds and 2.5 L of water incubated for 12 hr at 22 C. The NaOH treatment included 10 dead birds treated with 2.5 L of 0.4 N NaOH for 2 hr at 22 C. During incubation, a 45° mixer with rubber picking fingers vigorously agitated the dead birds. After incubation, the enzyme or NaOH treated dead birds were ground and placed in 19

L plastic buckets with 10% sugar (w/w) for fermentation. Two plastic pipes (1.5 cm inside diameter) with 10 holes drilled in the lower shaft were inserted through the plastic lids into the ground birds. Rubber balloons located on the top end of the plastic pipes were used to collect gases (NH_2, and H_2S) emitted from the fermenting treatments. Through the plastic pipes, samples of treatment fluids were collected to measure pH without opening the lids. Treatment pH and gas concentrations (NH_3 and HS) were measured on Days 1, 3, 7, 14, and 21. Concentrations of NJ_3 and H_2S were measured from gases collected in the balloon samples using a sampling kit (samplair pump kit, model A, Pittsburgh, PA 15230) and pH was determined by pH meter. The buckets were opened on Day 21 and evaluated for appearance and odor. Control (fresh dead birds), and two fermented treatments (enzyme and NaOH) were autoclaved at 18 PSI and 260 F for 90 min. After autoclaving, samples were dried in a forced air oven at 60 C until a constant weight was reached, then grounded in a hammer mill and stored at -20 C until they were analyzed for fed. The dried ground samples were analyzed for crude protein (CP), ether extract (EE), ash (AOAC, 1990), calcium (Ca), phosphorus (P), and sodium (Na) (USEPA, 1986). Pepsin digestible nitrogen was analyzed according to the procedure of the AOAC (1990). The samples were also evaluated for the presence of *E. coli, Staphylococcus aureus,* Lactobacillus species, Streptococcus species and Salmonella. All analyses and determinations were done in triplicate. A broiler chick bioassay was utilized to evaluate the autoclaved end-products (control hen meal (C-HM) that was non-fermented, and the enzyme treated hen meal (E-HM) and NaOH treated hen meal (N-HM) that were fermented before autoclaving). Dietary treatments consisted of a non-protein diet, two positive controls (23% and 13% CP), and the 13% CP C-HM, E-HM, and N-HM.

RESULTS AND DISCUSSION

Figure 1 shows the pH change of the enzyme or NaOH treated dead hens during the 21 day fermentation. The initial pH levels of the enzyme and NaOH treated hens were 6.01 and 7.66, respectively. By Day 1 of fermentation, pH levels had dropped approximately 1 and 2 units to 5.06 and 5.38 for the enzyme and NaOH treated hens. By Days 3 and 7, pH levels for the enzyme and NaOH treatments were 4.92 and 4.61, and 4.37 and 4.52, respectively. Final pH levels of the enzyme and NaOH treated birds were 4.18 and 4.24 on Day 21. Although initial pH of the NaOH treatment was higher than that of the enzyme treatment, pH was reduced considerably from the first day of fermentation. From Day 3, pH levels of the NaOH treatment were similar to the enzyme treatment. These results indicated that the fermentation process generated enough lactic acid to reduce the pH level of either enzyme or NaOH treated dead hens to approximately 4 while the sodium hydroxide pretreatment had little affect on the overall pH of dead hens during fermentation.

The gases (H_2S and NH_3) generated by enzyme or NaOH treated dead hens during fermentation are shown in Figure 2. No H_2S was detected on Days 1 and 3 for the enzyme treated hens. However, 347 ppm of H_2S gas was measured on Day 7. Hydrogen sulfide production decreased to 258 ppm on Day 14 and 75 ppm on Day 21. For the NaOH treatment, H_2S gas was measured from the first day of fermentation. Over 800 ppm of H_2S gas was measured on Days 1 and 3. Then, H_2S gas production started declining to 627 ppm on Day 7 and 233 and 78 ppm on Days 14 and 21, respectively. Ammonia gas was not detected during the entire fermentation period in either the enzyme or NaOH treatments. A possible reason why H_2S production was elevated in the NaOH treatment is that sulfate from sulfur containing amino acids, especially, cysteine was available for H_2S production since sodium hydroxide could hydrolyze cystine disulfide bonds during the NaOH pretreatment. Under the conditions with low oxygen and organic substrate and sulfate are available, H_2S can be produced by some anaerobic bacteria, e.g. *Desulfovibrio* and *Desulfotomaculum* (NRC, 1979). Lactic acid fermentation provides good conditions for hydrogen sulfide producing bacteria as long as sulfate is available.

Table 1 shows the microbiological analysis of control (non-treated dead hens) and enzyme or NaOH treated dead hens before and after 21 day fermentation period. Levels of *E. coli* in the control, enzyme, and NaOH treatments before fermentation were 4.23, 5.66, and 4.53 log cfu/g, respectively. Higher levels of *Staphylococcus aureus* were also observed for the enzyme treated hens compared to either the control or the NaOH treated hens suggesting pathogen multiplication early with the enzyme treatment of the dead hens. While *E. coli* and *Staphylococcus aureus* were present and a concern before fermentation was initiated, enzyme and NaOH treatment samples taken after the fermentation period indicated these potential pathogens were eliminated. Streptococcus concentrations were not much changed for the treated hens during fermentation. However, Lactobacillus levels of the enzyme and NaOH treatments increased during the 21 day fermentation period.

The chemical composition and potential feeding value of the control hen meal (C-HM) e.g. autoclaved fresh hens, enzyme treated hen meal (E-HM) e.g. enzyme treated, fermented, and autoclaved hens, and NaOH treated hen meal (N-HM) e.g. NaOH treated, fermented, and autoclaved hens. There were not significant differences in dry matter (DM) among treatments ($P<0.05$) averaging 40.15%. Crude protein (CP) level of the C-HM (49.38%) was significantly higher CP level than either the

E-HM (39.11%) or N-HM (40.66%) (P<0.05). Ether extract (EE) concentration of the C-HM (36.43%) was significantly higher than the E-HM or N-Hm (30.45 and 28.13%, respectively) (P<0.05). Ash content of the E-HM was significantly less than the C-HM and E-HM treatments (P<0.05). The C-HM overall had higher nutrient concentration than the other treatments because it did not include 10% sugar (w/w) that the others contained for fermentation. The NaOH treated hen meal (N-HM) was negatively affected in terms of pepsin digestibility compared to either the control or enzyme treated hen meals (P<0.05). It indicated that although enzyme treatment improved pepsin digestibility, significantly over the N-HM, and numerically over C-HM. These later differences were not significant. Calcium level of E-HM was significantly lower than C-HM (P<0.05). However, there was no significant difference between N-HM and C-HM or E-HM. The phosphorus level of C-HM was significantly higher than E-HM and N-HM, and the sodium level of the N-NH was significantly greater as a result of NaOH pretreatment.

Table 3 shows the growth performances of chicks fed 13% CP test diets made from C-HM, E-HM, and N-HM compared to control diets with 13% and 23% CP made from casein and gelatin. The weight gain of chicks fed non-protein diet decreased from -3.1 to -10.1 g as the assay period increased from 2 to 8 days. However, the weight gain of the 13% and 23% positive controls increased from 28.0 and 41.7 to 138.1 and 158.4 g, respectively, as the assay period increased from 2 to 8 days. The weight gain of C-HM, E-HM, and N-HM also increased from 11.26, 6.78, and 6.86 on Day 2 to 87.78, 24.54, and 14.68 g on day 8, respectively. The 23% positive control diet had the highest weight gain while the non-protein diet has a net negative weight gain during the entire assay period. The weight gain of the chicks fed 13% positive control diet was higher than either the 13% C-HM, E-HM, and N-HM treatments. Of the test diet treatments, the C-HM chicks had a higher weight gain than either the E-HM or N-HM during entire assay period. Although the weight gain difference between chicks fed E-HM (6.79 g) and N-HM (6.86) at 2 days was small, the weight gain of chicks fed E-HM were approximately 1.5 times higher than the N-HM at 4, 6, and 8 days. The gain to feed ratio (G/F) of the non-protein fed chicks was realtively constant (-0.11 and -0.12) during entire assay period. The G/F of the 13% positive control (0.66) on day 2 was higher than those on day 4, 6, and 8 (0.60, 0.59, and 0.59).
The C/F of 23% positive control gradually decreased from day 2 to day 6. However, the G/F of the C-HM fed chicks increased from 0.35 to 0.49 as assay period increased. The 23% positive control showed the highest C/F while the non-protein was negative. The 13% positive control had a higher G/F than the 13% C-HM, E-HM, and N-HM treatments during entire assay period and the G/F of C-HM was higher than E-HM or N-HM. The G/F of

E-HM was higher than N-HM during entire assay period except for day 2. In this study, the fermented products (E-HM and N-HM) had lower weight gain and G/H than the non-fermented product (C-HM). These results indicated that fermentation of dead birds depressed the growth performance and sodium hydroxide further depressed growth performance of chicks compared to enzyme treated dead birds.

CONCLUSIONS

This study showed that enough lactic acid was produced to reduce pH to approximately 4 in either enzyme or sodium hydroxide treated dead hens during 21 days of fermentation to preserve dead hens without contamination. However, the sodium hydroxide pretreatment of dead hens significantly reduced *in vitro* pepsin digestibility compared to control or enzyme treated dead hens. Furthermore, fermentation had a adverse effect on growth performance in a broiler chick bioassay. This study demonstrated that although fermentation is a good preservation method for dead hens, fermented end-products would be not a good feed ingredient for young chicks. The utilization of fermented hen meal as a protein source for ruminant might be a better idea.

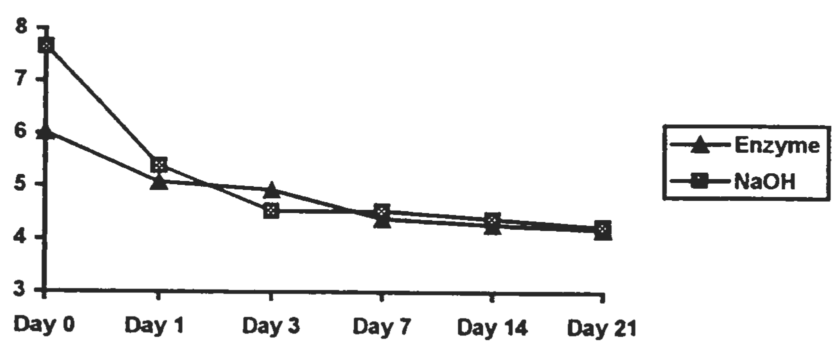

Figure 1. The pH Change of Enzyme or NaOH Treated Dead Hens During a 21 Day Fermentation.

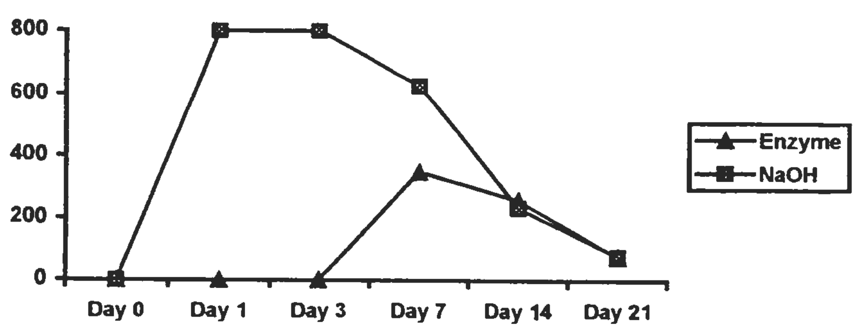

Figure 2. The Hydrogen Sulfide Production of Enzyme or NaOH Treated Dead Hens During a 21 Day Fermentation.

Table 1. Microbiological Analysis of Control, Enzyme or NaOH Treated Dead Hens Before and After 21 Days of Fermentation.

Treatment	*E. coli*	*Staphylococcus aureus*	Streptococcus	Lactobacillus
	(log cfu/g)			
Before:				
Control	4.23	4.16	0	3.95
Enzyme	5.66	5.24	5.91	5.45
NaOH	4.53	4.26	5.04	4.03
After:				
Enzyme	0	0	5.45	5.61
NaOH	0	0	5.01	6.26

Table 2. Chemical Composition of Control Hen Meal (C-HM), Enzyme Treated Hen Meal (E-HM), and NaOH Treated Hen Meal (N-HM) (DM Basis).

Treatment	Moisture	CP	EE	Ash	Pepsin digestibility	Ca	P	NA
	(%)							
C-HM[1]	59.58	45.53[a]	36.43[a]	9.30[a]	87.33[a]	2.93[a]	1.49[a]	0.29[b]
E-HM	59.32	35.98[b]	30.45[b]	7.42[b]	88.56[a]	2.29[b]	1.16[b]	0.,31[b]
N-HM	60.65	37.40[b]	28.13[b]	8.78[a]	78.22[b]	2.48[ab]	1.20[b]	0.54[a]

[a-d]Means within a column with different superscripts differ significantly ($P<0.05$).
[1]C-HM (control hen meal) = autoclaved fresh dead hens, E-HM (enzyme treated hen meal) = enzyme treated, fermented, and autoclaved hens, N-HM (NaOH treated hen meal) = NaOH treated, fermented, and autoclaved hens.

Table 3. Growth Performance of Chicks Fed Control Hen Meal (C-HM), Enzyme Treated Hen Meal (E-HM) or NaOH Treated Hen Meal (N-HM) at Different Assay Periods.

Treatment	Day 2[2]		Day 4		Day 6		Day 8	
	Wt gain	G/F[3]	Wt gain	C/F	Wt gain	C/F	Wt gain	G/F
	(g)	(g:g)	(g)	(g:g)	(g)	(g:g)	(g)	(g:g)
Non-protein diet	-3.13	-0.11	-5.70	-0.11	-8.15	-0.12	-10.14	-0.12
Control (13% CP)	28.04	0.66	60.44	0.60	96.39	0.59	138.06	0.59
Control (23% CP)	41.74	0.92	83.39	0.86	115.92	0.78	158.38	0.80
C-HM	11.27	0.35	31.52	0.21	58.77	0.29	87.79	0.34
E-HM	6.79	0.27	11.16	0.21	17.72	0.22	24.54	0.23
N-HM	6.86	0.26	7.94	0.15	12.08	0.16	14.68	0.16

[1]13% CP positive control; 23% CP positive control; C-HM (control hen meal) = autoclaved fresh dead hens; E-HM (enzyme treated hen meal) = enzyme treated, fermented, and autoclaved hens; N-HM (NaOH treated hen meal) = NaOH treated, fermented, and autoclaved hens.
[2]Day 2 = 8 to 10 day posthatching; Day 4 = 8 to 12 day posthatching; Day 6 = 8 to 14 day posthatching; Day 8 = 8 to 16 day posthatching.
[3]G/F = gain to feed ratio.

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YIELD AND NUTRIENT UPTAKE OF FORAGES ON FIELDS HEAVILY MANURED WITH ANIMAL WASTE

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ABSTRACT

Applications of 9 or 18 mg ha^{-1} of broiler litter in split or singular treatments during the summer had inconsistent effect on N uptake by the bermudagrass (*Cynodon dactylon (L.) Pers*). Split applications were not usually better than single applications. Moisture stress appeared critical and earlier applications were more likely to get the needed rains. Modest irrigation of 1.8 cm wk^{-1} effected about 20% increase in yield and the inorganic N applications of 45 Kg ha^{-1} to broiler treatments of 9 or 18 Mg ha^{-1} resulted in about a 10% increase in yields. Concentrations of P and N in the bermudagrass was constant unless the soil nutrient concentrations were very high. The common bermudagrass may remove as much P as the hybrid bermudagrasses even when it's herbage yield is 10 to 15% less.

INTRODUCTION

Effectiveness of forage as a nutrient-removal crop is dependent, in part, on the predictable and dependable growth in the field. Adapted summer and winter forages are needed in 12-month production systems to capture and mine potentially polluting nutrients, nitrogen and phosphorus. In the sequence of summer and winter crops, each species must not adversely affect the performance of the species that follows it. Increasing manure application is expected to increase forage yield, but not all nutrients in the animal waste are available to the plant. For poultry litter, estimates of N volatilization shortly after field application are 10 to 37% (Kee *et al.*, 1996). Soil storage of P may be near 90% of the total P applied (Scott *et al.*, 1995). Time of application affects the apparent uptake or recovery of N (Bigeriego *et al.*, 1979). Earlier applications usually result in greater recovery.

MATERIALS AND METHODS

A series of experiments are executed on private fields which have a history of two to thirty years of application of animal waste. The foci of the experiments include measuring for forage yields and concentrations of nitrogen and phosphorus in the forage of 1) seven bermudagrass cultivars (six hybrids and common) grown on soils fertilized with poultry litter or swine effluent, 2) applications on different dates and rates of poultry litter on Alicia bermudagrass, 3) two application rates of litter, with and without and inorganic N fertilization and with and without irrigation on Alicia hybrid bermudagrass, and 4) establishment with different dates of seeding of three winter cover crops and their effects on recovery of common bermudagrass in the Spring.

Plots are 2 by 6 m and yields are estimated from a 1 by 6 m swath cut to 5-cm height with a sickle-bar mower at either 4-week or 6-week intervals. Sub samples (approximately 1 Kg) are taken for moisture determination and for nutrient concentration determination.

In one experiment,broiler litter was applied at 9 and 18 Mg ha^{-1} as single application on ?Alicia hybrid bermudagrass in early April, May, and June,or split applications at same rates in April and June, May and July, and June and August. In the second experiment, broiler litter was applied to Alicia hybrid bermudagrass in split applications at 9 and 18 Mg ha^{-1} with or without 45 Kg of inorganic N and plots were either irrigated on 7 da intervals with 1.8 cm of water or not irrigated. In a third experiment, 9 Mg ha^{-1} of litter was applied in split application and swine effluent was applied (4 inches effluent =~380 Kg ha^{-1} of N). Tests of establishment of winter crop were made in the fourth experiment which used seeding at two week intervals with either ryegrass (*Lolium multiflorum Lam.*), red clover (*Trifolium pratense L*), or berseem clover (*Trifolium alexandrinum L.*) on fields fertilized with swine effluent. In the Spring, different plots were harvested in two week intervals.

RESULTS AND DISCUSSION

Nitrogen uptake for 18 Mg ha^{-1} litter application was greatest with single June treatment and for 9 Mg ha^{-1} application, the N uptake was greatest with a single May treatment. N uptake was not consistently affected by whether the application of litter was singular or split. Moisture appeared to be critical to the uptake and early singular applications of the litter appeared more effective.

The modest irrigation treatment increased for forage yields about 20 to 25% over the unirrigated plots. The application of inorganic N also increased yields for both 9 and 18 Mg ha^{-1} of broiler litter. This latter effect was more apparent with irrigated plots. The supplemental N fertilization increased yields by about 10%. This suggests that both N and moisture are limiting production even when 18 Mg ha^{-1} of broiler litter is applied to fields with a 30 year history of litter application.

When the bermudagrass cultivars were grown on land which had been used for waste deposition for only two years, the concentration of either N or P in the forage was constant. Thus the removal of either nutrient was proportional to the yield of bermudagrass which ranged from about 5.1 to 12.0 Mg ha^{-1} with removal of up to 180 Kg ha^{-1} of N and 30 Kg ha^{-1} of P. When effluent had been applied for about five years, the concentration of N and P was not constant for the different cultivars. On this field, the forage dry weight yields varied from 22 to 26.5 Mg ha^{-1}. The concentration of N was the same for five of the hybrid bermudagrasses. The Russell hybrid bermudagrass had a lower concentration of N and the common bermudagrass had a greater concentration of N. The N removed varied from 360 to 440 Kg ha^{-1}. Four of the cultivars had the maximum uptake of P which was near 50 Kg ha^{-1}. The common bermudagrass yielded 3 Mg ha^{-1} less than the best cultivar, but removed the same amount of P. This is very significant because the cost of planting and maintaining the common bermudagrass is much less than of any hybrid bermudagrass. These measurements were made with applications of swine effluent where moisture stress is less likely to be a persistent problem and thus may be more related to the plots with irrigation than those without irrigation.

Planting of the winter crops, ryegrass, red clover, and berseem clover, showed the establishment of clovers to be adversely affected by the bermudagrass. In the Spring, the bermudagrass regrowth was adversely affected by the berseem clover but little affected by the ryegrass. The winter clovers did produce bermudagrass plots which were much darker green, but measurements of concentrations of nutrients in these plants are incomplete.

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USE OF SOLDER FLY LARVAE TO REDUCE MANURE, CONTROL HOUSE FLIES, AND PRODUCE HIGH QUALITY FEEDSTUFF

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The black solder fly, *Hermetia illucens (L.)*, is a large wasp-like fly. It is distributed throughout the sub-tropical and tropical regions of the world and is often observed colonizing decomposing material, such as fruits, animals, and manure (Sheppard, 1983; James, 1947). We have developed a simple system for caged layers to contain the soldier fly larvae and use them to reduce manure, control house flies, *Musca domestica L.*, and produce high value feed; 29 tons (dry; 42% protein, 35% fat)/100,000 hens.

The black solder fly has a simple life cycle. In the Southeastern United States, it has three generations annually and can be collected form late spring through fall. Egg clutches average 998 eggs and usually hatch within 4 days (Booth and Sheppard, 1984). The larvae take 2-3 weeks to reach the pupal stage which usually lasts an additional 9-10 days (May, 1960). This time can vary depending on food supply and environmental conditions.

In poultry, the black soldier fly is often considered a pest species due to the apparent liquification of the manure. Actually, soldier fly larval activity reduces the moisture content of the manure, but does make it flow (Sheppard *et al.*, 1994). Modern caged layer facilities, and especially our design for soldier fly larvae harvest will contain the manure. In all of our large-scale trials, manure colonized with soldier flies was easily handled with conventional techniques.

Colonization of chicken manure by the soldier fly controls house fly populations. Researchers determined that solder fly colonization resulted in a 94-100% house fly control (Bradley and Sheppard, 1984; Tingle *et al.*, 1975; Furman *et al.*, 1959). Currently, no other method for house fly control offers more benefits. Larvadex® is the only available insecticide that comes close to producing the same level of control, but unlike soldier flies, can be significantly lower when used on resistant house flies (Sheppard *et al.*, 1989).

Two additional advantages of soldier fly larvae are the reduction in poultry manure and production of a high quality feed (Sheppard *et al.*, 1994). Other researchers have proposed using animal manure as a substrate on which house fly maggots can be reared (Calvert *et al.*, 1970; Booram *et al.*, 1977). These and similar systems require large inputs of energy and a separate facility, while our system requires neither. Bioconversion and self-collection occur within the high rise layer house (Figure 1).

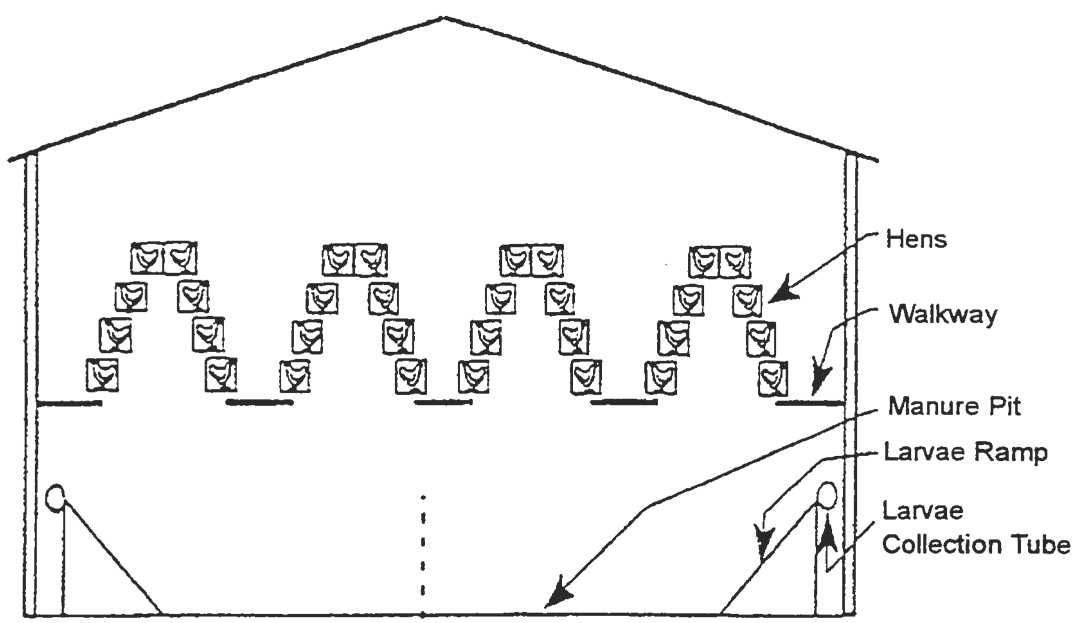

Figure 1. High Rise Hen House Modified for Soldier Fly Manure Management.

Soldier fly prepupae can be used as feed for a variety of animals, such as swine (Newton *et al.*, 1977), poultry (Hale, 1973), fish (Bondari and Sheppard, 1987), and bull frogs. The prepupae soldier flies have emptied their gut of waste and developed a large fat body to provide energy for their migration and pupation to an adult. An empty gut and maximal stored energy make this the desired stage to collect for feedstuff. Nutritional analysis (Table 1) of soldier fly larvae collected from manure has shown them to be similar to soybean meal (Table 2) (Newton *et al.*, 1977). In caged layer houses, Sheppard *et al.* (1994) determined that an estimated

1.2 pounds of soldier fly larvae could be produced annually from each hen's manure. Swine actually prefer the larvae meal over soymeal in a similarly formulated feed. Growth and development of these swine did not significantly differ from those raised on standard feed (Newton *et al.*, 1977). The value of the larvae meal is estimated at $400/ton and may be much higher when marketed to specialty markets, such as salmon or Koi where these larvae are viewed as a more "natural" feed and may command a premium price.

Table 1. Amino Acid Content of Dried Larvae Meal.[a]

Amino Acid	Percent (moisture free basis) Total	Free
Aspartic Acid	4.56	0.05
Threonine	0.55	0.04
Serine	0.12	0.04
Glutamic Acid	3.81	0.13
Proline	3.26	0.16
Glycine	2.88	0.08
Alanine	3.69	0.65
Cystine	0.06	0.03
Valine	3.41	0.12
Methionine	0.86	0.03
Isoleucine	1.96	0.07
Leucine	3.53	0.11
Tyrosine	2.51	0.24
Phenylalanine	2.20	0.05
Histidine	1.91	0.21
Lysine	3.37	0.19
Arginine	2.24	0.13
Tryptophine	0.20	0.18
Ammonia	1.20	0.07
Unknown	0.06	0.25

[a]Newton *et al.*, 1997.

Another industry that would benefit from soldier flies, as feedstuff, is the bull frog industry. However, bull frogs are not produced commercially within the U.S., because of a lack of inexpensive live food. During a two year period, we produced bull frogs, from tadpole to edible frog, using soldier fly larvae as feed. These can be produced at no real cost, as a by-product of manure management. Bull frogs are raised commercially in Latin America, using house fly larvae, produced at considerable cost, as the requisite live food.

Table 2. Proximate Composition and Calcium and Phosphorus Content of Dried Larvae and Digestion Trial Diets.[a]

Item	Dried Larvae	Diet	
		Soybean	Larvae
Crude Protein %	42.1	20.5	20.6
Ether Extract %	34.8	11.7	13.5
Crude Fiber %	7.0	2.1	3.8
Moisture %	7.9	10.7	10.1
NFE, %	1.4	59.0	53.0
Ash, %	14.6	5.9	9.0
Calcium %	5.0	0.52	2.71

[a]Newton *et al.*, 1977.

A simple method has been developed for self-harvest of soldier fly larvae (Newton *et al.*, 1977). The system uses a concrete manure basin under the cage batteries. The floor of the basin has a 40° gradient which allows the prepupae to exit the manure. A 4 in diameter plastic pipe with a 0.75 in gap is attached at the top of the 40° slope with the gap meeting the top of the slope. Migrating prepupae climb the incline into the pipe which leads to a collection center. Standard waste removal procedures are used for this manure basin design. This system has been successfully used in a pilot study (2,000 hens, mini high-rise) and a schematic is shown in Figure 1.

The black soldier fly can save on the cost of manure removal, house fly control, and product a valuable feedstuff. The larvicide, Larvadex®, can cost as much as $0.09/hen/year and manure removal and surface application costs $0.28/hen/year in high-rise houses (Ritter, 1992). Soldier fly activity can reduce manure accumulation by 25% and eliminate house flies all together. Using these savings, we calculate a value of $0.16/hen/year (0.25 x $0.28 + $0.09). Additional income is acquired through the sale of the harvested larvae which has been estimated at $400/ton, dried (29 tons dry/100,000 hens). Adding all of the economic benefits for utilizing black soldier fly yields a total of $0.28/hen/year. Extrapolating this information to a 100,000 hen house results in an additional $28,000 annually for the poultry producer. This is if the larvae meal is valued similarly to meat and bone meal. If marketed to take advantage of the live-food market (frogs), or it's perceived "natural" quality (salmon, koi), its value would be much more.

Managing black soldier flies in poultry houses offers economic and environmental advantages. Not only will waste be reduced by 25% annually, but a valuable feedstuff will be produced, as well as, house fly populations being eliminated. Current research is focusing on the development of a soldier fly rearing method for the establishment of colonies and the isolation of odor deterrents of house flies which are though to be released by soldier fly larvae.

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EFFECT OF DYNE-O-MIGHT ON BACTERIAL AND MOLD LOAD IN POULTRY LITTER

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SUMMARY

Spraying of litter in broiler chicken houses with Dyne-O-Might (an acid sanitizing spray) immediately increased the acidity of the surface a thousand fold (3 units drop in pH); after 72 hr. the acidity was still ten times higher than before treatment. The spraying reduced total viable bacteria, *Clostridium perfringens, E. coli* and mold by more than 90% on the average. The numbers of Salmonella was consistently low.

INTRODUCTION

Poultry litter is expensive; it is therefore desirable to re-use litter. However, microbial build-up in used litter represents a risk of infection of poultry with bacteria that can cause disease in poultry and/or man. The microbial ecology of poultry litter is not well known. However, there is evidence that certain pathogenic microorganisms can not survive the deeper layer of old litter. Probably because of accumulation of ammonia and reduction of oxygen resulting from the activity of saprophytic microorganism (Turnbull *et al.*, 1973). There is little doubt that the surface of the litter represents the greatest risk; here disease producing bacteria are deposited and mold can produce spores. The application of liquid acid complex on the surface of litter by spraying is a potentially effective method to reduce the numbers of potential pathogenic microorganisms. Most of the disinfectants approved for use in poultry houses can not efficiently kill microorganisms in the litter because of high load of organic matter. Formaldehyde is a very potent disinfectant (Williams, 1980); however, it causes irritation and is a potential carcinogen in humans (Smith, 1992; Holmstrom *et al.*, 1991; Partanen *et al.*, 1990; Griffin, 1990). Dyne-O-Might seems to be a good alternative to the formaldehyde. Formaldehyde may cause eye damage and allergic contact dermatitis. It is considered an occupational carcinogen by federal OSHA and federal EPA and users must be aware of the occupational exposure standard PEL (permissible exposure limit) of 0.75 ppm. On the other hand, organic acids are recognized by FDA and GRAS (General Recognized As Safe) and are not carcinogenic. In this study the effect of a combination of organic acid and iodine spray on microorganisms on the surface of broilers chicken litter was measured.

MATERIALS AND METHODS

Two poultry houses with litter of wood shavings on which three flocks of broilers had been raised were used in the study. Sterile drag swabs (Kingston, 1981) moistened with double strength skim milk were used for surface sampling of litter and walls; approximately one square yard was covered by each swab. Forty swabs were used to sample the floor (50 x 40 ft) and 10 swabs to sample the walls just above the floor. The swabs were combined in numbers of five and placed in sterile whirl-pak bags. To each bag was added 100 sterile 1% protease peptone which after shaking was plated on nutrient agar (for total plate count), eosinmethylene blue agar (for *E. coli*), brilliant green novobiocin agar (for Salmonella), tryptose-sulfite cycloserine egg yolk agar (for *Clostridium perfringens*) and Sabouraud agar (for yeast and mold). Ten ml of the liquid in the whirl-pak bags were transferred to two whirl-pak bags with 90 ml protease peptone and two more ten-fold dilutions were made in duplicate for most probably number estimation. The whirl-pak bags were incubated for 20 hr at 37°C and these pre-enrichment cultures were streaked on the media listed above except nutrient agar, brilliant green novobiocin agar and sabouraud agar. One hundredth of a milliliter of the pre-enrichment broth was incubated in tetrathionate broth for 24 hr at 37°C and streaked on brilliant green novobiocin agar that was incubated for 48 hr at 37°C for detection of Salmonella. Suspect colonies were inoculated on triple sugar iron agar for confirmation. The two houses were sampled for bacteria on March 4, 1994 and again on March 15, three days after spraying with Dyne-)-Might solution. A second test for mold was done on May 19, at this time only floors were sampled and only one hour or less elapsed between spraying and sampling for mold and acidity test (pH).

RESULTS AND DISCUSSION

Bacterial and mold counts and pH values in litter are shown in Tables 1-5. The data show consistent decrease in microbial counts after spraying with Dyne-O-Might. The counts of *E. coli* were low, only around 100 per swab, even before spraying and the counts of Salmonella were too low, 1-3 per swab, to permit conclusions. However, total aerobic counts (over 100 millions) and *C. perfringens* counts (between 1000 and 10000) before spraying were high enough to demonstrate significant reduction. Spraying reduced pH by 1.1 unit (equals approximately a ten-fold increase in acidity) on the average. Samples for pH measurement were taken one day after spraying and included more than just the surface layer. Presumably the pH on the surface would be much lower immediately after spraying. This was confirmed by tests performed in May (Table 4).

Table 1. Log Bacterial and Mold Counts, Per Swab, and Standard Errors (in parenthesis) Before and After Treatment of Floors with Dyne-O-Might.

	House num. 45		House num. 47	
	Before	After	Before	After
Total count	8.79 (0.13)	7.9 (0.14)	8.86 (0.18)	8.01 (0.22)
Cl. perfringens	3.51 (0.59)	1.60 (0.26)	3.82 (0.75)	0.94 (0.25)
E. coli	2.14 (---)	0.89 (0.33)	2.14 (---)	1.08 (0.31)
Salmonella	0.06 (---)	0.12 (0.04)	0.48 (0.19)	0.06 (---)
Mold			4.48 (0.23)	<4.00

Table 2. Log Bacterial and Mold Counts, Per Swab, and Standard Errors (in parenthesis) Before and After Treatment of Walls with Dyne-O-Might.

	House num. 45		House num. 47	
	Before	After	Before	After
Total count	8.38 (0.02)	6.96 (0.59)	8.25 (---)	6.15 (---)
Cl. perfringens	2.80 (1.50)	0.81 (0.27)	1.30 (---)	1.32 (0.25)
E. coli	1.1 (1.04)	0.06 (---)	1.32 (0.25)	0.57 (0.50)
Salmonella	0.06 (---)	0.06 (---)	0.48 (0.38)	0.06 (---)
Mold		5.36 (0.02)		3.60 (---)

Table 3. Percent Reduction (rounded numbers) in Bacterial and Mold Counts After Spraying with Dyne-O-Might.

	House num. 45		House num. 47	
	Before	After	Before	After
Total count	87%	96%	86%	99%
Cl. perfringens	99%	99%	100%	---
E. coli	94%	92%	91%	81%
Mold	---	---	97%	---

Table 4. pH in Litter Before and Shortly After Spraying with Dyne-O-Might.

Sample	Before Spraying	1 Hr After Spraying
House num. 47	8.24	5.06
	8.62	5.34
	8.24	5.36
	8.38	5.41
	8.16	5.84
	8.22	5.34
Mean	8.31	5.39
Standard Deviation	0.17	0.25
Sample	**Before Spraying**	**Immediately After Spraying**
House num. 45	7.92	4.94
	8.10	5.37
	8.50	5.50
	8.06	5.30
	8.02	5.26
	8.47	5.00
Mean	8.18	5.23
Standard Deviation	0.25	0.22

Table 5. pH in Litter Before and 72 Hours After Spraying with Dyne-O-Might.

	House num. 45		House num. 47	
Sample	Before	After	Before	After
Front, Right	8.72	8.62	8.56	8.16
Front, Left	8.86	8.13	8.79	6.51
Middle, Right	8.78	4.72	8.48	8.6
Middle, Left	8.77	5.07	9.01	8.26
End, Right	9.27	7.38	9.01	8.73
End, Left	8.71	8.86	8.39	8.82
Mean	8.85	7.13	8.71	8.18
Standard Deviation	0.21	1.81	0.27	0.86

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EFFECTS OF DE-ODORASE ON HOUSE AMMONIA AND NITROGEN CONTENT OF MANURE BEFORE AND AFTER COMPOSTING

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Reducing the amount of ammonia (NH_3 arising from decomposing manure has both animal health and environmental implications. *Yucca schidigera* extract is a natural feed additive that represents one means of affecting aerial NH_3 via the diet. The objectives of this trial were to study effects of De-Odorase (*Yucca schidigera* extract) added to the diet on NH_3 in the atmosphere of the layer barn and on chemical composition of poultry manure before and after composting.

METHODS

Effects on House Ammonia Levels

The trial was conducted in three layer barns of the same size, age, construction and bird density at a large commercial layer farm in Indiana. De-Odorase was added to the layer diet at 4 ounces (120 g) per ton in one barn while the other two barns served as controls. Aerial NH_3 was measured in three areas of each house using three Drager diffusion tubes at each measuring point. The widest variation in NH_3 concentrations existed between the sides of the house and the middle of the house. For that reason, values were averaged (north, south and middle independently) in order to reduce variability.

Manure Composition and Ammonia Evolution

Dry matter and chemical composition of manure from control and treated birds were valuated on samples taken on different locations in the compost pile (9 samples per treatment).

Effect of De-Odorase on Ammonia Arising from Composted Manure

Evaluation of NJ_3 arising from samples was accomplished by taking 500 g (dry weight) samples and placing them in airtight containers fitted with a small sample port sealed with a removable bung from ammonia determination. Ammonia measurements were taken daily for a period of five days.

RESULTS

House Ammonia Levels

Ammonia levels were comparatively low in all measurements, but tended to be higher in the Control 2 barn. De-Odorase reduced NH_3 in all locations with differences between Control and Treated houses significant between similar locations in the Control 2 and De-Odorase barns (Table 1).

Table 1. Effect of De-Odorase on NH_3 Concentrations (ppm/hour) in the Houses.

Date	Control 1	De-Odorase	Control 2
March 27, 1995			
South	4.90	5.60	5.33
Middle	12.25^{a}	8.39^{b}	12.44^{a}
North	7.35^{a}	6.39^{b}	7.11^{ab}
May 4, 1995			
South	1.79^{a}	1.51^{*a}	5.15^{b}
Middle	8.06^{a}	7.37^{*a}	12.27^{b}
North	1.80^{a}	1.76^{a}	5.50^{b}

*These values represent the average of two samples.
[a,b]Values in the same row with different superscripts differ ($P<.05$).

Effects on Poultry Manure Composition Before and After Composting

Dry matter and crude protein content of manure in the put from birds given de-Odorase was significantly lower (Table 2). Soluble NH_3 and total N were lower in treated manure while manure phosphorus content and content of other minerals were unaffected. In contrast to manure samples taken from the pit, compost from treated manure contained significantly more total N and crude protein than the control compost (Table 3).

Effect of De-Odorase on Ammonia Arising from Composted Manure

De-Odorase effectively reduced NH_3 evolving from the compost as measured in the three locations in the compost pile (Figures 1 and 2).

Table 2. Effect of De-Odorase on Dry Matter, Nitrogenous Fractions and Phosphorus Content of Manure Prior to Composting.

	Control	De-Odorase
Dry Matter, %	52.44	45.26[b]
Crude Protein, %	28.23[a]	18.22[b]
Total N, %	4.52	2.91
NH_3, %	0.666	0.521
Phosphorus, %	2.45	2.48
Potassium, %	0.863	0.830
Zinc, ppm	43.3	50.0
Manganese, ppm	15	18
Calcium, %	2.6	2.4
Iron, ppm	96.7	85.3

[a,b]Values in the same row with different superscripts differ (P<.05).

Table 3. Effect of De-Odorase on Chemical Composition of Composted manure*.

	Control	De-Odorase
Moisture, %	33.62	35.22
Dry Weight, %	66.38	64.78
Nitrogen, %	2.57[a]	3.14[b]
Crude Protein, %	16.08[a]	19.63[b]
Potassium, ppm	43.4	40.97
Phosphorus, %	2.56	1.94

*Values represent the average of six samples.
[a,b]Values in the same row with different superscripts differ (P<0.05).

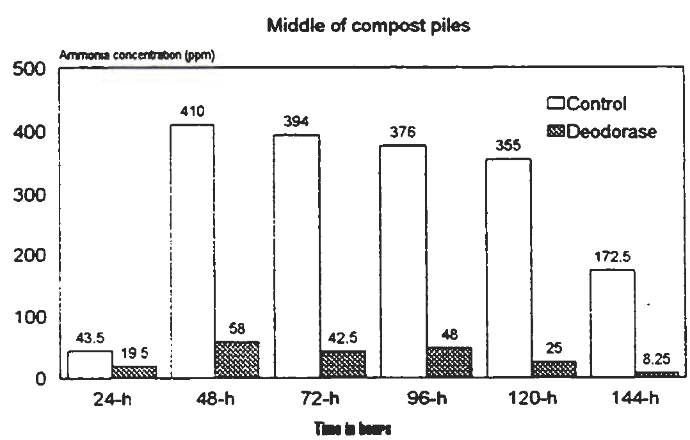

Figure 1. Effect of De-Odorase on Ammonia Evolution from Compost

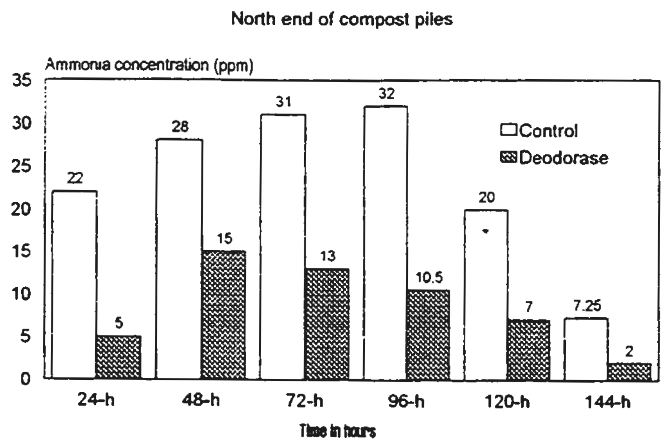

Figure 2. Effect of De-Odorase on Ammonia Evolution from Compost.

THE APPLICATION OF ENZYME TECHNOLOGY TO IMPROVE NUTRITIONAL VALUE OF FEATHERS AND REDUCE THEIR POTENTIAL TO CAUSE ENVIRONMENTAL POLLUTION

CASE STUDY 1: BRAZIL

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As poultry production increases worldwide, feather predication increases concurrently. Using current technology, feathers are processed by hydrolysis using stream under pressure followed by drying. The resultant hydrolyzed feather meal (HFM) is a dry, protein-rich by-product. Although the protein content of HFM (> 82%) indicates that it should be a useful feed ingredient, applications are rather limited due to the perceived low nutritive value. In fact, *in vivo* amino acid digestibilities range from 50 - 85% depending on literature source, for example NRC (1994). Typically, nutritionists regard feather as a poor source of digestible amino acids and commonly values of 65% protein digestibility are used today.

One reason for the conservative use of HFM is that the low protein digestibility indicates a high proportion of indigestible nitrogen which when excreted by the animal would add to the pollution load. In terms of mass balance, for every 100g of feather meal protein ingested up to 35g could be excreted. However, if the indigestible protein could be reduced, the consequences for reducing pollution loading are apparent. For example, if *in vivo* digestibility were increased to 88%, then only 12g per 100g feather protein would be excreted.

One objective of the enzyme assisted processing method for feather is to reduce the indigestible component of feather meals. An experimental program was set up to compare the effectiveness of the enzyme assisted process when compared with current processing methods.

MATERIALS AND METHODS

A series of process trails were completed in three countries (Brazil, USA, Thailand) to produce current feather meal (Control) and Enzyme processed feather meal (Enzyme) in steam jacketed batch processors with mixing paddles. The enzyme used was Allzyme FD (Alltech, Inc., Nicholasville, KY). In Case Study 1 (Brazil) the following process conditions were used for processing 100% broiler feathers (Table 1).

Table 1. Process Conditions for Production of Control and Enzyme Processed Feather Meal.

Process Step	Control	Enzyme
1	Steam pressure on jacket. Load cooker, paddles mixing, 30 minutes loading.	No steam pressure on jacket. Load cooker, paddles mixing. Add Enzyme & Co-pack* after 15 minutes. Continue mix @ 50°C for 40 mins.
2	Increase jacket pressure (15 mins) to give internal pressure 3.5 bars and maintain for 35 mins.	Increase jacket pressure (10 mins) to give internal pressure 2 bars and maintain for 15 mins.
3	Release pressure to atmospheric (15 mins).	Release pressure to atmospheric (10 mins.)
4	Dry in cooker to moisture <10%.	Dry in cooker to moisture <10%.
Total Process	95 minutes.	90 minutes.

*Allzyme FD (0.5 kg/raw tonne) and sodium metabisulphite (2.5 kg/raw tonne).

Samples of Control and Enzyme feather meals were assayed for crude protein, moisture, oil, ash and cystine content (Table 2). *In vivo* true metabolizable energy (TME) and amino acid digestibility studies were completed on the samples collected using the technique of McNab and Blair (1988) (Table 3).

Table 2. Results of Process Trails Producing Control and Enzyme-Hydrolyzed Feather Meals.

	Control	Enzyme
Analysis, %		
Crude Protein	80.5	82.1
Oil	8.87	8.0
Ash	2.5	2.7
Moisture	9.2	9.7
Cystine	3.1	4.5

Table 3. *In vivo* Evaluation of Control and Enzyme-Hydrolyzed Feather Meals.

	Control	Allzyme FD
TME, MJ/kg	13.9	15.6
Average Amino Acid Digestible, % of Protein	68.2	83.6
Calculated Indigestible Protein, % of Protein	31.8	16.4

DISCUSSION

The process trials described produced samples of Control and Enzyme feather meals which were assayed for chemical and *in vivo* parameters. As expected, the chemical analyses of protein, fat, moisture and ash were similar. This allows comparisons to be made in the analysis of the key parameters, i.e. cystine and *in vivo* assays. Cystine levels were higher in Enzyme feather meal, confirming results seen in Hanley *et al*. (1998). TME values and digestible amino acids were also increased in the Enzyme processed feather as a result of increased concentrations and digestibilities of amino acids in the crude protein fraction. As a result, the indigestible protein component was reduced by approximately 48% in the Enzyme-hydrolysed feather meal. This reduction, together with the improved availability of amino acids, should increase the nutritive and economic value of Enzyme-hydrolyzed feather meal when compared with current batch-processed feather meal.

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THE APPLICATION OF ENZYME TECHNOLOGY TO IMPROVE NUTRITIONAL VALUE OF FEATHERS AND REDUCE THEIR POTENTIAL TO CAUSE ENVIRONMENTAL POLLUTION

CASE STUDY 2: USA

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As poultry production increases worldwide, feather predication increases concurrently. Using current technology, feathers are processed by hydrolysis using stream under pressure followed by drying. The resultant hydrolyzed feather meal (HFM) is a dry, protein-rich by-product. Although the protein content of HFM (> 82%) indicates that it should be a useful feed ingredient, applications are rather limited due to the perceived low nutritive value. In fact, *in vivo* amino acid digestibilities range from 50 - 85% depending on literature source, for example NRC (1994). Typically, nutritionists regard feather as a poor source of digestible amino acids and commonly values of 65% protein digestibility are used today.

One reason for the conservative use of HFM is that the low protein digestibility indicates a high proportion of indigestible nitrogen which when excreted by the animal would add to the pollution load. In terms of mass balance, for every 100g of feather meal protein ingested up to 35g could be excreted. However, if the indigestible protein could be reduced, the consequences for reducing pollution loading are apparent. For example, if *in vivo* digestibility were increased to 88%, then only 12g per 100g feather protein would be excreted.

One objective of the enzyme assisted processing method for feather is to reduce the indigestible component of feather meals. An experimental program was set up to compare the effectiveness of the enzyme assisted process when compared with current processing methods.

MATERIALS AND METHODS

A series of process trails were completed in three countries (Brazil, USA, Thailand) to produce current feather meal (Control) and Enzyme processed feather meal (Enzyme) in steam jacketed batch processors with mixing paddles. The enzyme used was Allzyme FD (Alltech Inc., Nicholasville, KY). The following process conditions were used for processing broiler feathers at a commercial poultry processing/rendering facility (Table 1). The objective was to have minimum contamination with blood for both treatments.

Table 1. Process Conditions for Production of Control and Enzyme Processed Feather Meal.

Process Step	Control	Enzyme
1	Steam pressure on jacket. Load cooker, paddles mixing, 30 minutes loading.	No steam pressure on jacket. Load cooker, paddles mixing. Add Enzyme & Co-pack* after 15 minutes. Continue mix @ 50°C for 30 mins.
2	Increase jacket pressure (40 mins) to give internal pressure 2 bars and maintain for 35 mins.	Increase jacket pressure (20 mins) to give internal pressure 2 bars and maintain for 30 mins.
3	Release pressure to atmospheric (15 mins).	Release pressure to atmospheric (15 mins.)
4	Dry in cooker to moisture ≅ 30%.	Dry in cooker to moisture ≅ 30%.
5	Final drying to moisture <10% in continuous drier.	Final drying to moisture <10% in continuous drier.
Total Process	115 minutes.	110 minutes.

*Allzyme FD (0.5 kg/raw tonne) and sodium metabisulphite (2.5 kg/raw tonne).

Samples of Control and Enzyme feather meals were assayed for crude protein, moisture, oil, ash and cystine content (Table 2). *In vivo* TME true metabolizable energy (TME) and amino acid digestibility studies were completed on the samples collected using the technique of McNab and Blair (1988). The results (average of two laboratories; one in UK and one in USA) are described in Table 3.

Table 2. Results of Process Trails Producing Control and Enzyme Feather Meals.

Analysis, % sample	Control	Enzyme
Crude Protein	81.1	82.6
Oil	8.5	7.5
Ash	2.6	3.8
Moisture	6.1	6.1
Cystine	4.2	4.7
Lysine	2.2	1.7

Table 3. *In vivo* Evaluation of Control and Enzyme-Hydrolyzed Feather Meals.

	Control	Allzyme FD
TME, MJ/kg	13.8	14.3
Average Amino Acid Digestible, % of Protein	80.1	81.5
Calculated Indigestible Protein, % of Protein	19.9	18.5

DISCUSSION

The process trials described produced samples of Control and Enzyme feather meals which were assayed for chemical and *in vivo* parameters. As expected, the chemical analyses of protein, fat, moisture and ash were similar. However, lysine levels were higher in the control samples indicating a significant contamination with blood. Combinations of blood and feather are known to increase energy (TME) level synergistically (MacLeod *et al.*, 1996) so this may invalidate the direct comparison of the control and enzyme samples. However, the small improvements in TME value and digestible amino acid content of enzyme-hydrolyzed feather warrants further investigation and perhaps replication of trials at this or other sites.

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THE APPLICATION OF ENZYME TECHNOLOGY TO IMPROVE NUTRITIONAL VALUE OF FEATHERS AND REDUCE THEIR POTENTIAL TO CAUSE ENVIRONMENTAL POLLUTION

CASE STUDY 3: THAILAND

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As poultry production increases worldwide, feather predication increases concurrently. Using current technology, feathers are processed by hydrolysis using stream under pressure followed by drying. The resultant hydrolyzed feather meal (HFM) is a dry, protein-rich by-product. Although the protein content of HFM (> 82%) indicates that it should be a useful feed ingredient, applications are rather limited due to the perceived low nutritive value. In fact, *in vivo* amino acid digestibilities range from 50 - 85% depending on literature source, for example NRC (1994). Typically, nutritionists regard feather as a poor source of digestible amino acids and commonly values of 65% protein digestibility are used today.

One reason for the conservative use of HFM is that the low protein digestibility indicates a high proportion of indigestible nitrogen which when excreted by the animal would add to the pollution load. In terms of mass balance, for every 100g of feather meal protein ingested up to 35g could be excreted. However, if the indigestible protein could be reduced, the consequences for reducing pollution loading are apparent. For example, if *in vivo* digestibility were increased to 88%, then only 12g per 100g feather protein would be excreted.

One objective of the enzyme assisted processing method for feather is to reduce the indigestible component of feather meals. An experimental program was set up to compare the effectiveness of the enzyme assisted process when compared with current processing methods.

MATERIALS AND METHODS

A series of process trials were completed in three countries (Brazil, USA, Thailand) to produce current feather meal (Control) and Enzyme processed feather meal (Enzyme) in steam jacketed batch processors with mixing paddles. The enzyme used was Allzyme FD (Alltech Inc., Nicholasville, KY). In Case Study 3 (Thailand) the following process conditions were used for processing 100% broiler feathers at a commercial poultry processing unit (Table 1).

Table 1. Process Conditions for Production of Control and Enzyme Processed Feather Meal.

Process Step	Control	Enzyme
1	Steam pressure on jacket. Load cooker, paddles mixing, 30 minutes loading.	No steam pressure on jacket. Load cooker, paddles mixing. Add Enzyme & Co-pack* after 15 minutes. Continue mix @ 50°C for 30 mins.
2	Increase jacket pressure (15 mins) to give internal pressure 3.0 bars and maintain for 30 mins.	Increase jacket pressure (10 mins) to give internal pressure 2 bars and maintain for 20 mins.
3	Release pressure to atmospheric (15 mins).	Release pressure to atmospheric (10 mins.)
4	Dry in cooker to moisture <10%.	Dry in cooker to moisture <10%.
Total Process	90 minutes.	85 minutes.

*Allzyme FD (0.5 kg/raw tonne) and sodium metabisulphite (2.5 kg/raw tonne).

Samples of Control and Enzyme feather meals were assayed for crude protein, moisture, oil, ash and cystine content (Table 2). *In vivo* TME metabolizable energy (TME) and amino acid digestibility studies were completed on the samples collected using the technique of McNab and Blair (1988). The results are described in Table 3.

Table 2. Results of Process Trails Producing Control and Enzyme Feather Meals.

Analysis, % sample	Control	Enzyme
Crude Protein	81.1	83.6
Oil	4.2	5.1
Ash	2.3	2.4
Moisture	10.5	11.1
Cystine	4.4	5.5

Table 3. *In vivo* Evaluation of Control and Enzyme-Hydrolyzed Feather Meals.

	Control	Allzyme FD
TME, MJ/kg	14.65	15.95
Average Amino Acid Digestible, % of Protein	72.1	84.4
Calculated Indigestible Protein, % of Protein	27.9	15.6

DISCUSSION

The process trials described produced samples of Control and Enzyme feather meals which were assayed for chemical and *in vivo* parameters. As expected, the chemical analyses of protein, fat, moisture and ash were similar. This allows comparisons to be made in the analysis of the key parameters, i.e. cystine and *in vivo* assays. Cystine levels were higher in Enzyme feather meal, confirming results seen by Hanley *et al.* (1998). TME values and digestible amino acids were also increased in the Enzyme processed feather as a result of increased concentrations and digestibilities of amino acids in the crude protein fraction. As a result, the indigestible protein component was reduced by approximately 44% in the Enzyme feather meal. This reduction, together with the improved availability of amino acids, should increase the nutritive and economic value of Enzyme feather meal when compared with current batch processed feather meal.

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Hanley, F., A. Wildish, W. Johnson, E. Sonega, J. Harvey, J. Everington, and S. Woodgate. 1998. The use of enzyme processing to improve the nutritive value of keratin-containing raw materials: case studies from around the world. In: Biotechnology in the Feed Industry. Proceedings of the 14th Annual Symposium. (T.P. Lyons and K.A. Jacques, eds) Nottingham University Press, Nottingham, UK.

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RAPID COMPOSTING OF POULTRY MORTALITY USING IN-VESSEL TECHNOLOGY

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Composting is an acceptable and recommended means of recycling organic wastes and is rapidly gaining acceptance in the U.S. as a method for stabilizing/sanitizing animal and municipal wastes. Confined Animal Feeding Operations (CAFO's) including dairy, cattle feedlot, poultry and swine operations, generate more than 136 million metric tons (dry weight basis) of waste products annually containing significant levels of nitrogen and phosphorous which threaten surface and ground water resources if not managed correctly. Composting is a totally natural decomposition process, which if performed under controlled conditions, can produce value-added products. The success of a composting process depends on several basic conditions including moisture content of the raw material, aeration of the compost mass, degradability of the organic material, and the presence of appropriate microflora.

Research initiated in 1992 at Texas A&M University-Commerce has resulted in development of prototype, in-vessel, aerobic mechanical composters designed for on-site (on-farm) use in decomposing organic wastes. A composter of this type may be of utility in broiler production facilities as an environmentally appropriate/low management option to static-bin composting of bird carcasses. Composting of mortality, which will average between 34% and 5% of the total population during the five to six week growth cycle, may become the preferred alternative to on-farm burial, landfilling, or incineration.

Co-composting of poultry carcasses and poultry litter from broiler production facilities using in-vessel composters results in thermophilic stabilization in four to five days. Carcasses included in the composting process at the rate of 25% (by weight) with 75% broiler litter will decompose in the first three days of the process. The composting product will maintain thermophilic temperatures for a total of three or more days and is free of coliform and salmonella bacteria as well as botulism spores and toxin.

Although the finished product is ready for disposal through land application procedures, utilization of the compost as a ruminant livestock feed ingredient may provide a value-added use for the material.

Composted poultry litter containing 25% mortality tests 24.9% crude protein, 4.0% fat, 15.3% fiber, and 82% total digestible nutrients. Compared to composted poultry litter alone, co-composting with 25% mortality increases crude protein by 21.8% and iron by 131.9%. Estimated elevations in fat content are approximately 300%.

Feeding poultry litter to ruminant livestock is not a new concept, but inclusion of poultry carcasses in a controlled decomposition process is new and theoretically improves the value of the resulting product for use as a pathogen-free ruminant livestock feed ingredient. In-vessel composting of poultry mortality provides an environmentally appropriate/low management alternative to the currently recommended static-bin composting or incineration processes. Co-composting of litter and mortality could be mutually beneficial to both the poultry and livestock industries, as well as the environment. A three-year beef cattle feeding trial utilizing co-composted mortality and litter will be initiated in the Fall of 1998.

This on-site (on-farm) in-vessel technology appears to have applicability in other waste streams including confined dairy, swine and feedlot operations; horse stables; food residuals; fish processing waste; hatchery waste; and municipal and brewery sludges. Additional information as well as photos of in-vessel composting of poultry mortality and other waste products can be found at: http://www.TAMU-Commerce.edu/coas/agscience/dic.html

EFFECT OF HACCP REGULATIONS ON WATER USAGE IN POULTRY PROCESSING PLANTS

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On January 26, 1998, the Food Safety and Inspection Service (FSIS) began enforcing the second phase of the Pathogen Reduction/Hazard Analysis Critical Control Point (HACCP) regulations. At this time all very large meat and poultry processing establishments were required to implement a HACCP plan. These regulations also establish testing for generic *Escherichia coli* and *Salmonella*.

HACCP is a systematic way of identifying potential food hazards, assessing those hazards, and ultimately controlling them. One requirement of HACCP is that Critical Control Points (CCPs), locations where hazards can be controlled, are identified and monitored regularly. By looking at the overall process, HACCP allows companies to prevent hazards from occurring, instead of relying on end product safety testing.

The HACCP model of inspection is drastically different from traditional FSIS inspection. In the past, inspectors took a command and control approach. If an inspector found a problem, he/she would immediately take control of the situation and tell the establishment how to fix it. Under the HACCP model of inspection, inspectors are responsible for ensuring that establishments are implementing their HACCP plan and that the plan is working. If an inspector sees something that is not right, he must give the establishment a chance for their HACCP plan to recognize and correct the situation before taking control of the situation. This change from the command and control culture has been difficult for many inspectors and plant employees.

FSIS believes that a significant portion of the pathogens that they are trying to control comes from fecal contamination. For this reason, FSIS has stated that all HACCP plans must address zero tolerance for fecal material, or "zero fecal." This means that there must be a Critical Control Point (CCP) that ensures that no fecal material is present on the carcass before the carcass enters the chiller. In addition, FSIS requires plants to conduct microbiological tests for generic *E. coli* and requires inspectors to test for *Salmonella*. FSIS considers these tests as indicators of how a plant's HACCP plan is performing. Plants, on the other hand, question whether or not these tests accurately portray the effectiveness of their HACCP plans.

Fecal contamination typically occurs during the evisceration, or removal of the bird's intestines. If the intestines break, the fecal material can spread to the inside or outside of the carcass. This material can spread from carcass to carcass if the evisceration equipment is not cleaned adequately between carcasses.

The incidence of having problems with fecal contamination typically varies from flock to flock. If feed withdrawal occurs too close to time of slaughter, there is an excess of fecal material in the intestine, which increases the chance of contamination (Wabeck, 1972).

If an inspector finds that carcasses with fecal material on them are entering the chiller, he/she can write a noncompliance report, or NR. FSIS uses these reports to determine if a plant is in compliance with the regulations. If a trend of noncompliance is found, FSIS can withhold inspection from that plant until the situation has been addressed.

The two most common ways for plants to increase compliance with the regulations are through increased bird washing and the use of antimicrobials such as chlorine and trisodium phosphate (TSP). Traditionally inside/outside (I/O) bird washers placed after evisceration are used in order to wash away any contamination on the birds, and equipment rinsers are used to clean the evisceration equipment between carcasses. Since the introduction of NACCP, many plants have begun using other intervention strategies such as cabinet washers and brush washers to address zero fecal contamination.

These intervention strategies invariably require that establishments use more water. Before HACCP implementation, the average poultry plant used 7 gallons of water per bird (Carawan and Merka, 1991). Since HACCP implementation, that average has jumped to 9 gallons a bird (Carawan *et al.*, 1998). This increase can result in considerable water and wastewater treatment costs and could have a negative impact on both the company and the environment.

The purpose of this study was to identify ways that broiler plants have changed their processes in order to comply with

HACCP regulations, and how these changes have increased water usage.

METHODS

A survey of broiler plants in southeastern states was conducted to see how compliance with the PR/HACCP rule has effected water usage and poultry processing in general. A general written survey was mailed to processing plants to get a picture of the industry. Follow up visits and in-depth surveys were then conducted at participating plants. Survey topics included 1) average water usage and treatment/disposal cost, 2) number of birds processed a day and gallons of water used per bird, 3) water conservation efforts, 4) processing changes made in order to comply with HACCP regulations (ex: added I/O bird washers, TSP), and 5) IIC acceptance of processing changes.

FINDINGS

Water Usage

All plants surveyed reported an increase in water usage since the implementation of HACCP. These increases were as high as 50%. Most of the plants reported that they once had active water conservation programs. The constant threat of a shutdown has forced these programs to take a back seat to HACCP. For example, several plants have experienced increases in excess of 2 gallons a bird since the implementation of HACCP. Before HACCP, the industry average was 7 gallons per bird (Carawan and Merka, 1991). After HACCP, some plants are up to 12 gallons a bird. The average 2 gallons per bird increase has the potential to cost the broiler industry over $87 million a year (based on annual water and sewage cost of $4.00 per thousand broilers) (Carawan *et al.*, 1998).

Processing Changes

Every plant surveyed had implemented some change in order to increase compliance with zero fecal, *E. coli*, or *Salmonella* requirements. Each one of these changes resulted in an increase in water usage. Tables 1 and 2 list examples of the changes that have been implemented.

Table 1. Equipment Added Due to HACCP.

Brush Washers	Inside/Outside Bird Washers
Cabinet Washers	Pumps to Handle New Equipment
Equipment Rinsers	Trisodium Phosphate Systems
Final Washers	

Table 2. Modifications Made to Existing Equipment.

Increased Use of Chorine
Increased Water Pressure to Carcass Washing and Equipment Rinsing
Nozzles Added to Existing Washers

The most common change reported was the addition of carcass washers. Many different configurations of washers have been used. Table 3 lists samples of these configurations. The establishments surveyed have taken the approach that washing the carcass multiple times will increase compliance with the regulations. Very few of the plants surveyed had measured the increase in water usage due to these modifications.

Table 3. Washer Combinations Implemented to Increase HACCP Compliance.

1. Outside Carcass Washers Placed After Picking
2. I/O Washer and Brush Washer
3. I/O Washer and Cabinet Washer
4. I/O Washer, Brush and Cabinet Washer
5. Series of Several I/O After Evisceration

The increase in water usage that results from these intervention strategies has pushed many establishments to their limit of available water. In these cases, the establishments are in danger of exceeding their permits but are unable to focus their efforts on water reduction due to the pressures of HACCP. These plants are eventually going to be forced to find ways to reduce water usage or recycle water in order to supplement these intervention systems or face action from the EPA.

Effectiveness of Changes

In many cases, the establishments reported that the changes made to their processing lines increased their zero fecal and microbial compliance. However, many plants made many changes at one time, or in close succession, making it impossible to know the reason for any improvements without further testing. In most cases, QA/QC departments have focused all their energy on complying with HACCP in order to keep their plant running, therefore they have not had an opportunity to identify which intervention strategies were effective.

Interactions with FSIS

IIC support of processing changes varied greatly from plant to plant. In many cases, plants were allowed to use new equipment on a trial basis. However, some IICs would not allow equipment to be installed permanently, even though the equipment proved to eliminate fecal material more effectively than the existing system. Other IICs would not allow new equipment to be installed, even on a trial basis.

At the opposite end of the spectrum, a few plants reported that an IIC suggested that a piece of equipment be installed. Others allowed equipment to be installed in response to a corrective action given on an NR, but would not let the equipment be removed once it proved to be ineffective. This variation between inspectors demonstrates that many are having trouble adapting to the new culture and that an inspector's interpretation of the regulations and communication with the establishment plays a key role in the establishment's success.

CONCLUSIONS

In all plants surveyed, water usage has increased due to changers in the processing line meant to increase HACCP compliance. The resulting increase in water and water treatment costs was an unexpected cost of HACCP for many plants. In a plant that has increased from 6 to 9 gallons a bird and processing 250,000 broilers a day, this could mean an increase of $3,000 a day or $750,000 a year in water and sewage costs. The cost can be even greater for plants that are already having trouble meeting their water demands.

With the potential implementation of FSIS's new inspection model, this situation can only get worse. The effect of increased use of trisodium phosphate and other antimicrobials on the environment needs to be studied further.

Methods that can control fecal contamination while maximizing water resources are necessary in order to ensure food safety without doing further damage to the environment. The effectiveness of these water intensive intervention strategies must be determined so that the potential benefit of using these strategies can be weighed against the great costs to the industry and the environment.

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RECOVERY AND UTILIZATION OF USEFUL BY-PRODUCTS FROM EGG PROCESSING WASTEWATER USING ELECTROCOAGULATION AND ULTRAFILTRATION

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The egg processing industry generates about 2.5 billion gallons of wastewater (WW) annually which typically contains a high concentration of organic matter attributed primarily to egg losses (Carawan *et al.*, 1979). Because of the previous low costs associated with municipal treatment and land costs, these WW were generally discharged into municipal sewers or pretreated and then applied to pastures or crop lands. With rapidly rising water, land, and sewer charges and the associated pollution problems, regulations limiting these practices have become more stringent. Thus, these methods of handling WW are so longer favorable to egg processors. The development of treatment technologies that recover useful by-products form WW, reduce municipal treatment costs and surcharges, and allow for water recycling opportunities by processing plants has attracted increased interest in recent years. A number of wastewater treatment technologies exist that may be effective in treating egg processing plant WW. The focus of this study was to evaluate two of these technologies, ultrafiltration (UF) and electrocoagulation (EC). The objectives of this study were to demonstrate the effectiveness of UF and EC for treating egg processing WW, to evaluate the feed potential of the recovered egg solids, and to estimate the cost savings for the UF and EC systems.

MATERIALS AND METHODS

Wastewater Samples

Wastewater effluent samples were collected on multiple days from two commercial egg processing plants during mid-shift. In addition, model egg wastewater samples (MWS) were also prepared and treated (0.4% w/v, liquid whole egg in tap water).

Ultrafiltration Experimental Apparatus and Procedures

An Amicon HIP30-20 hollow fiber membrane cartridge consisting of 250 fibers (0.5 mm i.d. x 20.3 cm long) having a nominal molecular weight cut-off point of 30,000 daltons and encased in a clear plastic shell (2.29 cm i.d.) was employed and oriented in a vertical configuration. Wastewater (22-23°C) was circulated through the fibers at 25 psi using a W.R. Grace & Co. LP1 pump (760 GPD @ 25 psi). Each experimental run consisted of circulating 4 liters of the WW through the system for approximately 1 hour until a concentrate volume of 0.5 liters was produced. Samples of both the permeate and concentrate were taken every 10 minutes and analyzed for COD, turbidity (formazin turbidity units - FTU), total suspended solids (TSS), protein, and fat using procedures described in Standard Methods for Water and Wastewater Analysis (APHA, 1994). Recovered dried solids were analyzed for protein, fat, ash, protein digestibility using the OPA procedure (Porter *et al.*, 1984), and essential amino acid profiles using a reversed phase HPLC separation procedure (Gehrke *et al.*, 1985; Liu *et al.*, 1995). All experiments were replicated 2 to 3 times.

Electrocoagulation Experimental Apparatus and Procedures

Electrodes used in this study were made of either aluminum, iron, or stainless steel with surface areas of 27 cm^2 (1.0 cm x 13.5 x 2), 54 cm^2 (2.0 cm x 13.5 x 2), or 108 cm^2 (4.0 cm x 13.5 x 2). Two electrodes were placed vertically (7 cm apart) in 1 liter of WW (22-25°C) in a 2 liter glass container and a 10-20 D.C. voltage applied using a Tri-Power Supply (Health Co., Benton Harbor, MI). The current varied from 2.0 to 5.0 amps. Two precipitation/coagulation agents (PCA) were also evaluated [carboxymethylcellulose (CMC) and bentonite (BEN)] as treatment aids to EC.

The procedure began first with pH adjustment of the WW to 4.5 using 1 N NCl for WW samples without PCA treatment and to a pH of 2.5 to 9 for WW samples with PCA addition. Following pH adjustment a single coagulation agent was added to the WW at one of ten different concentrations (50-1000 mg/L) and mixed for 2 min at 40 rpm. For the MWS samples, 1.5 g of NaCl was added to the WW to increase conductivity. Water samples were taken from the container for determining turbidity every 2 min. Floc forming time (treatment time) was determined as the length of time from initial treatment until the turbidity was reduced to below 5 FTU. Floc forming times ranged from 10 to 40 min depending on the characteristics of WW, electrode materials, and treatment conditions. Initial water samples and samples after treatment were also analyzed for COD, TSS, protein, and fat. Recovered egg solids were dried at 70°C and analyzed as described above. The effects of treatment time, pH, waste concentration, WW type, coagulant concentration, water temperature, electrode surface area and type, and floc formation time were evaluated following the above general operating procedures. All experiments were replicated twice.

RESULTS AND DISCUSSIONS

Ultrafiltration

The quality of the recovered filter permeates from different egg processing plants was evaluated by measuring COD, TTS, and turbidity (Table 1). Over 95% of the COD, 98% of the turbidity, and 99% of the TSS were removed by the ultrafilter. Initial COD, TSS, and FTU values ranged from 4,090 to 14,725 mg/L, 1,035 to 5,004 mg/L, and 2,570 to 3,020 FTU, respectively, across the three samples. These removal efficiencies were similar to those previously reported for treating oily WW, poultry processing WW, and cheese whey (Cartwright, 1992). the TSS and turbidity values of the permeate were typically below 10 mg/L and 20 FTU, respectively. These UF permeates could potentially be reused for washing equipment and floors without any further need of treatment except the possible addition of a chlorination disinfection step. The UP membrane selected for this study (30,000 daltons cut-off) retained over 95% of the wastewater proteins removed from the egg processing plant WW were soluble proteins which have not been successfully removed by traditional screening and dissolved air flotation methods (Beszedits, 1982).

The volume of the final UP concentrate was reduced to only 10% of the initial WW volume for all three samples. Further reductions in concentrate volume are possible which would better facilitate nutrient recovery by dewatering techniques. In this study the MWS concentrate stream contained 20,450 mg/L of TSS (~6.0% solids in the WW stream). After drying, approximately 20.4g of dried solids were recovered from approximately 360 ml of concentrate. The solids averaged 48% protein and 45% fat. Based on the essential amino acid profiles (Table 2), it appears that the recovered solids may be suitable as a feed ingredient for animal feeds. The recovered by-product had a similar essential amino acid

Table 1. Efficacy of Hollow Fiber Ultrafiltration for Treating Egg Processing Plant Wastewaters (n = 3).

Sample Sources	COD (mg/L)	% COD Reduct[a]	TSS (mg/L)	% TSS Reduct.	Turbid. (FTU)[b]	%Turbid Reduct.
Plant A	12,000	97	5,004	99	2,810	99
Plant B	4,090	96	1,035	98	3,020	99
MWS[c]	14,725	98	1,200	99	2,570	99

[a]Percent reductions calculated by comparing treated to untreated samples.
[b]Turbidity expressed a formazin turbidity units (FTU).
[c]MWS: Model egg processing wastewater (0.4% w/v liquid whole egg in tap water).

pattern as liquid whole egg confirming our hypothesis that the organic load comprising the egg processing plant WW effluent is composed primarily of lost egg from the processing operation. Compared to the United Nations FAO essential amino acid profile for animal feeds, the recovered egg solids contained adequate concentrations of essential amino acids to satisfy animal nutritional requirements. The sulfur-containing amino acids, cystine and methionine and tryptophan were partially destroyed by the acid hydrolysis and thus were either not detected or were detected in concentrations below the control.

Table 2. Essential Amino Acid Composition of Liquid Whole Egg and By-Products Recovered by Ultrafiltration (g/100g protein).

Amino Acid	UF By-Product	Liquid Whole Egg	FAO Pattern
Threonine	4.11	4.08	2.8
Valine	6.18	6.32	4.2
Lysine	6.02	6.32	4.2
Methionine[a]	2.21	2.72	2.2
Isoleucine	5.66	5.56	4.2
Leucine	8.85	8.55	4.8
Phenylalanine	5.65	5.22	2.8
Tryptophan[a]	ND	1.52	1.4

[a]Methionine, cystine, and tryptophan were destroyed or partially destroyed by acid hydrolysis procedure.

Since egg protein has the highest biological value and protein efficiency ratio (PER) compared to other food proteins such as meat, milk, corn, rice, and flour, the relative digestibilities of the recovered egg solids were determined to assess any protein degradation resulting from UF and the values compared to a corn/soybean meal sample and to a liquid whole egg control sample that was assumed to represent a 100% digestible protein. The protein digestibilities of the recovered solids and corn/soybean meal averaged about 100% and 56%, respectively. The UP recovery treatment apparently did not affect the quality of the recovered egg proteins. Furthermore, the recovered proteins had similar digestibilities as liquid whole egg indicating that they would be an excellent source of animal protein.

For a process to be utilized it must be economical as well as technically feasible. A cost analysis of the UF treatment for plant A was undertaken based on heating costs, chemical costs, and sewer use surcharges and were expressed in dollars per million gallons treated (Table 3). The total treatment cost was compared with the surcharge cost without treatment to obtain an approximate savings that would be available for capital, operation, and maintenance costs. The sewer surcharge costs were estimated based on BOD and TSS limits over 250 mg/L where the processor would be assessed at a rate of $.30 and $2.00 per pound, respectively. A savings of $17,698 was estimated per million gallons of UP treated WW. This savings does not include potential savings from recycling reconditioned WW and proceeds from marketing the recovered solids as an animal feed ingredient.

Table 3. Estimated Costs and Savings for UP Treatment of Egg Processing Plant Wastewaters.

Variables	Costs ($/MG Treated)
Power (30 & 20 hp motors)	2,610
Heating ($0.07/kwh, 30-50°C)	5,008
Chemicals (Cl backwash every 4 h)	625
Sewer Surcharge (BOD, TSS)	0
Total Costs	9,243
Sewer Surcharge w/o UF	26,941
Total Savings (excludes capital costs)	17,698

Electrocoagulation

The removal efficiencies for a portion of the electrocoagulation studies are summarized in Table 4. Over 92% of the COD, 99% of the turbidity, and 97% of the TSS were removed by EC [15 volts, stainless steel electrodes, with or without coagulant addition (CMC, BEN)]. COD, TSS, and FTU values ranged from 4,150 to 8,800 mg/L, 1,008 to 1,802 mg/L, and 1,100 to 1,700 FTU, respectively, across the four samples. These removal efficiencies were similar to those previously reported for treating meat and poultry processing wastewaters (Beszedits, 1982). The addition of the coagulants resulted in greater COD removal and shorter forming times than EC alone. The TSS and turbidity values of the treated WW were typically below 30 mg/L and 10 FTU, respectively, similar to those of drinking water. Moreover, the solids contents of the recovered sludge from the EC treatment contained 9-12% solids which is significantly higher than the solids concentration of sludges recovered from dissolved air flotation (3-5%) and precipitation (1-2%) WW treatment technologies. TSS and turbidity reductions were independent of coagulant type and WW source. The recovered solids contained 36 to 50% protein and 32 to 42% fat.

Table 4. Efficacy of Electrocoagulation for Treating Egg Processing Plant Wastewaters (15 Volts, Stainless Steel Electrodes).

Samples	COD (mg/L)	% COD Reduct	TSS (mg/L)	% TSS Reduct	Turbid (FTU)	% Turbid Reduct.
MWS	8,800	97	1,802	97	1,100	99
Plant A, w/o coag	4,150	92	1,008	97	1,700	99
Plant A, w/CMC	4,150	94	1,008	9 7	1,700	99
Plant A, w/BEN	4,150	95	1,008	97	1,700	99

Similar to UF, the recovered by-product from the EC treatment had a similar essential amino acid pattern as liquid whole egg (Table 5). Moreover, compared to the FAO essential amino acid profile for animal feeds, the recovered egg solids contained adequate concentrations of essential amino acids to satisfy animal nutritional requirements. The relative protein digestibilities of the recovered solids and corn/soybean meal were 130% and 56%, respectively. The digestibilities of the EC-treated WW were actually higher than the liquid whole egg control indicating that the treated proteins were slightly denatured making them more susceptible to enzymatic (pepsin) digestion, a factor of considerable importance when considered as an animal feed ingredient.

Table 5. Essential Amino Acid Composition of Liquid Whole Egg and By-Products Recovered by Electrocoagulation (g/100g protein).

Amino Acid	UF By-Product	Liquid Whole Egg	FAO Pattern
Threonine	4.11	4.08	2.8
Valine	6.18	6.32	4.2
Lysine	6.47	6.32	4.2
Methionine[a]	2.02	2.72	2.2
Isoleucine	5.63	5.56	4.2
Leucine	8.44	8.55	4.8
Phenylalanine	5.17	5.22	2.8
Tryptophan[a]	MD	1.52	1.4

[a]Methionine, Cystine, and Tryptophan were lost or partially lost by the acid hydrolysis procedure.

A cost analysis similar to that of UF was conducted on the EC process and indicated a potential savings for egg processors ranging from $25,585 to $26,733 per million gallons of treated WW depending on the use or omission of CMC or BEN (data not shown). These estimates were based on an average removal rate of 90% and 95% for BOD and TSS, respectively. The capital costs of this system were estimated at $500,000 with a projected life of 12 years. A typical egg processor producing 42.5 million gallons per year of WW would recover their capital costs in six months and then save over 1 million dollars per year thereafter.

These findings demonstrate that UF and EC treatments can be successfully applied to egg processing plant WW yielding a high quality reconditioned water suitable for recycling and valuable by-products of high protein and fat value.

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THE EFFECTS OF PARTICLE SIZE ON NUTRIENT LEVELS IN BROILER LITTER

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Previous studies, performed by Ndegwa (1991), Kelley (1998), Koon *et al.* (1992) and Cabrera (1993), have demonstrated that the nitrogen levels in broiler litter increases as the particle size decreases. These studies have utilized pine shaving based litter with 3-4 flocks between clean outs. As a result of advances in ventilation, drinker design and limited availability of litter base materials, current management practices result in 7 or more flocks between clean out. The use of other litter base materials, such as rice hulls, peanut hulls and composting of litter have become common. It is for this reason that studies were conducted to evaluate the nutrient composition of litter samples of various particle sizes to determine the impact of recent management decisions on nutrient distribution among litter particle sizes.

BACKGROUND INFORMATION

It has been shown that the number of flocks (1-3) on a litter base influences the fine particle fraction of the litter (Ndegwa, 1991). The large particles of litter, in pine shavings after four flocks, compile the majority of the litter mass, while the fine particles contain the highest nutrient concentration (Koon *et al.*, 1992). These fine particles compost a powder like material in which ammonia volatilization was more rapid early after application. It has also been shown that pelleted litter experiences a higher rate of denitrification (Cabrera *et al.*, 1993).

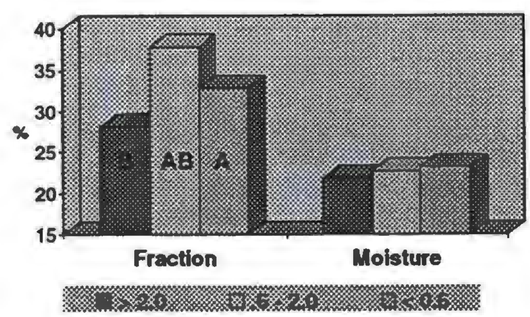
OBJECTIVE

The implementation of multi-flock management has allowed for litter to be utilized longer between complete clean outs.

These management practices provide litter with different characteristics from that of previous studies. The knowledge of nutrient content in the different particle sizes provides the potential for improved nutrient management plans.

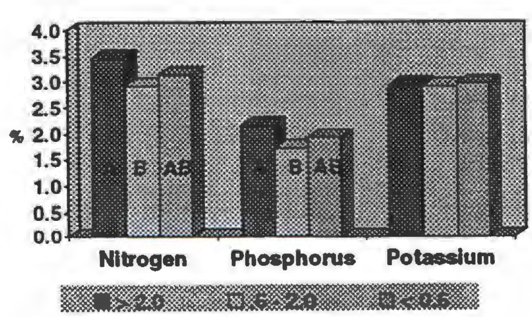
EXPERIMENT 1

An experiment designed to determine the nutrient content from 20 commercial broiler farms. The litter from all farms had been stored in deep stack prior to collection. Litter was sifted using a sieve shaker to divide the particle sizes. The sieve sizes used were 2.0 mm and 0.6 mm, for initial analysis. These samples were submitted to the Soil, Water and Forage Testing Laboratory at Texas A&M University. This trial showed that the mass of the litter was in the 0.6-2.0 mm size category, with no significant difference in the percent moisture (Figure 1). In this trial it is shown that the most significant nitrogen and phosphorus levels were in the >2.0 mm size group (Figure 2). There was no significant effect on the Ca, Na, Fe, Ma, Mg, Zn, or Cu levels in any of the size categories.



A,B P<0.05

Figure 1. Litter Particle Size Impact on Composition, Trial #1.

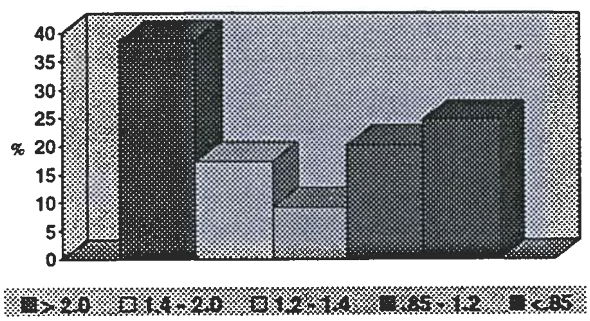


A,B P<0.05

Figure 2. Litter Particle Size Impact on Nitrogen, Phosphorus and Potassium, Trial #1.

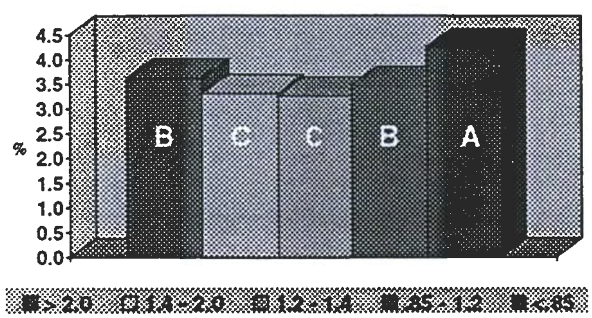
EXPERIMENT 2

Designed similarly to the first, this experiment was conducted using a rice hull based litter from a commercial broiler farm, after 7 flocks. The sieve shaker was again used, utilizing sieve sizes of 2.0, 1.4, 1.2, and 0.85 mm. Samples were submitted for analysis as in the first trial. The litter material was sifted resulting in no significant differences in the fraction distribution of the litter particle size (Figure 3).



A,B P<0.05

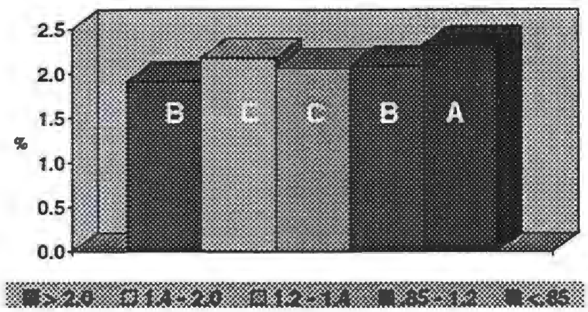
Figure 3. Litter Particle Size Impact on Fraction Distribution, Trial #2.



A,B P<0.05

Figure 4. Litter Particle Size Impact on Nitrogen, Trial #2.

The percent moisture in this trial also had no significant difference between particle size. Nitrogen and phosphorus levels were again the highest in the smallest particle size, <0.85 mm (Figures 4 & 5). The Ca, Mg, Zn, Fe, Cu, and Mn levels were all significantly higher in the 0.85 mm particles. In the trial, the K levels were not affected by the particle size.

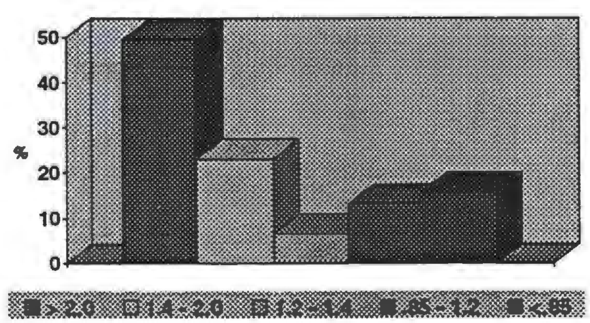


A,B $P<0.05$

Figure 5. Litter Particle Size Impact on Phosphorus, Trial #2.

EXPERIMENT 3

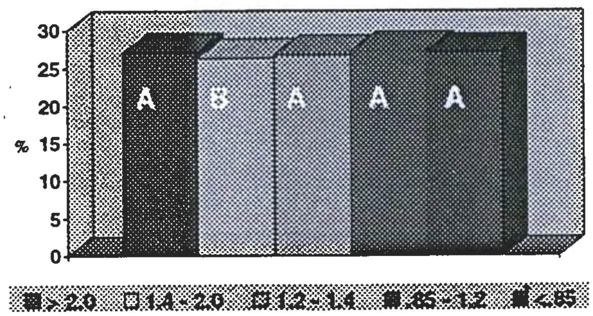
The third trial followed the same experimental design as the first two, this time utilizing a wood shavings litter base from a commercial broiler farm that had gone several years without a total clean out. The same sieve sizes were used for this trial as in the second (2.0, 1.4, 1.2, and 0.85 mm), and the samples were again submitted for analysis. The fraction distribution was not subjected to statistical analysis; however, approximately 50 percent of the material was >2.0 mm (Figure 6).



A,B P:0.05

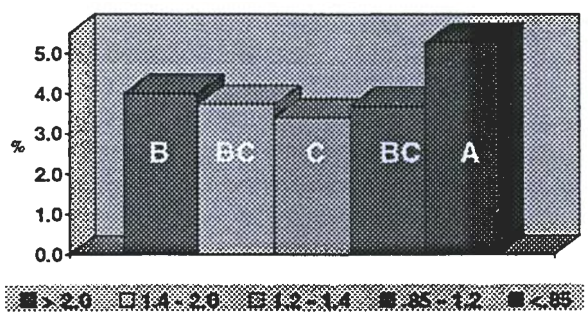
Figure 6. Litter Particle Size Impact on Fraction Distribution, Trial #3.

The percent moisture of the samples was again not significantly different (Figure 7). The nitrogen (Figure 8) and phosphorus (Figure 9) levels were again significantly higher in the <0.05 mm particles. In this trial the K, Mg, Na and Mn levels were higher in the >2.0 mm particles. The Ca and Cu were higher in the <0.85 mm particles, and the Fe and Zn was high in both the >2.0 and <0.85 mm particles.



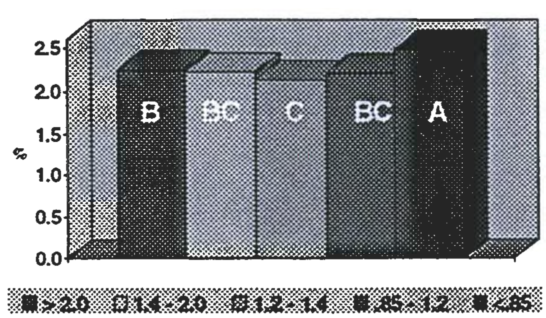
A,B P<0.05

Figure 7. Litter Particle Size Impact on Moisture, Trail #3.



A,B,C P<0.05

Figure 8. Litter Particle Size Impact on Nitrogen, Trial #3.



A,B,C P<0.05

Figure 9. Litter Particle Size Impact on Phosphorus, Trial #3.

CONCLUSION

These three trials show that the particle size of litter does make a difference in the nutrient content. The results have consistently shown that the N and P levels are the highest in the fine, powder like particles, concurring with previous work done in this area. This information shows, that even with increased life spans of litter in commercial broiler houses, the trend of smaller particles containing higher nutrient concentrations continues. Nutrient management plans can benefit from this information knowing that as more fine particles are used the higher the nutrient concentration, and vice versa with the larger particle sizes. This information currently is not being factored into most nutrient management plans causing inaccurate application rates.

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COMPARISON OF LACTIC ACID FERMENTATION AND ACIDIFICATION WITH PHOSPHORIC ACID AS STABILIZATION METHODS FOR GROUND POULTRY MORTALITY

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The production of vegetative silage from corn or other forage crops as a method of nutrient preservation has been practices for many years. Acidification of the material by direct acid addition or by bacterial fermentation increases the on-farm storage potential of the product by lowering the pH of the material to prevent microbial spoilage and to destroy pathogenic organisms. The build-up of lactic acid that results from ensilation has also been used as a method of stabilizing poultry carcasses for subsequent reuse as feed ingredients. Fermented poultry mortality and processing waste has been used directly for the feeding of several species of animals. Ensiled poultry viscera and poultry offal have been incorporated into swine and poultry diets with no adverse effects (Hassan and Health, 1986; Szakacs *et al.*, 1985; Tibbetts *et al.*, 1981 and 1987; and Tibbetts and Seerley, 1988). No effect on average daily gain, feed to gain, dressing percentage, or carcass characteristics was reported when poultry silage was included at up to 20% of a complete swine diet (Tibbetts *et al.*, 1987). However, higher levels of inclusion of fermented products often resulted in detrimental effects on the animals. Reduced growth rates and detrimental carcass changes occurred when poultry silage was included in swine rations at $\geq$ 30% (Tibbetts *et al.*, 9187). Diets composed of between 20 and 40% fermented by-products impaired reproductive performance and reduced the growth rate of both mink and fox (Lassen *et al.*, 1990a,b).

High levels of protein and amino acid breakdown products (ammonia nitrogen, total volatile nitrogen (TVN), and biogenic amines) were hypothesized to explain the detrimental effect of the fermented products on growth and reproduction (Urlings *et al.*, 1993a,b). Biogenic amines and total volatile nitrogen compounds result from the enzymatic breakdown of amino acids in fermented by-products and decrease their nutritive value. The use of these products was questioned until the effects of feeding elevated levels of these amino acid breakdown products were known (Urlings *et al.*, 1993a,b). Sander *et al.* (1996) concurred with Urlings *et al.* (1993a) that carcasses stabilized by fermentation may not be usable as raw ingredients for poultry meal due to the high levels of biogenic amines present in the material (Sander *et al.*, 1996).

Stabilization of by-product materials by direct acidification has been utilized as an alternative to fermentation to prevent spoilage and to control pathogenic organisms in many raw materials (Cai *et al.*, 1995; Divakaran and Sawa, 1986; and Norman *et al.*, 1979). Because bacterial proliferation is not required, the toxic by-products of microbial protein degradation are lower in raw materials stabilized by direct acidification and improved performance would be expected in animals fed ingredients prepared using these by-products (Raa and Gilbert, 1982). Phosphoric acid has been used successfully for the preservation of many by-products and foods for a number of years (Dziezak, 1990) and is currently used by the feed industry in the production of monocalcium and dicalcium phosphate. In addition, because it is a 100% bioavailable source of phosphorus, any expenses incurred by its use as a preservative can be offset by the value of the material as a source of phosphorus in any feed ingredients produced. An experiment was therefore conducted to determine the phosphoric acid requirements for storage of mortality silage and to compare the effectiveness of the lactic acid fermentation versus acidification with phosphoric acid for the stabilization of ground poultry mortality.

EXPERIMENTAL PROCEDURES AND RESULTS

Whole carcasses from 12-14 month old spent Leghorn hens were ground to approximately 1 cm particle size using the Fermac™ grinding system (Environmental Machine Systems, Inc., Fletcher, NC). Acidification treatments were prepared by blending feed grade, 54% phosphoric acid (Amberphos™, PCS Phosphates, Kinston, MC) with the ground poultry at 3, 4, 5, and 6% (wt/wt, concentrated acid basis). The lactic acid fermentation controls were prepared by mixing the ground poultry with 7.5% cane sugar (wt/wt) as a carbohydrate source and Stabisil™ silage inoculant (Medipharn, USA. Des Moines, IA) at recommended levels to provide adequate levels of lactic acid forming bacteria in the fermentation mixture. Three replicates of each of these treatments were incubated anaerobically at 21°C for 13 or 45 days and monitored for various parameters reflective of silage quality.

The pH of the vessels was monitored regularly to evaluate the effect of level of acidification on the pH of the material versus the lactic acid fermentation control. The acidity of the lactic acid fermented material decreased rapidly to approximately pH 4.65 and remained essentially stable. However, the pH of all the silage prepared by acidification increased over the course of the experiment. Figures 1 and 2 indicate the pH responses of the various treatments that occurred during the course of the experiment. The pH increase for the 5 and 6% H_3PO_4 treatments was significantly less ($p<0.005$) than for the 3 and 4% acidification treatments for both storage periods. No difference ($p>0.245$) in pH increase was demonstrated between the 5 and 6% H_3PO_4 treatments. The magnitude of pH increase following 13 and 45 days of storage was highly negatively correlated with the percentage of phosphoric acid (H_3PO_4) addition, indicating increased biological stability at the highest levels of acidification ($r = -0.878$, $p<0.001$ and $r = -0.941$, $p<0.001$, respectively.

To evaluate the materials for protein degradation products, the percent nitrogen (%N) in the form of non-protein nitrogen (NPN), ammonia nitrogen (NH_3-N), and volatile nitrogen (VN) were determined for the silage materials at 13 and 45 days of storage and compared to the values determined for the baseline materials. Significant ($p<0.001$) treatment effects were demonstrated for all nitrogen evaluation parameters. Figure 3 represents the %N in the form of NPN and VN for the phosphoric acid treated silage materials at the two time points of evaluation versus the levels in the original baseline material (Treatment 0). The %N in the form of NPN was significantly increased ($p<0.001$) in all silage treatments over baseline values following both storage periods. A linear decrease in the %NPN was demonstrated with increased levels of acidification at both 13 and 45 days of storage ($p<0.004$). The percent NPN levels were significantly ($p<0.005$) higher in all silage treatments following 45 days of storage versus 13 days of storage. The NPN levels in the lactic acid stabilized silage were significantly greater ($p<0.002$) than in the 6% H_3PO_4 treatment following 13 days of storage, and greater than both the 5 and 6% H_3PO_4 treatments ($p<0.036$) following 45 days of storage. As demonstrated in Figure 4, the % N in the form of VN was significantly lower ($p<0.001$) in all acidification treatments than in the lactic acid stabilized silage materials following 13 days of storage. However, by Day 45 of storage, only the 6% H_3PO_4 silage demonstrated values for this parameter significantly less than those seen in the lactic acid silage ($p<0.01$). Graded additions of H_3PO_4 resulted in a quadratic decrease ($p<0.001$) in the % VN among the acid treatments following 13 days of storage and a linear decrease ($p<0.001$) after 45 days of storage. As seen in Figure 5, the %NH_3-N was also greater in the lactic acid stabilized silage than in any of the acidification treatments following 13 days of storage ($p<0.001$). No differences in this parameter were demonstrated among the 4, 5, and 6% H_3PO_4 treatments at this time point ($p>0.292$). However, following 45 days of storage, the %N in the form of NH_3-N was significantly lower in the lactic acid prepared silage than int he 3 and 4% H_3PO_4 treatments, but not different from the values in the 5 and 6% H_3PO_4 treated silage materials ($p<0.001$ and $p>0.09$, respectively). A linear decrease ($p<0.001$) was demonstrated among the graded H_3PO_4 treatments with respect to this parameter following this storage period.

Table 1. Salmonella spp. Detected (Brilliant green agar w/Novo).

Preservation Treatment	Day 13	Day 45
Lactic Acid	Negative	Positive
3% Phosphoric Acid	Negative	Positive
4% Phosphoric Acid	Positive	Positive
5% Phosphoric Acid	Negative	Positive
6% Phosphoric Acid	Negative	Negative

The most acidic silages were not only biochemically stable, but in this experiment, they were also free of enteric pathogens. Fecal coliform bacteria were quantitated using Procedure 9222A: The Fecal Coliform Membrane Filer Procedure (Standard Methods for the Examination of Water and Wastewater, 1992). A qualitative determination of *Salmonella* spp. was performed by a 24-hour enrichment of silage samples in tetrathionate broth followed by streaking on Brilliant Green agar with novobiocin (Difco Laboratories, Detroit, MI). Direct swabbing onto MacConkey's agar was also performed as a qualitative confirmation for fecal coliform bacteria (Difco Laboratories, Detroit, MI). Table 1 and Figure 6 represent the results of this analysis. Baseline samples contained 10^5 CFU (colony forming units) of fecal coliform bacteria/gm of ground material. Acidification with 6% H_3PO_4 resulted in a material free from fecal coliform bacteria. Fecal coliform bacteria were enumerated in all other acid silage treatments. However, none were detected in the silage material prepared by lactic acid fermentation. By Day 45, *Salmonella* spp. were identified in all treatments except at the 6% H_3PO_4 level of acidification. Because none of the lactic acid fermentations resulted in technically successful fermentation (pH<4.5), microbiological safety of the material was not expected.

Representative samples were submitted to the North Carolina Department of Agriculture Forage Testing Laboratory (Raleigh, NC) for nutrient analysis. Significant treatment differences ($p<0.006$) were demonstrated for many of the nutrient analysis parameters (Table 2). When compared to the lactic acid fermentation control (LA), crude protein (CP) was significantly increased in the 3 and 4% H_3PO_4 silage materials, but not different than the control ($p>0.05$) for the 5 and 6%

acidification treatments. Crude fat (CFAT) was similarly affected, presumably due to dilution effects. Phosphorus (P), iron (Fe), and manganese (Mn) were significantly increased over the lactic acid control for all levels of acidification. No significant differences ($p>0.05$) were demonstrated for calcium (Ca) among the treatments.

Table 2. Dry Matter Proximate Analysis of Spent Hen Mortality Silage.

TRT	DM[1]	CP[1]	CFat[1]	Ca[1]	P[1]	Fe[2]	Mn[2]
3%	40.8[b]	43.8[a]	32.6[a]	2.87	4.90[a]	1502[c]	66.7[a]
4%	40.1[b]	45.3[a]	31.6[a]	2.37	4.79[a]	2033[b]	62.3[a]
5%	51.9[a]	34.4[b]	24.3[b]	2.70	4.75[a]	2214[a]	68.0[a]
6%	53.1[a]	30.3[b]	18.7[c]	2.32	4.87[a]	2217[a]	73.3[a]
LA	52.0[a]	34.8[b]	21.8[b,c]	2.46	1.05[b]	64.3[d]	4.67[b]

[a-d]Means within columns with no common superscript differ significantly ($p<0.05$).
[1]Percent (%)
[2]PPM.

Results of this study to date demonstrate that ground poultry can be stabilized and maintained under ambient conditions for a period of up to 45 days by using either lactic acid fermentation or the addition of feed grade phosphoric acid at 6% (wt/wt, concentrated acid basis). No differences in proximate analysis values for crude protein or crude fat were demonstrated between silage material prepared using 5% or 6% H_3PO_4 and that of silage prepared by lactic acid fermentation. This indicates that the materials should have similar feeding values once adjusted for dry matter. Significant mineral value differences were demonstrated and should be taken into consideration in ration formulation. However, mortality silages prepared using 6% H_3PO_4 contained lower levels of protein degradation by-products than did silages prepared by traditional lactic acid fermentation. Therefore, feedstuffs manufactured using mortality silages prepared by the addition of 6% phosphoric acid would be expected to result in improved animal performance in nutritional trials versus feedstuffs manufactured using silages prepared by lactic acid fermentation.

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