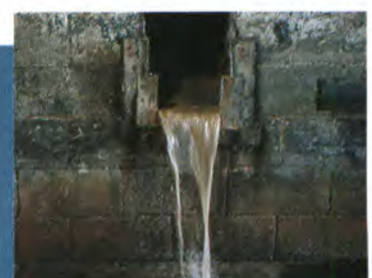
Proceedings

1992

National Poultry Waste Management Symposium



Edited by
J.P. Blake
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Proceedings

1992 NATIONAL POULTRY WASTE MANAGEMENT SYMPOSIUM

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1992 NATIONAL POULTRY WASTE MANAGEMENT SYMPOSIUM

DATES:

October 6-8, 1992

LOCATION:

Sheraton Civic Center Hotel
Birmingham, Alabama

PREFACE

The symposium is a cooperative effort of USDA-Extension Service, land-grant universities, state and national poultry organizations, poultry companies, and allied industries. The symposium has been organized to discuss the issues, problems, and potential solutions to problems in the area of poultry waste management. Growth and concentration of the poultry industry has resulted in large volumes of manure, hatchery wastes, farm mortalities, and processing plant wastes that must be utilized in an environmentally sound manner. Increased concern for these matters is evident within the poultry industry, by the public, and regulatory agencies.

The program for this symposium is organized on the basis of a general session addressing environmental issues that impact the poultry industry, followed by concurrent sessions that converge on specific aspects of poultry production and processing wastes. The **Proceedings 1992 National Poultry Waste Management Symposium** is an integral part of this meeting, since it contains a wealth of information concerned with poultry waste management that is not available elsewhere.

The program committee thanks all persons, exhibitors and corporate and government sponsors that graciously helped to make this symposium successful and well attended.

EDITORIAL

The manuscripts presented for this workshop were reviewed and subjected to minor revision, as necessary, by the editors. The manuscripts were not evaluated by a peer review process. We want to thank all authors for their diligence and timeliness in preparation of their manuscripts.

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

John P. Blake
James O. Donald
Paul H. Patterson

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Acknowledgements

The organization and administration of a successful symposium requires 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 thank you is deserving of those who were 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 local arrangements. Their involvement has definitely contributed to the success of this symposium.

The editors and organizing committee are indebted to Patricia Owen, Department of Poultry Science, Auburn University for her technical assistance and dedicated efforts in ensuring the quality and timeliness of this proceedings.

NATIONAL POULTRY WASTE MANAGEMENT SYMPOSIUM WELCOME

J. E. Marion
Dean
College of Agriculture
Auburn University
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Welcome to the 1992 National Poultry Waste Management Symposium. Welcome to the State of Alabama, and to the City of Birmingham. It is most appropriate that this meeting be held in Alabama. If there is a "heart of the poultry industry" in the U.S., it would be near the spot where we meet today. With the exception of the poultry industry on the west coast, at least 90% of poultry production and a majority of the market for poultry products in the U.S. are within a 24-hour drive of north Alabama. The poultry industry here in Alabama and in the U.S. continues to grow at an unprecedented rate. With that growth, many opportunities are afforded those associated with this industry and many problems accompany this growth.

Those individuals associated with this Symposium, especially the Program and Local Arrangements Committees, have long recognized the problems and opportunities associated with the growth of the poultry industry, and have made laudable progress in finding answers to problems. Thus, problems became opportunities.

Chief among the problems facing the poultry industry are those of waste management and associated environmental issues. Practically all of these problems are addressed in-depth by the wide range of speakers and poster presentations scheduled for this Symposium. Also, discussions on the floor and in hallways will further disseminate the information formally presented here.

Let me suggest that one desirable outcome of this Symposium would be to find new terminology to replace that of "waste". A dictionary definition of the word "waste" emphasizes careless use, consumption, loss, expenditure, etc.; whereas, we define waste as by-products that have measurable value when recovered and managed properly. A further benefit to the recovery and utilization of these by-products is that of environmental protection. Wastes have been defined by some scientists as resources out-of-place in the environment.

Perhaps then our substitute for the word "waste" may be by-products, bio-resources, recyclables, etc.

Now let me return to the statement of welcome and the reference to Birmingham, Alabama as a fitting site for this conference. This city has seen some very wonderful improvements in its environment in the last 25 years. Historically viewed as a steel town of the South with associated environmental problems, Birmingham was not viewed as the best place in the world to live. With the cooperative efforts of the citizenry, city leaders, and leading industries, the air has been cleared, waterways cleaned, buildings renovated, new industries built, educational institutions strengthened and a new outlook on life established. This new outlook is based on many substantive improvements including landscaping the downtown area and new office complexes on the outskirts of the city.

While the city folks have undergone improvements, we in the country, especially in the poultry industry, have done our share. You will hear about numerous ideas that have been successfully translated to reality with the result that our waste or by-products are being recycled, utilized and managed to both economic and environmental advantage. These changes are a result of producers, processors, academia, government and others working hand-in-hand to achieve what one organization alone could not have accomplished.

Again, I welcome you and wish you a most successful Symposium.

INTRODUCTION TO THE 1992 NATIONAL POULTRY WASTE MANAGEMENT SYMPOSIUM

John P. Blake
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It is with great enthusiasm that I welcome you to the 1992 National Poultry Waste Management Symposium. This is the third consecutive Symposium that has been held on a biennial basis concerned specifically with the utilization of poultry by-products. The previous Symposia were held in 1988 and 1990 in Columbus, OH and Raleigh, NC, respectively.

The Symposium in which you are about to participate is the culmination of two years of planning by university and industry representatives. The program committee has organized an excellent program concerned with the environmentally safe disposal and utilization of by-products produced by the poultry industry.

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. We are fortunate to live in a society where a mere 2% of the population actively farms to feed the remaining 98% percent and where food costs account for only 11% of income. No other society in the world can match the level of economy of productivity exhibited by U.S. agricultural production.

Unfortunately, the concentration of poultry production and processing has resulted in the production of large volumes of by-products including: manure, farm mortalities, hatchery wastes, and processing plant wastes that require daily attention. The 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. This Symposium has a vested interest in providing the most current research and technology available to the poultry industry for directing the management and utilization of their by-products in an environmentally sound manner.

As you can see from the program, this Symposium was organized to discuss issues, opportunities, and potential solutions to problems associated specifically with poultry waste management. The General Session will set the stage by addressing some environmental issues that are relevant to the poultry industry. The remaining sessions will be concurrent and will encompass issues relevant to either production or processing. Production sessions are concerned with the management of on-farm wastes such as litter, carcasses, and other environmental concerns. Processing sessions are concerned with those by-products generated by hatcheries, processing plants, and reclamation facilities associated with by-product usage.

There are two firsts for this Symposium. Poster presentations will be displayed during the meeting and their written counterpart appears in the Proceedings. Secondly, a hands-on Processing Workshop will be conducted on the final morning of the Symposium.

Symposium participants are provided with a copy of the Proceedings and additional copies are available at a cost of $20.00 plus $5.00 for postage and handling from:

John P. Blake
Department of Poultry Science
Auburn University, AL 36849-5416

Please make check payable to:

National Poultry Waste Management Symposium

The program committee of the 1992 National Poultry Waste Management Symposium hopes that everyone attending the Symposium will acquire useful and interesting information. Please take the opportunity to complete the evaluation and provide comments for guiding future programs.

SUMMARY AND RECOMMENDATIONS FROM THE NATIONAL LIVESTOCK, POULTRY AND AQUACULTURE WASTE MANAGEMENT WORKSHOP

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COMMENTS ARE STRICTLY THE OPINION OF THE AUTHOR, AND MAY OR MAY NOT REFLECT US DEPARTMENT OF AGRICULTURE OR EXTENSION SERVICE POSITION OR POLICY.

The United States Department of Agriculture (USDA) Extension Service (ES) Water Quality National Initiative Team sponsored a National Livestock, Poultry and Aquaculture Waste Management Workshop, held on July 29-31, 1991 in Kansas City, MO. The event was co-sponsored by the USDA Agricultural Research Service (ARS), USDA Soil Conservation Service (SCS), US Environmental Protection Agency (EPA), and the Tennessee Valley Authority (TVA). The USDA Cooperative State Research Service (CSRS) was a cooperating agency. Michigan State University acted as liaison with the American Society of Agricultural Engineers (ASAE), who provided local support, and published the proceedings.

The purpose of the workshop was to provide a national forum to develop a broad consensus on the scope, dimensions and implications of the impacts of animal residuals (waste) on water quality. The prioritized recommendations from commodity work groups represented the educational, research and technical assistance requirements, responses to problems and opportunities, and an identification of potential barriers and constraints when dealing with water quality issues related to animal waste management.

There were 300 registrants, about 275 participants in the specific commodity sessions, and about 225 ballots cast in the final session to determine overall priority rankings. Participants were from forty states, three territories, one foreign country, and the District of Columbia.

The prioritized recommendations for each commodity group and the overall recommendations for animal agriculture are listed in the proceedings from this workshop. The listings may be consulted for research ideas or policy recommendations.

Copies of the proceedings may be purchased from ASAE (616/429-0300). The top ten priorities as established by a vote of participants, and brief evaluation of the priorities and potential policy implications follow.

TOP TEN RECOMMENDATIONS FROM ANIMAL AGRICULTURE

1. (794 points; these are converted ranking scores) DEVELOP EDUCATIONAL PROGRAMS FOR LIVESTOCK, POULTRY AND AQUACULTURE MANURE MANAGEMENT, NUTRIENT CYCLING, FOOD PROCESSING BY-PRODUCT USE.

Evidently, current national, state and local educational programs are insufficient or are not being adequately communicated. Material may not be getting into the hands of people that will use it, or may not be relevant to their needs. For example, there are several nutrient management programs in the states, produced or supported by various state and federal agencies, and one may yet hear comments that many farmers are not really using the information.

Educational programs are more than just preparing a bulletin or holding a workshop. Written material must have sufficient distribution, and workshops must be held in enough locations for maximum attendance. The existance of educational efforts are normally publicized through various trade media, and should include cooperation with commodity and other agricultural groups. Site specific assistance is generally essential for successful transfer of technology, and the availability of this assistance must be similarly publicized. Unfortunately, given the budgetary problems in most states, and altered areas of emphasis within Extension there is not sufficient personnel to adequately cover all these responsibilities for all commodities.

Educational programs should improve the farmer's understanding of the value of various animal residuals such as compost or unprocessed manure or litter, and therefore their trust in nutrient management programs. Farmers may understand that they are wasting money and potentially polluting our environment by excessive nutrient application, yet are not comfortable enough with available information to reduce the nutrients provided to their crops. One must remember that it is the farmer's future which they gamble each year, and so they may not be willing to forego the cheap insurance of extra nutrient application.

It is very important that accurate and timely information, which is easily understood, be available to farmers if they are to be expected to make changes in management practices. Credibility of any agency is destroyed when information they provide is out-dated, wrong, impractical, or otherwise of marginal value.

2. (665 points) IMPROVE COMMUNICATIONS AND COOPERATION BETWEEN GOVERNMENT AGENCIES AND WITH ENVIRONMENTAL GROUPS, FARMERS, INDUSTRIES AND UNIVERSITIES.

Some participants noted the lack of teamwork by government agencies required to help solve industry problems, and turf protection as being obvious in various programs. For example, do county ES, SCS, and Agricultural Stabilization and Conservation Service (ASCS) personnel voluntarily work together to help farmers find the optimal (holistic) solution to a problem, provide independent assistance, or maintain an antagonistic or non-cooperative relationship? Some industry and agency personnel see the ES, SCS, ASCS, and EPA as great pretenders of teamwork, and as having an insufficient number of people within these organizations who are able or willing to facilitate cooperation on a broad scale.

In some places, there is exemplary cooperation and teamwork between personnel in various government agencies at the local, state, and national levels, the universities, and the private sector. A good example of cooperation between agencies is the effort between the USDA SCS, USEPA, TVA and the Southeastern Poultry and Egg Association to establish a pilot project whereby a water quality liaison was hired for the poultry industry. In other cases, personnel are very territorial, hence equally non-cooperative. Personnel or agencies are perhaps afraid of someone else receiving credit for providing assistance they are not capable of providing (or, unwilling to provide). The probable real answers for various examples of insufficient cooperation are undoubtedly somewhat more political, personal, or as observed by some personnel, perhaps juvenile.

There is a multitude of reasons for insufficient communication between water quality coordinators and persons working in water quality programs at many universities. Part of the communication problems would be corrected by administrators matching work assignments with responsibility and authority, and by everyone participating in a team approach to solving water quality problems.

The need to address political questions should be minimized, as should complaints generated by neighbors wishing to exclude animal agriculture from their area, or environmental organizations seeking to expand their treasury by recruiting new members through (high profile) issue development. Unless they can influence the EPA and thus regulations, environmental groups have not been generally viewed by the industries as wanting to work with government agencies. This may be changing for mainstream groups. Multi-issue groups seem especially anxious to provide input.

3. (565 points) ENSURE REGULATIONS ARE DEVELOPED WITH A SOUND SCIENTIFIC BASIS.

Keeping personnel in state and federal government agencies appraised of changes in the nutrient values contained in organic materials from all species is an important task that is not being adequately addressed. There should be **SHORT** and reasonably priced educational seminars available that keep everyone up to date. Similar information should be periodically and regularly condensed in pamphlet format. Water quality/waste management meetings should be used as a mechanism to foster cooperation between regulators, university scientists, and the animal industries.

Of great concern is that misinformation or arbitrary levels, not established using scientific methodology, but demanded by environmental groups, may be used to establish regulations. Although progress in cooperation is being made, the USEPA has historically been perceived as being staffed by persons sympathetic to environmental groups and having limited knowledge or concern for the impact their regulations may have on agricultural enterprises. Our agricultural system cannot be at the mercy of persons not willing to use scientific methods and reason in the promulgation of regulations.

A clear-cut explanation of the process to establish various environmental standards would help people understand how scientific information is used to develop regulations. There is a need to monitor water sources, and develop regulations based on sound scientific data. Farmers and others need to know how to interact with state and federal environmental protection personnel who develop regulations/standards, not for the purpose of halting progress, but to ensure unfair or inappropriate regulations are not imposed on the system. Farmers are concerned for their environment, and are the first line of defense in its preservation. Teamwork, educational programs which provide an understanding of the environmental consequences of unsuitable actions, and an on-going commitment to progress are essential components of environmental protection.

4. (418 points) DETERMINE IF N SHOULD BE USED AS THE LIMITING FACTOR INSTEAD OF P IN DEVELOPING NUTRIENT MANAGEMENT PROGRAMS.

There is considerable confusion regarding which element should be rate limiting for land application of animal residuals or to evaluate the extent of water contamination. Some areas of the country are more concerned with phosphorus saturation of the soil than leaching of nitrogen into the groundwater or runoff into surface water. Everyone working in water quality/animal waste management should have ready access to information which explains in understandable terms the advantages and disadvantages of each system, which standard is most appropriate, and when it should be used.

5. (407 points) DEVELOP A TOTAL SYSTEMS APPROACH TO MANURE MANAGEMENT.

We currently have guidelines for manure management, nutrient management plans, etc., so why is this listed as a priority? Perhaps because what we have is not sufficient, not easily understood, or not feasible. Our challenge is to define the components for a systems approach to manure management for individual farms and for regions, and to work with farmers to implement these programs. For example, how may the ration be modified to reduce the amount of N, P, or heavy metals excreted? Alternative marketing opportunities for animal residual material, different forms of the product, different transportation equipment, and different processing equipment may be required.

Is there a real need for nutrient management plans to be written for each state? Soil types probably vary as much within a state as between most surrounding states. Do we need a basic national program or guidelines for nutrient management plans, to be modified by universities or government agencies for soil types in different regions, and for individual fields/farms?

Farmers in various states are not going to the ES or SCS for assistance in nutrient management programs. A comment was heard that there is "nothing to (that will) get ES or SCS people out of their office and into the field to help with soil tests". This farmer may not appreciate the extent of understaffing of production agriculture personnel in ES offices. Fertilizer dealers in some areas are filling this educational void by writing nutrient management plans, and providing soil tests as part of their business dealings.

People do not see a flexible, coordinated approach to waste management. In the past, new techniques such as dead bird composting have been inhibited by a lack of cost share funds and confusion regarding these funds, as well as prohibitory state regulations. Although regulations have been modified to eliminate the five year requirement for cost sharing dead bird composting units, cost sharing is not available for this residual utilization procedure for new housing.

6. (378 points) ADEQUATE FUNDING BE MADE AVAILABLE FOR RESEARCH AND DEVELOPMENT FOR MANURE USE AND MARKETING.

This is a perpetual problem. One which should be explored from the context of grants for research or education projects. Multi-agency or multi-state grants should be considered, especially if government funding is desired. If we are to make progress, a critical minimum level of financial assistance is required to ensure high quality, coordinated programs are delivered to farmers.

Each state is provided a small amount of money by the USDA/ES Water Quality NIT as Improved Program Support. There is also the potential of funding of non-research (evaluation) projects through the Water Quality or Waste Management NIT contact at each Land Grant University. Also, the USEPA and other government agencies have grant money that could be utilized. Each person has the responsibility of staying in touch with the designated coordinator at their university, or contacting agency personnel to determine deadlines, etc. More money needs to become available, but existing limited funds need to be wisely spent, and the results given widespread distribution. Cooperative projects between states and disciplines is one way to increase the efficiency of resource utilization.

7. (295 points) DEVELOP IMPROVED MANURE APPLICATION EQUIPMENT CONSIDERING CALIBRATION, UNIFORM APPLICATION, INCORPORATION AND MINIMIZATION OF COMPACTION.

Calibration is at this time too troublesome (time-consuming, nasty---how do you accurately get the very high moisture manure off of the collection tarp?), especially with the more liquid manure dispersed by the flail type spreaders for farmers to consistently conduct calibration trials. Few farmers have time to routinely calibrate their equipment.

Manure piles do not necessarily have a uniform composition, which is seen as negating the accuracy of calibration---so should the farmer recalibrate for sections of the pile or house? Must laboratory analyses be conducted for segments of the house or pile? More than one type of manure spreader is used on many farms, which increases the difficulty of frequent calibration and therefore it's absence. These factors may contribute to the application of commercial and animal fertilizers in excess of plant requirements. There is also the problem of compaction of soil from making numerous trips over the field to spread residuals thinly.

Everyone working in the water quality area has to play the devil's advocate and attempt to answer all the practical questions that will arise when their recommendations are being implemented. Or they will not be.

8. (284 points) INCLUDE INDUSTRY, SCS, AND UNIVERSITY/EXTENSION IN DEVELOPING REGULATIONS.

These personnel are seen as a moderating force, and as being objective. Their presence is seen as increasing the probability that regulations will reflect practical and achievable environmental goals. Cooperation must be initiated, facilitated and maintained if these regulatory (and educational) goals are to be possible. Unfortunately, personal, activist, or agency agendas too often surface as the first priority in program planning or regulation development.

Farmers probably have the most to gain by maintaining potable water supplies and a clean environment because their families may be the first to consume contamination from their farm. But, there may be short term financial and personnel constraints that conflict with desires or force modification of expected behavior. 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.

9. (279 points) RECOMMEND THAT REGULATIONS AND BEST MANAGEMENT PRACTICES RECOGNIZE THE ECONOMIC COSTS AND RETURNS TO THE REGULATED PRODUCER.

Regulations are, or are perceived to be, imposed that do not consider the consequences to the farmer. Is it better to force someone out of business or to work with them to correct a problem over a longer period of time? Personnel should develop nutrient management systems that are cost and time effective, and transfer these ideas to regulatory agencies. Feasibility studies or expected economic impact statements should be an integral part of the regulation development process. Many things are possible and preferred if you are not personally involved in the implementation.

10. (272 points) ENCOURAGE PROCESSING AND DEVELOPMENT OF MARKETS FOR OFF-FARM CONSUMPTION OF WASTES AND WASTE BY-PRODUCTS.

Composting is an important and viable option for manure management, but is not well understood by farmers and others producing, marketing, or utilizing the product. Even after paying for an accurate laboratory analysis, most farmers will undoubtedly need to have many questions answered regarding compost application rates for specific crops, nutrient activity versus raw manure, and value compared to commercial fertilizer or other manure products. There are bound to be questions regarding the procedure to maintain, and the consequences of not maintaining, a correct C:N (e.g., how and to what degree does a high C:N compete with plants by robbing soil N?).

Standards must be developed for the use of animal manure and other residuals and their compost, municipal sludges, or animal production residual and sludge compost mixtures. Information should be available on how to blend compost or manures to use with commercial fertilizers. These production and use guidelines and standards must be easily understood and trusted by producers and users of the product. Information needs to be available regarding nutrient content and release time, by type of compost, to properly fertilize each category of crop.

Procedures need to be refined, and recommendations developed for using composted dead bird mixtures. Mechanisms need to be developed for the economical transport of composted manures; e.g., (from Glenn Carpenter, West Virginia University; 304-293-5229) use the rail system to move compost or other residual material from the eastern states to the mid-west to directly or eventually return nutrients to the land from which the grain was grown. Also, alternatives should be developed to deal with saturation of the compost market.

10. (272 points) RECOMMEND MORE RESEARCH IN WATER MONITORING TO ACCURATELY IDENTIFY SOURCES OF GROUND WATER DEGRADATION.

Agricultural engineers and others may need to work closer with the USEPA, and personnel from other government agencies to develop methods to monitor contaminants from ground and surface water. Procedures need to accurately identify and quantify the contributions of various sources of pollution. For example, is the nitrogen in contaminated ground or surface water from commercial fertilizers, manures, or lawn care products? Is the fecal coliform in water supplies from animal sources or humans via leaking septic systems? Also, can we quantify the odor from a production facility to prove that a neighbor's complaint is frivolous---or to show the producer the neighbor has a valid grievance? Is there a way to provide similar information regarding a fly problem blamed on an animal production facility, versus a complaining neighbor's horses?

REFERENCE

Reynnells, R.D., 1991. Animal Agriculture: Priority Nominations, pp. 327-336. In: National Livestock, Poultry and Aquaculture Waste Management, Proceedings of the National Workshop. American Society of Agricultural Engineers, 2950 Niles Road, St. Joseph, Michigan 49085-9659.

TARGETING SOLID WASTE COMPOST MARKETS

C. Ron Albrecht, President
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Annapolis, MD 21401

The marketing of solid waste compost is a relatively new endeavor in the United States. Currently there are only a few facilities producing a limited amount of compost. As a result of the growing interest in composting municipal solid waste and concerns about the marketability of compost, the Solid Waste Composting Council commissioned a study of potential applications for compost in the U.S.

The study estimates the current and potential quantities of compost in million cubic yards per year from municipal solid waste, wastewater treatment plant sludge and horticultural and agricultural wastes. Since the study focuses on the use of compost made from municipal solid waste, potential application areas are limited to within 50 miles of urban centers. Estimates of the potential applications of compost are developed for 10 different potential use segments: landscaping, topsoil, bagged/retail trade, landfill cover, surface mine reclamation, container nurseries, field nurseries, sod production, silviculture, and agriculture. Most of the segments are further divided into subsegments and detailed information is presented. In addition, information on the current penetration into each of these market segments is developed. Source information is provided for all of the data. Comparison of the resulting supply and demand estimates indicates potential applications of approximately 1,000 million cubic yards per year and potential production of 100 million cubic yards per year. Potential uses are a magnitude greater than potential supply.

The three application segments with the greatest immediate potential to use large quantities of compost are landscaping, topsoil and the retail/bagged market. Although there is significant penetration into the bagged/retail industry, there is limited penetration into the landscaping and topsoil industries. These applications appear most critical for successful distribution of compost. Other segments with large potential use include field nurseries, silviculture, and agriculture. Constraints that complicate penetration of these markets include the cost of the compost and transportation to the point of use. These markets will require time and effort before significant penetration is achieved.

Project planners are provided with an accurate method of identifying and quantifying local markets. Data is presented on a regional and state basis. By using county census data and following the detailed instructions provided for each segment given in the study, it is possible to estimate the potential amount for each application segment. This then allows the development of a total estimate of potential use for any area. Further refinement requires the application of constraints specific to the study area.

PROGRESS AND POTENTIAL OF THE LIAISON POSITION BETWEEN SEPEA, USDA, TVA AND EPA

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Each year, poultry production in the U.S. makes significant impacts on our economy and environment. In 1991, the National Agricultural Statistics Service published these figures: the combined value of production from poultry was $14.7 billion; value of broilers was $8.39 billion; value of egg production was $3.89 billion, value of turkey production was $2.34 billion, other was $68 million. Quite impressive amounts, but look at what these dollar figures represent: number of broilers produced were 6.14 billion with 5.5 billion produced in just 15 states (AL, AR, CA, DE, FL, GA, MD, MS, NC, PA, SC, TN, TX, VA and WV); egg production (I think for consumption) was over 69.0 billion; number of turkeys produced was 285.0 million weighing over 6 billion pounds. There is more, but any way we look at the figures for every action there is an opposite reaction.

In this case, the opposite reaction is in the form of poultry mortality, manure/litter and waste water. Annual poultry mortality (excluding processing) is over 50 million birds and the annual production of manure and litter is approximately 41 billion pounds, all of which has to be disposed. The amount of acre-feet of waste water (326,000 gallons in an acre-foot) used each year is anybodys guess.

As the industry grows, protecting natural resources is a major priority. There is a demand for new technologies in poultry by-product development, storage, utilization and land application. Recognizing that environmental concerns have become both an economic and social issue throughout the world, foresighted individuals in the poultry industry are seeking ways to minimize impacts on the environment and that improvement in by-product disposal and utilization are needed. At the same time, the federal agencies are seeking cooperative efforts toward the same goal.

The poultry industry and three federal agencies have joined together to enhance environmental management by the rapidly growing poultry industry. An Industry/Interagency Agreement was signed in 1991, which recognizes the environmental challenges of protecting the natural resources and focusing on pollution prevention. The purposes and approaches of the signatories were a little different; but communication, cooperation and education are the key to pollution prevention and protecting our natural resources. Signatories of the agreement are: Southeastern Poultry and Egg Association, USDA-Soil Conservation Service, Tennessee Valley Authority, and U.S. Environmental Protection Agency. While this agreement is the first known of its type in the nation, its direction is clear, to provide information to the industry in the use of poultry by-products as a sustainable resource and prevent them from becoming a pollution source. Members of the agreement, in joining together, have now become known as the **Poultry Water Quality Consortium** (PWQC).

Following is a short synopsis regarding each of the Consortium members.

Southeastern Poultry and Egg Association is the largest and most active industry organization of its kind. Through the years since 1947, the association has recognized that mutual challenges of their industry can best be solved by joining together and sharing ideas. This principle can be called technology transfer and Southeastern specializes in this, insuring that knowledge and information continues to be exchanged and shared.

Southeastern represents the entire poultry industry, from producers of eggs, broilers and turkeys, to the processors of poultry and egg products, as well as, the allied companies that serve the industry.

Southeastern is known for its International Poultry Exposition held annually in Atlanta. More than 800 exhibitors and 22,000 people attend, representing over 75 nations. Continuing education is high on its priority list. Each year, a comprehensive schedule of workshops, clinics and seminars are used to keep the industry informed of management functions. In 1993, a seminar on water quality will be held.

Southeastern's extensive research program encompasses every phase of the poultry industry. In the last couple of years, over 2.5 million dollars has been returned to the industry in the form of research grants to answer challenges and find better ways of producing poultry products.

USDA-Soil Conservation Service (SCS) traditionally has provided technical and limited financial assistance, primarily under RC&D, Small Watershed and Great Plains Programs, to the agricultural community. The 1990 Farm Bill focused on major agricultural concerns including pesticides, nutrients, animal wastes and agricultural pollutants in surface and groundwater.

In 1986, USDA issued a Departmental Regulation - "USDA Nonpoint Source Water Quality Policy". SCS policy promotes economically feasible and practical measures for treating or preventing water quality problems, such as poultry mortality management, nutrient management plans and constructed wetlands to treat liquid wastes, to name a few. SCS also encourages voluntary approaches to solving resource problems and the continued exchange of information.

Tennessee Valley Authority (TVA) is committed to resource development and environmental quality in the Tennessee Valley and throughout the nation. Protecting water quality is a major concern for TVA, as illustrated by their ongoing projects related to proper management and utilization of animal wastes, poultry litter and dead birds. TVA is in an excellent position to identify, demonstrate and transfer poultry by-product resource technology to potential users through its close ties with federal and state agencies, universities and private organizations.

U.S. Environmental Protection Agency (EPA) is dedicated to improving and protecting the quality of the environment, and under the Clean Water Act is required to address point and nonpoint sources of water pollution. Certain poultry operations and rendering plants are regulated as point sources and may be required to obtain a permit. However, many of EPA's efforts to prevent or reduce water pollution associated with poultry by-products involved nonpoint source pollution. EPA has helped states to develop their nonpoint source assessments and management programs and is providing assistance to implement nonpoint source controls through Section 319 and other grant programs. Through the Poultry Water Quality Consortium, EPA is seeking to promote better management of poultry by-products in protecting water quality. Also, to achieve a better understanding by the poultry industry of EPA's programs. At the same time, assist EPA to recognize the poultry industry's efforts to protect water quality and manage its by-products.

In a little over one year, the Consortium has responded to the environmental challenges by seeking and promoting cooperation and the exchange of information between the poultry industry and government agencies, including state agencies on water quality and by-product utilization issues.

An exhibit display was developed which reflects the environmental concerns and explains the mission of the Consortium. The exhibit is on display at this meeting and has been exhibited at 12 other events during the past year. Reception has been very positive. The SCS offices in Kentucky and California have their own copy for display. Upon request and scheduling, the exhibit is available for appropriate functions.

I have attended thirty-three various state poultry federations or associations, agencies, workshops, conferences and committee meetings last year to explain and discuss the functions of the Consortium. Contacts have been made with organizations and companies interested in by-product development and utilization. The Consortium now has a complete listing of point and nonpoint source State regulatory agencies. The industry is using this list to identify contacts for their various operations across state lines.

We are in the process of developing a Water Quality Protection Handbook which will contain information sheets on various topics related to poultry by-products and by-product management, such as composting, structures for dry storage, composters, managing nutrients. Plans are for the handbook to be completed for distribution during next January at the International Poultry Exposition. Material presented in the information sheets will include a variety of topics, including published data and areas where additional work is needed. It will be written for the poultry grower, producer and managers.

Down the road, the Consortium is looking to provide the poultry industry with the opportunity to make management decisions based on Geographical Information Systems (GIS) when expanding or locating new facilities. Tennessee Valley Authority, USDA - Soil Conservation Service and U.S. Geological Survey will be involved. We're also open to ideas from you how the Consortium can best help the industry address the environmental challenges.

As the poultry industry grows, one of its major priorities, is the protection of our natural resources. The industry demands new technologies in poultry by-product development and utilization in its efforts to protect water quality and foster a cleaner environment. The Consortium and liaison position bring emphasis to industry's and the Federal agencies commitment to do everything possible to protect the environment and improve the use of our poultry by-product resources.

REFERENCES

USDA, National Agricultural Statistics Service, 1991. Poultry Production and Value Summary.

CORPORATE MANAGEMENT COMMITMENT TO WASTE AND ENVIRONMENTAL MANAGEMENT

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Jerome Foods is a family- and employee-owned company that has been growing and processing turkeys for more than 60 years. Jerome's is headquartered in Barron, Wisconsin and has facilities in Pennsylvania and Minnesota.

Jerome Foods is an integrated company, owning our own hatcheries, farms, feed mills, and processing plants.

We employ 2,600 people, produce 8 million turkeys annually, and process over 200 million live-weight pounds per year.

Jerome products are primarily marketed under **THE TURKEY STORE®** Retail, **JEROME'S®** Foodservice, and **NORWESTERN®**, and The Turkey Store® Deli Meats™ brand names.

We believe in having a company philosophy and committing to it. We developed The Jerome Team Charter which describes our company's mission and purpose. A participatory environment--one of working together for a mutual benefit--is the founding principle of our business.

Our commitment to waste and environmental management is defined in our "Safety, Health, and Environmental Principles."

Why are we committed to protecting the environment through waste and environmental management? Because we have a responsibility and a personal interest.

It's not realistic to believe we can continue to dispose of our waste in the same manner as we have during the past 30 years. We are no longer small turkey farmers and processors. We are a rapidly growing industry.

Consumers and customers are demanding businesses to be environmentally-friendly.

Communities are concerned about our environmental impact. And legislators are passing laws and regulations in response to these concerns.

We have a responsibility to address these concerns and improve our waste management practices.

We live in or near the communities where we work. Our children and their children may do the same. We will all drink the water and breathe the air. What quality of life are we planning for the future?

In order to address these concerns and make improvements towards environmental protection, we believe that a participatory environment is essential. By proactively working with communities, employees, legislators, and governmental agencies, rather than waiting for directives, we will create resolutions that are mutually beneficial.

Our environmental policy objective is as follows:

> Jerome Foods' definition of success requires a healthy work environment with the best safety record in the turkey industry. We are committed to protecting the environment and the health and safety of our employees, their families, and our neighbors. We will strive to be a leader in safety, health, and environmental protection within our industry and in the communities in which we work and live.

This policy outlines several opportunities for us to fulfill our environmental goals. We must...

- -- Provide a safe and healthy work environment for our employees.
- -- Communicate to employees, customers, and communities our commitment to safety, health, and environmental protection.
- -- Make health, safety, and the protection of the environment an equal priority with quality and profit when making business decisions.
- -- Provide employees with information about safety, health, and the environment and encourage their individual responsibility at work, home, and in their communities.

Communicate Commitment

We encourage employee participation in developing and maintaining a safe and healthy work environment. We also have a Safety Department, including an ergonomist, to assist employees in this effort.

We communicate our environmental commitment to our employees through the stating of our principles during employee meetings where policies, procedures, and opportunities for improvement are discussed.

We emphasize our environmental commitment to our customers and consumers in our response letters. Our employees work with suppliers to develop environmentally-friendly packaging and supplies.

We have a Soil Enrichment Program and brochure to inform area farmers about the benefits of turkey litter used as a crop fertilizer or crop amendment. Our agronomist works closely with local farmers to ensure that all nutrient credits are given to this product and are utilized by that crop in the upcoming growing season.

We communicate our commitment to our communities through company and employee participation when working with city and town officials and governmental agencies like the Department of Natural Resources, Minnesota Pollution Control Agency, Soil Conservation Service, and the United States Department of Agriculture.

Our commitment to making the protection of the environment an equal priority with quality and profit when making business decisions involves the basic awareness by our employees of our environmental philosophy so that it can be made a priority.

For instance, before building a farm, the location of the farm in relationship to lakes, rivers, and other water sources is a major consideration along with operating costs.

Minimize Waste, Recycle, Dispose Properly

Another part of our "Safety, Health, and Environmental Principles" states that we will:

> Minimize the creation of waste, whenever possible recycle materials, and dispose of all wastes in a safe and responsible manner.

In our processing plant, two of our main goals are water reduction and the improvement of the quality of the discharged water. We have allocated human resources and finances to this end.

We developed employee task groups to look for opportunities for improvement, study options, and create economical and environmental solutions to reduce our water usage.

For example, employees suggested recycling the compressor and condenser cooling water from our refrigeration department to cool water used in the evisceration vacuum pumps, to wash live haul trucks, to wash the by-products and feather picking areas, and to aid in feather flow. After receiving USDA approval, we implemented this process and reduced our water usage by 11 million gallons annually. The USDA also approved the reuse of screened viscera, flowing water which has saved another 11,000,000 gallons annually. We also installed water meters in high water usage areas. We record usage and then follow up with appropriate actions.

Our discharge water quality has improved through the use of items like non-phosphorus detergents.

In 1990, we asked suppliers for non-phosphorus cleaning agents for use in plant sanitation and laundry. They provided us with several alternatives. After testing and obtaining USDA approval, we implemented a non-phosphorus cleaning agent which reduced the total amount of phosphorus in our plant waste water by 10-15%.

Jerome Foods is committed to another opportunity to minimize the creation of waste that includes the selling of our by-products (offal) to a rendering plant. The rendering plant adds value to the product and resells it to the pet, fur, and feed industries.

Similar economical and environmental success is achieved through our selling of dead birds to a rendering company. The dead birds are picked up on a daily basis from our farms for transfer to the rendering plants.

The manure from our farms is also sold. Through our Soil Enrichment Program, local farmers purchase this high-quality fertilizer (28,000 acres of cropland are spread in MN and WI in one year). Our agronomist works with these farmers to ensure proper application and utilization of the available nutrients.

To protect the environment, we have built manure storage piling sites that minimize any negative environmental impact for both surface and groundwater.

In these instances, we have taken a waste and made it into a valuable resource.

If minimization of waste is not possible, then our next option is recycling.

Our office paper and processing plant cardboard is recycled, which saves trees and is profitable to us because we make money by selling the paper. Therefore, we do not have to pay for the garbage costs.

Our last option is disposing of waste in a safe and responsible manner.

1) In Wisconsin, we own and operate our own local water treatment plant that was originally city-owned.

2) Sludge is spread on fields at half of the approved rate.

3) Manure is transported in covered trucks, applied at appropriate rates, and stored when necessary on approved storage sites.

Working with Regulators

It is our policy to not only comply with all applicable laws and regulations, but to go beyond compliance, as appropriate, to protect employees, the community, and the environment.

The environmental laws and regulations in Wisconsin and Minnesota are more stringent than other states and we attribute this to our abundant supply of lakes and groundwater and the public concern associated with them.

In Wisconsin and Minnesota, residents and year-round tourists are attracted to the many lakes and streams for a variety of relaxation and sports activities--snowmobiling, fishing, water and snow skiing, sailing, and swimming, to name a few. There is more public concern over maintaining or improving water quality because people rely on lakes and streams for the aesthetics, their own recreation, and possibly their income (tourist trade).

We have been successful in working with and complying with all governmental agencies. We work with the United States Department of Agriculture; in Wisconsin, the Department of Natural Resources and the Soil Conservation Service; and in Minnesota, the Minnesota Pollution Control Agency.

We follow DNR and MPCA permits for manure and piling sites. We follow local and state regulations regarding our treatment plants. We go beyond what is required of us concerning our manure piling sites. These sites are regulated on our large farms only, but we have taken the initiative to follow the same procedures on all of our farms.

Our management practices for frozen ground spreading are more stringent than governmental regulations. We place more restrictions than the government when spreading manure on sloping hills or land.

Another part of our environmental policy is to participate with the government and others in creating responsible laws and regulations to safeguard the work place, community, and the environment.

Our final principle is to commit appropriate employee and management resources to support and implement these principles and to periodically review our performance to ensure that our programs and practices are consistent with these principles.

Jerome Foods' definition of success requires a healthy work environment with the best safety record in the turkey industry. We are committed to protecting the environment and the health and safety of our employees, their families, and our neighbors. We will strive to be a leader in safety, health, and environmental protection within our industry and in the communities in which we work and live.

A commitment to waste management has been part of our company heritage. It began with Wallace Jerome, our founder. Wallace's philosophy, adopted from 4-H, is to "Make the best better." He has always strived for improvement even when others thought it impossible or impractical. This determination and foresight and that of working together for a mutual benefit has contributed to our being in the business for more than 60 years.

CORPORATE MANAGEMENT COMMITMENT TO WASTE AND ENVIRONMENTAL MANAGEMENT

R.O.E.I.
(Return on Environmental Investment)

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In order to be an active member in the poultry community today, it is imperative that each poultry operation not only be committed to making a profit, but also be equally committed and actively investing toward the preservation and improvement of our environment.

Those of us in the poultry industry find it relatively easy to evaluate how well we are doing in the area of profits and losses from report cards that are issued annually, quarterly and even daily with stock market quotes. However, it is a much more difficult task to determine how effective a company's investments in environmental programs really are. Even though we lack a good environmental "yard stick", just about every decision we make on a daily basis whether it involves growout or processing, requires that we evaluate its impact on the environment.

Today, I would like to discuss corporate environmental commitment, which will include:

a. Past and present corporate practices.
b. Creation of an environmental commitment and taking a proactive position.
c. Returns we hope to derive from investing in sound environmental programs.

There are several reasons why I will be using Tyson Foods as an example, the first of which is that it is the company that I am most familiar with and one with which I am proud to be associated. Also, Tyson Foods and the poultry industry in Arkansas has within the last year been faced with some extremely difficult challenges due to the national political climate, which has focused undue attention on our state's environmental issues.

Whenever I have the opportunity to discuss the poultry industry and the environment with people inside or outside of the business, I like to take a brief historical view of an industry that pioneered many reclamation and recycling practices. The poultry industry has truly been the leading agricultural segment in developing vertically integrated operations. The forward thinking people who began integrating individual operations 40 years ago, did so by bringing together feedmills, processing plants, further processing plants and contracting independent farmers into highly efficient operating complexes. These integrated operations have not only proven profitable, but also continue to be successful in providing safe, nutritious and inexpensive meat products.

The same people that started this industry were faced with the same basic problems that we have today, which is what to do with one-third of the live weight of each bird that is considered inedible (i.e., heads, feet, blood, feathers and viscera). What resulted was the inclusion of rendering operations which have since evolved into specialized protein and oil recycling operations.

Most of the original rendering operations were not profitable but necessary for an acceptable means of offal disposal. They have since evolved into highly sophisticated recycling facilities that make high quality feed ingredients that are now used in not only poultry diets, but a variety of animal rations and pet foods. Hydrolyzed feather meal is another high protein animal feed ingredient that is now becoming an integral part of ruminant rations as an "escape or protected" protein component. Another innovative process that Tyson holds a patent on is that of creating a low-ash, high protein poultry meal ingredient that has been used extensively in specialty pet foods that retail in excess of one dollar per pound.

The next progression in reclamation and recycling that began primarily with the Clean Water Act of 1972 is the handling of the pollutants that have been removed from processing plant effluents by mechanical screens and DAF units. Most of you know this material as "sludge".

I will only use the "s" word once today because it is a word that we should not use in public because of its negative connotation. The "s" word has many meanings across this country that range from the material pumped into oil wells to hazardous waste that was buried in Love Canal.

The facts are that pollutants being captured from these poultry processing plant streams come from federally inspected food operations and consist primarily of safe biological organic compounds. These reclaimed pollutants consist of the three basic nutrients and their decomposition products are compatible with most ecosystems and life forms when introduced in the proper manner.

As a public perception policy, those of us associated with the poultry industry must stop using the "s" word when referring to any type of reclaimed or recycled poultry waste by-products. A phase that I suggested a few years ago was "secondary nutrients". The Tyson people have been quite good about using this phase and recently came up with another code phrase of "ESPN" which stands for emulsified secondary poultry nutrients. It is a phrase that is not only descriptive, but also has some good connotations.

The recycling of DAF skimmings via soil incorporation has become an environmental liability in certain parts of the country. As a result of this environmental challenge and our desire to reclaim the DAF nutrients coupled with the increase in by-products from the ever expanding further processing operations, a new generation of animal feed ingredients has been produced. The various types of further processing by-products could include materials such as batter, breading, cooking oil, oil filtrates and mechanical deboned residues. I believe we are moving into a win-win situation where environmental concerns will be alleviated and the cost of doing so will eventually be offset by the value derived from these reformulated and refined finished by-products.

This type of solution is the result of a concerted environmental commitment that Tyson Foods has made over the past several years in research, both formal and good old "trial and error", and also substantial monetary investments in building the major reclaiming facilities like the one completed this summer at our River Valley Operation near Scranton, Arkansas.

This leads me to the area of how a company makes this commitment and becomes environmentally proactive. There is definitely not any set formula to follow, but an obvious first step is the preparation of a printed environmental commitment. It should be relatively brief and to the point concerning the company's environmental concerns, accomplishments and goals. Tyson Foods has prepared such a document and I offer it as only an example. I would, however, encourage each poultry company to take the time to do the same. Its preparation should not be taken lightly, but should be the product of much forethought by upper management and ultimately related to all segments of the work force.

The next step which is most important is the execution of this commitment through implementation and investment in environmentally sound practices. I am not going to dwell on this area because you will be exposed to a host of environmentally good practices over the next two days.

The concept of being environmentally proactive is basically one of seeking or generating positive publicity concerning a company's environmental activities. The idea is not to create front-page, head-line-making news copy, but rather providing up-beat, positive, feel-good information that would normally be found in the business and community section of the newspaper.

A proactive approach is not without its risks because in making your company accessible to the media you do bring attention to blemishes your company may have. However, the major risks that we have found when trying to work with the media is first the difficulty in communicating the complexity involved in certain environmental concepts. It is very important that thorough preparation go into presenting concise, simplified explanations concerning concepts and environmental processes. I have recently seen many examples of inaccurate reporting that totally distort the issues and facts.

The second risk that is very difficult to control is the agenda or bias perspective that a reporter may have concerning a particular issue. In these instances, it is important to know your media people and not be afraid to ask questions prior to an interview. One word of advice, nothing is off the record in a pre or post interview conversation.

Probably the most widely used proactive vehicle is the press release which should be designed to stand alone or in many instances lead to follow up interviews. An updated version of the standard printed news release is the video news release. There are several different formats which range from your own script with voice over video, to what we have preferred to use which is a news release, B-roll (video with natural sound), interview sound bites and a cue sheet that describes the video scenes. The company in this instance produces a video and provides it to the TV news department. We believe that the latter format allows TV media more latitude in their reporting and also increases the chances of the subject being aired, hopefully, in a positive light.

Another area of future environmental investment that is critical to our industry's survival is that of applied research at the University and government agency levels. The information and knowledge gained from this research is vital to the formulation of the Best Management Practices in areas of litter recycling, dead bird disposal, offal reclamation and processing plant pollution control. The quality and number of presentations being given at this symposium definitely attest to the high level research that is being conducted; however, one subject that needs a considerable amount of commitment and funding is that of nonpoint source pollution (NPSP).

Presently, most of the NPSP monitoring being conducted gives little to no information about the specific sources of pollution such as commercial fertilizers, animal wastes, and natural background pollutants. As a result, speculation and misleading information is often used in the justification for implementing regulations that may not have beneficial results for either the environment and/or the people and industries that are directly affected. Two of the critical questions concerning NPSP that need to be addressed in several environmentally sensitive areas of this country are:

1. What is the relative contribution of the specific sources to NPSP?
2. How much NPSP is actually taking place?

In conclusion, the financial facts are that although the total returns on environmental investment are not yet positive, major strides have been and continue to be made in the poultry industry in deriving value from a variety of by-products that were once considered waste materials. The bottom line is that profitable poultry operations must continue to invest in progressive environmental practices.

CORPORATE MANAGEMENT COMMITMENT TO WASTE AND ENVIRONMENTAL MANAGEMENT

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Gold Kist and Golden Poultry are committed to protecting the environment. We firmly believe that we should all do our part to clean up and protect our environment. A part of our mission statement says that we will be a good citizen wherever we have facilities.

Where's the evidence that we do what we say? We now operate waste water treatment plants at five of our poultry processing plants. At the last two processing plants we built, in Sanford, North Carolina and Russellville, Alabama, we installed our own waste treatment facilities at a cost of some $3,000,000 largely because we were convinced that we could operate them more efficiently than local governments.

We also have pre-treatment facilities at all our other processing plants that reduce the loads to normal strength waste. We have installed belt presses to de-water the by-products from the DAF units. We operate three rendering plants. We have installed the best air scrubbing equipment we can find to eliminate odors. One plant operates in Trussville, AL and is surrounded by subdivisions. Since we upgraded the equipment about three years ago, there have been no complaints from our neighbors.

Gold Kist has a full time environmental engineering department. This department operates with a full time registered engineer in charge. Additionally, our poultry group director of engineering keeps updated on our environmental concerns and works closely with the environmental engineer. We don't hesitate to bring in outside engineers when needed.

We are not perfect - we make mistakes. The biggest challenge we have is convincing local operations people that environmental control equipment must be maintained and operated properly. We tell them that if pollution control equipment doesn't run, then the plant doesn't run.

We back this up by making changes in personnel immediately if we find that permits are deliberately being violated. We also take complaints from neighbors very seriously and followup and investigate. Many times we find that complaints are not caused by us, but some other facility that is discharging pollution.

However, there is another side to all of this. That is the high cost of cleaning up the environment. Industry is spending over $27 billion per year in environmental control. Yet, studies show that most toxic waste is not near as hazardous as the do gooders would have us believe.

There is some concern that too much money is being spent on the environment. More lives could be saved if less money went into cleanup and more into production facilities that would provide more jobs and allow people to improve their standard of living.

The other down side is the very high cost of administration. The time spent sampling, reporting and corresponding with the bureaucrats is large. Fines are levied without any concern for the damage done. It appears that in some states the EPA is an income producing agency. Doesn't it make much more sense to allow a company to spend $50,000 to upgrade it's production control equipment rather than pay a fine? This rarely happens. Is it better to cease operations for several days and put people out of work while some equipment is being repaired so that no bad odor may be released or is it better to operate until the problem can be corrected? Certainly no one wants to cause harm to wildlife or human life. However, should a company such as Exxon be made to pay the exorbitant sums to wipe oil from rocks that most experts now agree did very little good?

I hope I have not led you to believe that we don't practice what we preach. None of us want to go back to the days when we ran a 12" pipe direct from the offal room into a local stream and the water was red and greasy for many miles down stream. I do believe that we must ask ourselves as a nation how quick we need to undo what has been done over the past 200 years. We must also ask ourselves should the government be trying to control the environment through regulations or should we somehow find a way to clean up the environment through the free enterprise system.

Forbes Magazine of July 6, 1992, ran a very thought provoking article about the EPA and the politics involved. They suggested that one solution might be to return to the rule of property rights and the common law of tort. For example, neighbors could use nuisance law to sue a factory that emitted bad odors.

Of course, this relying on common law to protect the environment would deprive Congress of it's power to grant and withhold favors, cost thousands of bureaucrats their jobs and power and spoil the games played by lots of business people, but isn't the limiting of government control over people's lives an important part of what America is all about?

NEW DEVELOPMENTS IN MORTALITY COMPOSTERS

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Two-stage composting as a method of disposing of poultry mortality was originally described by Murphy and Handwerker (1988) and Murphy, (1988). Their method represented a significant departure from previous work which specifically excluded animal tissues as composting candidates. The two-stage method was successfully demonstrated at the Dutton Farm in Millsboro, Delaware, (Palmer and Murphy, 1989), on several broiler and turkey farms across the country, and is now generally recognized as a viable alternative to the more traditional disposal methods such as burial and incineration. (Carter et al, 1992; Murphy and Carr, 1990; Murphy, 1990a,b; Murphy, 1992b; Moore, 1992). Despite the advantages of economy, biological security and environmental friendliness in the two stage structures and method, they do not apply well in situations of massive disposal (Murphy, 1992a,c,d), where material handling equipment is not available, with non-avian species and under conditions of extreme seasonal cold or during intermittent periods of low mortality.

Applied (composting) research at the University of Maryland LESREC is continuing, and is attempting to develop and exploit new composting technologies for application to small non-automated operations, massive depopulations, non avian applications, and to test the performance and effects of environmentally sheltered small-scale composters.

MASSIVE (DEPOPULATION) COMPOSTING

Two stage windrow composting of carcasses has been attempted as a means of containing and reducing catastrophic (e.g. whole farm population) mortality (Murphy, 1992a). The volumetric proportions of litter, straw or peanut hulls, and carcasses are indicated in Table 1. Materials are organized into layered windrows as shown in Figures 1 and 2. As in two-stage contained composting, windrow composting requires two or more cycles of decomposition, mixing and aeration in order to completely reduce, decontaminate and deodorize soft tissues. The initial 5-10 day cycle generates temperatures ranging from 120^0F to 140^0F. During this period, approximately 90% of soft tissues (muscle and organs) are solubilized and consumed. Five experiments involving 2500, 10,000, 10,000, 320,000 and 40,000 lbs. of broiler carcasses, respectively, have successfully demonstrated that windrowing, with subsequent turning followed by stockpiling or land application is an economical and effective means of disposing of catastrophic mortality in a biologically and environmentally safe manner.

Table 1. Materials for a Whole-House[1] Broiler Carcass Compost Windrow

	Birds	Litter	Baled straw[2,3]
Cubic feet	1,869	11,667	1,000
Pounds	107,667	326,667	7,500

[1]25,330 broiler on 6" compacted, 6-12 flock, pine sawdust litter.
[2]Other bulky, fibrous, materials such as peanut hulls may be substituted for straw.
[3]Added sufficient water to thoroughtly wet bird feathers.

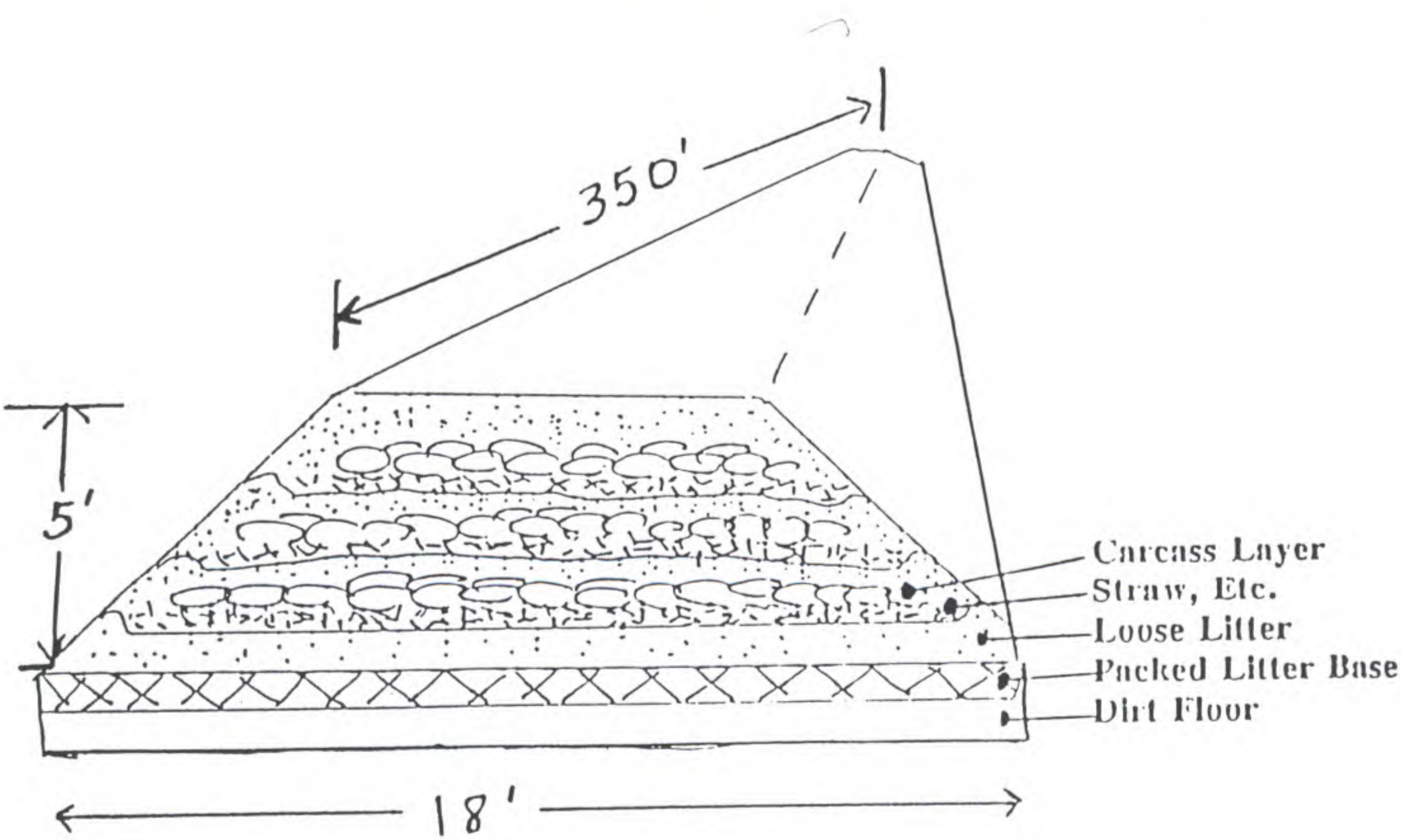

Figure 1. Poultry Carcass Windrow; Day One.

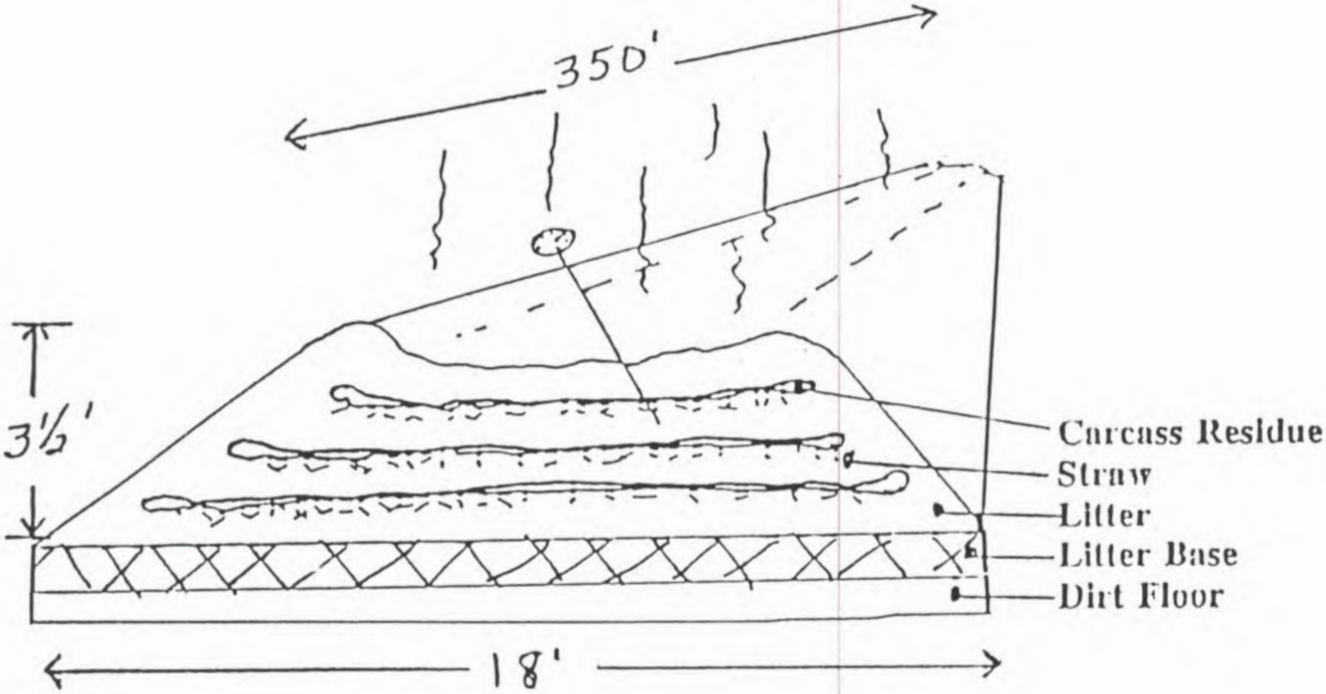

Figure 2. Poultry Carcass Windrow; Day Five.

MINI COMPOSTING

A simple single-stage composter has been designed and tested to determine its suitability for disposal of small quantities of mortality (Murphy, 1992a,c,d). Figure 3 represents a sectional view of such a composter to which have been added the essential ingredients of carcass, broiler litter, straw and water. Figure 4 illustrates the typical operating temperatures achieved within the core of an activated unit ($152^0 \pm 4^0$F), and the cumulative mortality mass (400-500 lbs.) which such a unit can process over the 42 days of a typical broiler production cycle. For a capital expenditure of approximately $40.00, and with simple tools such as a fork and thermometer, producers can build and operate this composter for disposal of up to 25 lbs. of mortality per day.

In-House Composting

Several tests were conducted to determine the effects of operating mini-composters within the controlled environment of the broiler house, and in close proximity to growing birds (Murphy, 1992e). Table 2 summarizes the effects of mini-composting mortality within test populations of broilers at the University of Maryland. "Composter" flocks performed equally, or slightly better, than control flocks in repeated comparisons over a one-year period (four consecutive flocks).

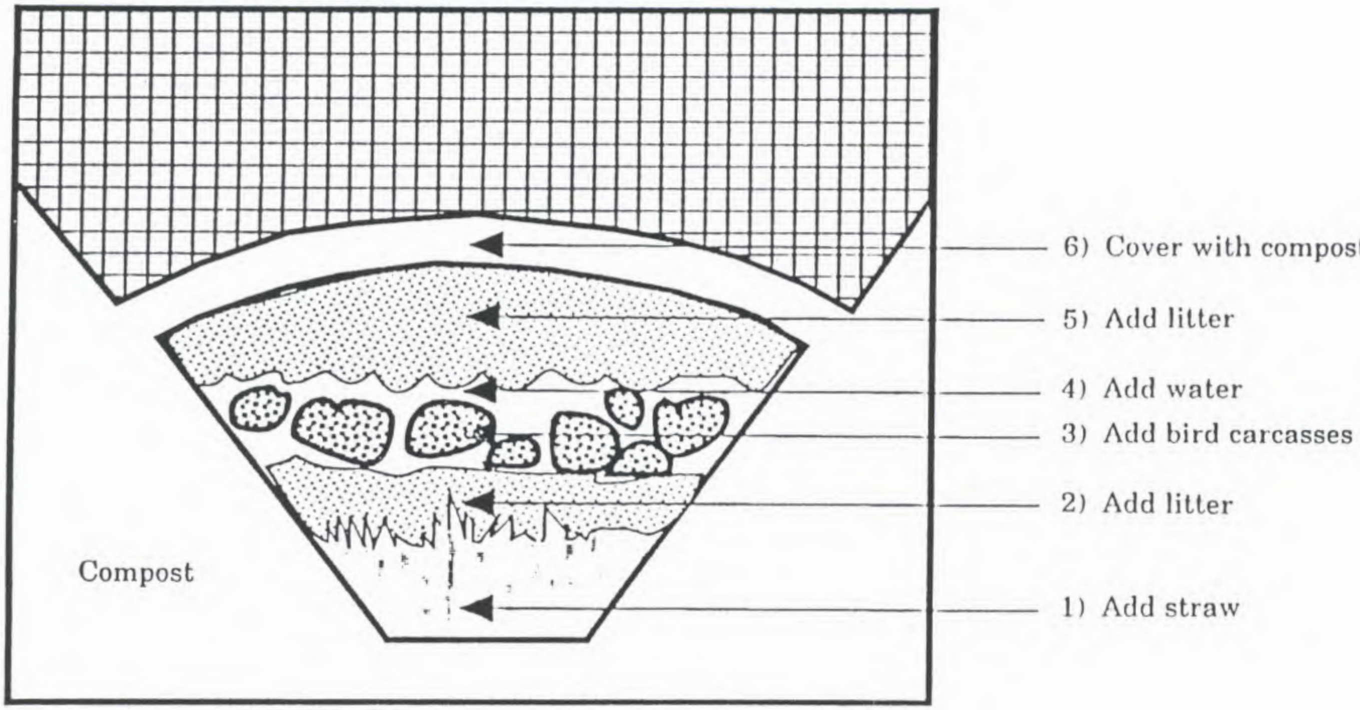

Figure 3. Schematic Cross-Section of a Loaded Mini Composter

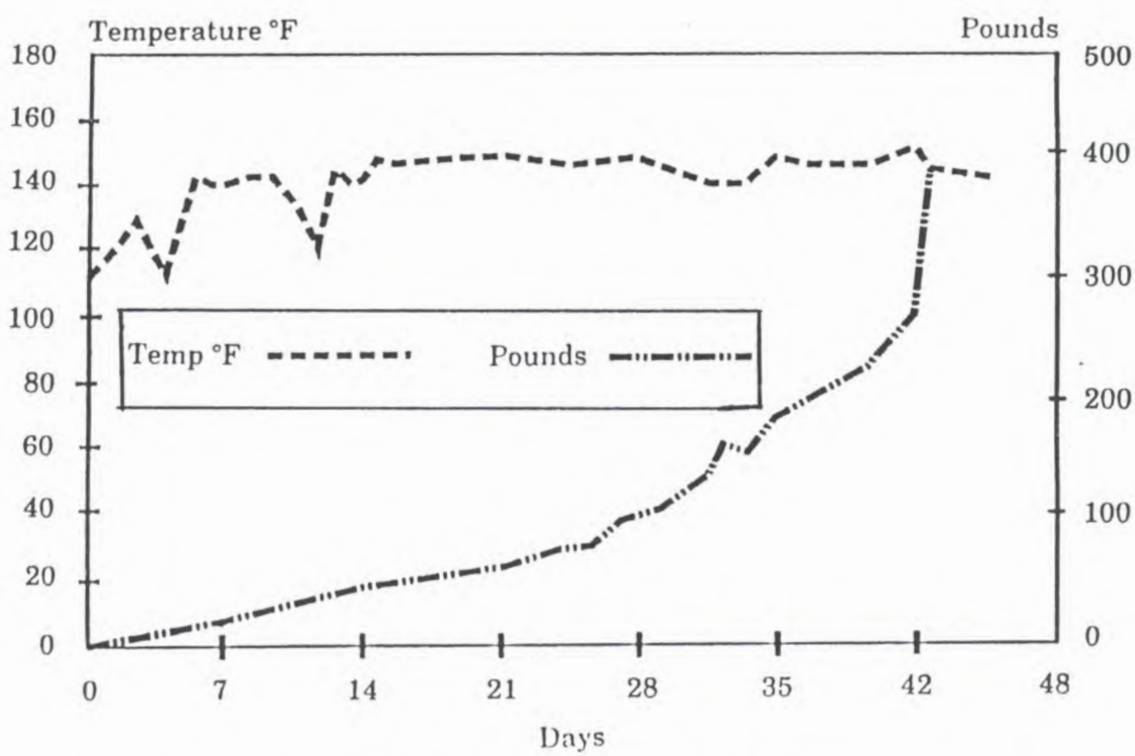

Figure 4. Loading rate and heating in a mini composter.

Body weight, feed efficiency and mortality of "composter" control birds compared favorably in repeated comparisons, despite the fact that "composter" populations were subjected to a 20-fold composting effect.

Table 2. Performance Effects of In-House (Mini) Composting

	Flock				
	1 (3.91)	2 (5/91)	3 (8/91)	4 (11/91)	Ave.
Body Wt. (lbs)					
House	4.23	4.51	4.23	4.34	4.33
Composter	4.39	4.66	4.44	4.32	4.45
Feed Conversion Ratio					
House	1.83	1.68	1.81	1.73	1.76
Composter	1.80	1.71	1.77	1.73	1.75
Mortality (%)					
House	4.67	3.53	5.07	3.24	4.13
Composter	4.60	4.20	3.80	3.00	3.90

This test demonstrated that it may be feasible to shelter small composters within the controlled environment of the broiler house without adversely affecting the health or performance of the resident flock. Such an operating mode might be useful, or essential, in areas where extreme cold prevents the operation of small composters in unsheltered environments.

COMPOSTING NON-AVIAN SPECIES

Fish, swine (Murphy, 1992f) and calf mortalities have all been satisfactorily disposed of in two-stage or mini poultry composting systems at the University of Maryland. When broiler litter is available, with straw and water, it appears almost any animal carcass of up to at least 300 lbs. may be treated in essentially the same manner as broiler or turkey mortality. Mini composters are useful systems for disposal of fish and fish offal from the Universities' tilapia aquaculture project, and have been successfully employed for the disposal of pig mortality and placentas from the Universities' research sows. Large animals (calves and market swine) are disposed of in a two-stage composter, as represented in Figure 5. Swine of up to 300 Lbs. are placed on their backs, on a layer of wet straw, and their thoracic and abdominal cavities are opened, their viscera opened, and their large muscle masses dissected. They are then covered with dry broiler litter, or a mixture of recycled compost and litter, and are reduced in two 5-10 day cycles of thermophilic composting. Temperatures, tissue reduction and odor control resemble poultry composting, and bones are the only residues which persist beyond the second stage of the process.

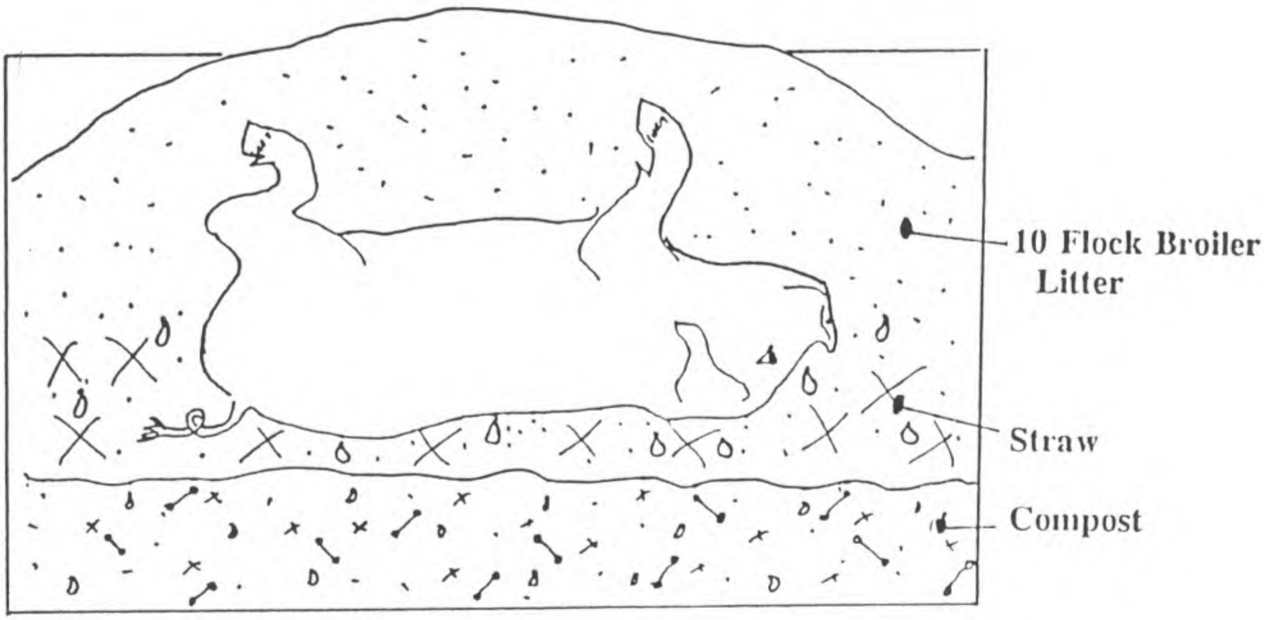

Figure 5. Schematic Cross-Section of a 2-Stage Composter Processing a Market Hog.

SUMARY

Thermophilic, aerobic composting is proving to be an effective, flexible and economical means of disposing of a variety of mortality problems. Applied research conducted at the University of Maryland within the past two years has demonstrated that windrowing is an effective method of dealing with catastrophic and even whole-population mortalities. Mini composting puts an effective and simple (small scale) composting system within the reach of virtually every poultry and swine producer. In-house composting is revolutionary, but continues to succeed in the research environment, and may have particular applications in industry. The general methods of composting poultry mortality translate effectively to other species including fish, swine and (small) cattle. Further research is needed to develop large-animal systems, to improve the efficiency of the general poultry composting system, and to develop a non-fecal waste, generic, composting system for application in non-agricultural situations.

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PRACTICAL EXPERIENCES WITH MORTALITY COMPOSTERS: ON THE FARM

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Our first experience with composting began with the construction of the composter on the farm. We used the plans from the Maryland Extension Service with modifications to fit our particular situation. The major modification was to widen the boxes of the composter to be able to use the front-end loader that we had on the farm to avoid having to purchase another piece of equipment. The size of our bins is 6 ft. by 9 ft.

The second modification was the gates on the boxes. Instead of using the boards that slide in we decided to build gates. The gates were put on by using 2 gates to each box and then using a 4 x 4 cross brace that can be lifted out to open the gates. This makes it much easier to handle in the very beginning of each flock. As it has turned out it works better for us for the entire flock.

The best way for us is to describe a normal flock progression and how we use our composter on a daily basis. We start a new flock by setting up a mini-composter in the corner of two bins. To do this, we use two pallets approximately 3 ft. by 3 ft. covered with wire and arrange them against the corner to make a small composter that is approximately a 3 foot cube. The first mini-composter was made of four 3 ft. by 3 ft. pallets, but as we have used them over the past 2 years we have found that the two sides will stand in the corner very well and can be easily removed when it is time to break it down. Starting with four to six inches of compost from the previous flock in the bottom of each mini-composter we are ready to begin a new bin. Each day we add the dead birds to the composter and we add a layer of straw and manure crust to the composter. After the first week we start to alternate between the two mini-composters, this seems to keep the temperature up in both composters. The temperature of the compost should be monitored after the first 3 to 4 days and at that point should have reached a temperature of between 135 to 150 degrees. If the mortality is very low we first make a small trench on one side of the composter to put the dead birds and the next day go to the other side. Going from side to side and alternating between the two composters makes it so you can stir and lift the compost, this helps add oxygen and really keeps the material heating. Alternâting between the two mini-composters can sometimes be done for up to five weeks when the mortality remains in the 3-4% range. When one of the mini-composters is approximately 3/4 full we then finish filling it so that one will be full several days before the second. We have enough room in the bin to store the manure and straw that we want to use for the mini-composter on a daily basis. After the second mini-composter is full we then go back to the bin where the first mini-composter was filled and remove the temporary sides made by the pallets. The cube of compost will stand very solid at this time after the sides are removed. The remainder of the floor of the bin is covered with manure and we can begin to compost in the full bin at this time by using the compost from the mini-composter as our manure source for several days until the bin is now level. At this point we then go back to the second mini-composter remove the sides and repeat the same procedure. The poultry flock should now be between six and seven weeks old. At this time we will start to use the front end loader to cover the dead birds with the manure. Up to this point all the composting has been done manually and we are probably spending 15 minutes per day. This is for 47,000 bird capacity farm with a 3% to 5% mortality rate.

There are several different ideas we have incorporated into our composting using the materials that are available on our farm. The first is the horse manure that we have from our pleasure horses. Stalls are cleaned every morning and the manure is moved to the composter. This seems to be a hotter material and we use it alternating with the poultry manure. It seems especially good to use when the poultry manure is dry. Nipple drinkers have made the manure in our poultry houses much dryer and at times we need to add moisture. The horse manure is one way.

The other way that we have found to be most effective is to keep the carbon source wet. We use most anything that is not usable for feed or bedding. Old hay or straw that got wet before baling is really good to use. When this happens, we sometimes mow over the material that has been ruined by the rain and then bale it for use in the composter. The mowing over the straw or hay helps break it up to make it easier to spread by the spinner spreaders that we use. We store the hay or straw at the end of the composter and as we use the bales we open them one or two at a time and leave them out to be rained on. If mother nature does not cooperate we pour water on them to keep them moist. This works much better for us than adding water to the compost directly.

If there is one thing that is most important in the operation of the composter it is the constant monitoring of temperature.

It only takes a second but it should be checked daily. This is a definite indication of the activity in the compost. If the temperature drops it means that something needs to be done. The first thing we check for is the moisture. Too wet is the most time consuming and in our situation is most often caused by a hard driving rain. However, it is easily corrected. The best way we have found if it is a full bin is to divide the material into two bins and to add dry manure and mix it together. It only takes a few minutes with the loader to do this. If the bin is only half full we open the bin add dry material and then mix it with the front end loader. If the material is too dry adding crust, wet straw or hay or adding horse manure corrects the problem easily.

The composter that we use has been in operation for 2 years now and the first question that most people ask is how do you like your composter and second is, but doesn't it smell? Our answer to the first question is that it is probably the best addition we have made to our poultry farm. We live in the Chesapeake Bay area where water quality is the number one problem for everyone. There is never a discussion about the quality of the Bay without someone making a statement about pollution from farms. Farmers have made more progress in stopping pollution than any other group in our state. With the use of composters in conjunction with nutrient management programs on the shore, we are not talking about what we as an industry can do, but we are showing people and government agencies what we are doing.

The answer to the second question "But doesn't it smell", of course it smells, even roses smell, but is it offensive, NO. At the very worst time, when it should get too wet and the temperature drops, if it is corrected immediately the odor is mildly offensive. There is no comparison to burial pits that caused horrible odors to say nothing of the environmental problems.

Composting for us has been an economical and easy method of disposing of our dead birds with the by product being a useful material that is environmentally safe.

PRACTICAL EXPERIENCES WITH MORTALITY COMPOSTERS

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In October 1990, a colleague and I attended the National Poultry Waste Management Symposium held in Raleigh, NC. The timing of this symposium was particularly relevant for several reasons, the first being that we had just completed a survey of our own manure management procedures to insure that we were following sound environmental and soil conservation practices. These practices involve matching manure produced, both volume and type, to the needs of the crop being grown, and the acreage on which it is to be spread. Secondly, a strictly enforced good neighbor policy and a strong environmental awareness on the part of Arbor Acres combine to insure that all of our waste management policies are based on sound environmental practices. We are always looking for alternative methods of poultry waste management that are economical, practical, sanitary, legal and socially acceptable.

The first five speakers in the production session discussed composting as a viable means of dead bird disposal. Dr. Dennis Murphy of the University of Maryland, who is considered the father of dead bird composting, was the first speaker. His report summarized some of the features of the composting method that makes it an acceptable alternative method of dead bird disposal.

I returned to Glastonbury with a great deal of enthusiasm, wrote a report about what I had seen, and it was decided that a prototype would be built and tested. Several calls were made to Dr. Murphy, procedural controls were set up, and a composter was designed and built (Table 1).

The initial trial results of the Arbor Acres' Composter were very encouraging, and it performed exactly as expected. The compost temperature went over 130°F very rapidly and remained there (Figure 1). It was still over 135°F and no new birds had been added a month later. We removed the compost from the bottom of the digester and used it as one half of the "fuel" for the second bin. When the second bin was full, we continued the recycling process by using that compost to "fuel" the first bin again. Following the composting trial, the incinerator consumed 422 gallons of fuel in a 30 day period; at $.80 per gallon this would more than pay for the composter. An additional benefit is that the "fuel" litter we used is wet caked litter that has always posed a disposal problem. Microbiological monitoring results indicated that pathogenic bacteria did not survive the composting process.

Based on the results of these first tests, six new composting units have been constructed. Some farms will only need two bins,while others may require three or more. This is an environmentally sound and cost effective procedure. Jim Rock, Poultry Extension Specialist, and I have approached ASCS in Connecticut, and they will reimburse us up to 75% of the cost of the composters, up to a budgetary limit of $3000 per year.

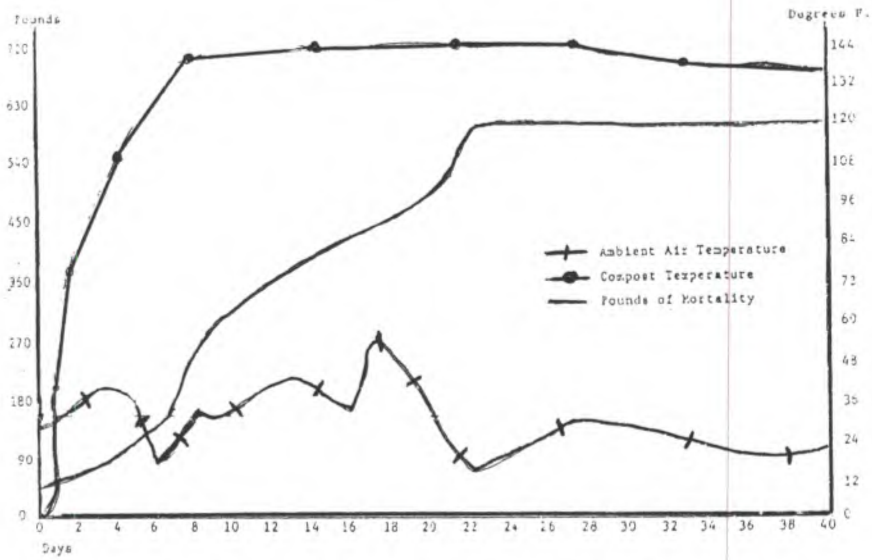

Figure 1. Arbor Acres Composter Trial

There are a few states, Massachusetts included,that do not allow the composting of solids without a license, but according to Dr. Murphy, "At the present time, cooperative research and/or demonstration projects of the two stage composting method are being conducted in all major broiler states, as well as Canada, Puerto Rico, the Bahamas, and Panama. Continuing success of demonstration projects is leading to rewriting of many state regulations on disposal and has resulted in approval of composting as a cost sharable practice at the national (USDA/ASCS) level."

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Table 1. Guidelines for the Construction and Operation of Arbor Acres Farms Dead Bird Composter Units

I. Construction Controls

A. The Maryland plan includes several essential features for the control and spread of disease organisms.

1. Roof - controls moisture in compost mixtures and insures that proper aerobic conditions for hot, rapid destruction of carcasses be maintained.
2. Concrete Pad - essential to maintain an acceptable level of sanitation around composters and to prevent leaching.
3. Pressure Treated Lumber - to resist rot and decay.

II. Procedural Controls

A. Normal mortality may be composted, but not the disposal of an entire farm. For example: A farm with 100,000 broilers weighing four pounds each, this could be 1,000 pounds per day when the birds attain market weight.

B. Composting of mortality is recommended only at the production site. Transport or collection of mortality from different farms and integrated operations is not recommended because of the risk of spreading disease organisms.

C. Loading with proper materials in recommended proportions, in organized layers, is essential to creating the physical and nutritional environment for active bacterial metabolism. The composter needs:

1. Carbon to nitrogen ratio of 15-25:1.
2. Moisture content of 40-55%.
3. Sufficient free air space to allow for the aerobic metabolism of bacillus vegetative bacteria.

D. Closely monitor temperatures to insure start-up and heating are sufficient to destroy pathogenic bacteria and viruses (greater than 130°F) and that the distribution of heat and its persistence over time are subjecting bird issue to pasteurizing conditions.

III. Physical and Biological Features

A. Areas that do not attain temperature minimums of 115°F may harbor insects.

B. Areas that do not attain temperature minimums of 130°F are suspect with regard to survival of potentially pathogenic viruses and bacteria.

PRACTICAL EXPERIENCES WITH MORTALITY COMPOSTERS: ALABAMA POULTRY MORTALITY REQUIREMENTS

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The Alabama Department of Agriculture and Industries, through the Animal Industry Division, is responsible for controlling, eradicating, and preventing the spread of contagious infectious diseases of poultry through the proper destruction and disposal of dead poultry, unhatched and unused eggs, and other poultry waste by requiring commercial growers of poultry and commercial hatcheries to be equipped with and to use approved disposal facilities.

The legislation authorizing the Department of Agriculture and Industries as the state agency responsible for assuring proper dead bird disposal was passed by the regular session of the Alabama Legislature in 1963 and can be found in the Alabama Code (1975) 2-16,-40, -41, and -42.

This enabling legislation requires every Alabama person that raises, grows, feeds, or otherwise produces poultry for commercial purposes, and every person who operates a commercial poultry hatchery for the production of baby chicks and turkey poults, to have equipment with adequate facilities for the handling, destruction, and disposal of all dead poultry, poultry carcasses, unhatched and unused eggs and other poultry waste.

The legislation authorizes the Alabama Board of Agriculture and Industries to prescribe the size, type and dimensions for pits used for burying dead poultry; to require and prescribe chemical or disinfectant treatments to be applied; approve the use of incineration or other burning methods and any other recommended methods or facilities for the handling, destruction, and disposal of dead poultry, poultry carcasses, unhatched or unused eggs, and other poultry waste. These facilities must be kept and maintained by every commercial poultry grower and every commercial hatchery in Alabama. The handling, destruction and disposal of dead poultry, poultry carcasses, unhatched or unused eggs and other poultry waste shall be performed by the use of the required facilities in a manner prescribed by the State Board of Agriculture and Industries.

These requirements are administered and enforced by the Commissioner of Agriculture and Industries, the State Veterinarian, his associates and assistants or other authorized employees or agents of the Department of Agriculture and Industries. They shall be authorized to quarantine and prohibit the removal or other disposition of any poultry and eggs from premises, buildings, and vehicles or other places unless such poultry and eggs are produced on premises equipped with approved disposal facilities.

This legislation also authorizes the State Veterinarian, his associates and assistants, or any other authorized employees of the Department of Agriculture and Industries, to enter any place or open any premises, to enter any buildings or other enclosures where poultry is produced, fed or kept, or open the premises of any commercial poultry hatchery for the purpose of performing any inspection work and duties necessary for the enforcement of rules and regulations relative to dead bird disposal.

Alabama's current dead bird disposal rules and regulations allow the state veterinarian to approve the use of other recommended methods and equipment for disposal of dead poultry carcasses. Based on this authority, Alabama was able to recognize composting as an accepted method of dead bird disposal without additional legislation. Alabama requires composters to be built according to specifications as outlined by the Alabama Cooperative Extension Service, Auburn University.

FERMENTATION OF MORTALITY

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Fermentation of mortality offers a means of on-farm preservation of tissue for subsequent recovery and recycling into a feedstuff. The combination of a storable product requiring minimum farm-to-farm collection frequency and an acidic (pH 4.1-4.5) product essentially pathogen free makes it an economical and biosecure attractive alternative dead-bird recovery process. Both lactic acid and yeast fermentation of mortality require the same basic procedural steps. They include grinding carcasses, addition of fermentable carbohydrate (CHO), a viable source of appropriate acid-forming bacteria and environmental conditions which support immediate growth of desirable bacteria resulting in a rapid production of volatile fatty acids and a decline in pH sufficient to stabilize tissue.

LACTIC FERMENTATION

Dobbins (1984) proposed lactic fermentation of mortality as a biosecure method for recycling carcasses. Research on the subject is currently being conducted at Georgia, Alabama, North Carolina, and Maryland. Sanders (1990) recently conducted an extensive literature review on the subject.

This procedure requires grinding carcasses in 1" or less particles. Particle reduction is essential for rapid tissue acidification. Grinding aids in dispersion and mixing of intestinal anaerobic acid-forming bacteria, any culture inoculant and the Carbohydrate (CHO). Among the CHO used successfully for lactic fermentation include lactose, glucose, sucrose, whey, whey permeate, molasses, condensed brewers solubles (CBS) and corn meal (Parsons and Ferket, 1990; Conner et al., 1991; Conner et al., 1992; Kotrola et al., 1992; Murphy et al., 1990; Murphy and Silbert, 1992; and Merka, personal communications). A minimum of 6% fermentable CHO (invert sugar) on a w/w basis with carcass is required for fermentation under optimum conditions. Higher levels (up to 10%) may be required at fermentation temperatures substantially less than 100°F or when the product is to be stored for a prolonged period of time. Results with corn meal have been conflicting in part due to the slow rate of fermentation and the amount of meal (>20%) necessary to achieve sufficient and rapid pH reduction. Condensed brewer's solubles (CBS) appears to be one of the most cost effective CHO sources. The cost and availability of CHO varies among regions. Method and equipment used for fermentation can also influence CHO selection. Moisture levels of the mixture should be in 60-70% range. Optimum temperature for fermentation is approximately 100°F. At lower temperatures, fermentation rate and thus pH reduction proceeds at a slower rate.

Fermentation will proceed utilizing endogenous gut microflora. Supplemental culture additives appear to initiate fermentation at a faster rate, may reduce the amount of CHO required and provides a margin of safety under diverse operating conditions. Murphy and Silbert (1990, 1992) have conducted extensive culture addition, temperature, CHO types and amount optimization studies. Fermentation success was not enhanced by additions of acidulants, protease, or antifungal agents (Conner et al, 1991; Merka, University of Georgia, personal communication).

Lactic fermentation requires anaerobic conditions yet the frequency of opening the tank/container does not interfere with the process. The fermentation container should be non-corrosive and vented to allow carbon dioxide release. Under optimum conditions, pH of fresh carcass is reduced from 6.5 to <4.5 within 48 hours. The resulting semi-liquid "silage" can be stored for prolonged periods under a wide range of temperatures. However, a pH increase above 4.5 during storage can produce a secondary undesirable fermentation resulting in spoilage. Early research with fish, poultry, and edible waste indicate the combination of elevated temperature, low pH from organic acids and possible antibiotics produced during lactic fermentation results in destruction of a wide range of bacterial and viral pathogens (Schroder et al., 1980, Wooley et al., 1980; Gilbert et al., 1983; Shotts et al., 1984; Dobbins, 1988).

Fermented silage can be separated into three fractions: liquid (water, soluble proteins and CHO), lipid and solid (feathers, bones, and undigested meat). The liquid fraction is 74.6% moisture and contains 38.6% protein, 3.2% fat, and 4.3% minerals on a dry weight basis (Kharlakian et al., 1992). The percent recovery of each fraction and its composition will vary due to process methodology. In the Maryland studies, the liquid, lipid, and solid components represented 35%, 30%, and 45%, respectively. Opportunities for reprocessing these fractions singularly or in various combinations include: direct refeed as a liquid ingredient (swine?), blending with offal at a protein reclaimation plant and/or co-extrusion with grain. The composition of lactic fermented whole carcasses (Murphy and Silbert, 1992) and offal (Russell et al., 1992) appear similar to their respective fresh counterparts. Thomas et al., (1991) has demonstrated the feeding value of extruded fermented carcasses (liquid fraction) with corn or soybeans to broilers while Tibbetts et al. (1987) used fermented offal successfully in swine rations. Both researchers indicate an upper limit for inclusion. Additional work by Kharlakian, et al. (1992) indicates heating silage which contains excess unfermented CHO, results in 68% decrease in lysine content compared to freeze drying due to a Maillard reaction. They recommend producing a silage with low residual reducing sugar content and/or drying in a manner that minimizes amino acid damage.

Commercial Lactic Fermentation Experiences

Dobbins (1984) described a portable fermentation system mounted on a trailer that was developed and tested for larger scale farm depopulations. Details of the system and its application are described in the report. Subsequent large scale commercial experience in Georgia with lactic fermentation of mortality is with a 650,000 layer operation. The process uses an 18 hp GPR grinder (Animal Health Sales, Inc., Selbyville, DE.) to reduce carcasses to 1/2" pieces. Dried whey (6% w/w) and lactobacillus silage inoculant (0.1% w/w) are mixed with water (2 parts water to 1 part whey) and added during grinding to facilitate distribution with tissue. The mixture is augered into a vented stainless steel tank truck and allowed to ferment anaerobically at ambient temperature. Approximately 13 tons of silage is delivered monthly to a protein reclaimation plant. The pH has exceeded stabilization levels only once during the past year.

A demonstration unit has been in place on a 90,000 capacity broiler farm in Alabama since the winter of 1992 (Blake and Donald, 1992). This system consists of an Autiomatic Model 601 grinder (Dixie Grinders, Inc., Guntersville, AL), K-tron Model S-200 CHO feed unit and several BTF-38 fiberglass tanks (Plastech, Warminster, PA) with a capacity of 1600 lbs. Whey (10% w/w) or ground corn (20% w/w) is added to ground carcasses using endogenous gut microflora to ferment at ambient temperature. The resulting product has a pH of <5.0. Storage on the farm has been up to 14 weeks. Tanks are loaded onto a truck with the silage going to a protein reclaimation plant for reprocessing.

A 75,000 broiler farm in Delaware has been fermenting mortality for the past year using 12% whey (w/w) and an inoculant. These are proportioned by hand, placed in a GPR grinder with carcasses and the resulting mixture transferred manually to 55 gal. barrels for fermentation at room temperature. The average processing time for this manual operation is 15 min/day. Similar to observations at Alabama, flies are a potential problem. The resulting silage (pH <4.5) has been refed directly to swine with mixed results.

At North Carolina State University, Peter Ferket and co-workers are currently working on an automated system that grinds, proportions CHO, and transfers the mixture to fermenting tanks. The systems use CBS or whey as CHO source and will accommodate broilers to large animal carcasses. A local poultry company will be evaluating this system and uses for the silage.

YEAST FERMENTATION

The potential of the Bertullo process for fermenting mortality utilizing a proteolytic yeast was described by Malone (1990) with more extensive evaluations recently completed (Malone, et al., 1992). Like lactic fermentation, the process requires grinding carcasses, adding CHO and a yeast culture (Hansenula montevideo). The starter yeast culture is added only upon initiation/startup 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. Of six commercial CHO sources evaluated, CBS (18.6% w/w or 4% actual fermentable CHO) appears to be the most cost effective. Another low cost by-product, out-dated non-diet soft drink syrup fermented equally to CBS. Excess fermentable CHO in this system may support alcohol production under certain conditions. Fermentation with whey permeate supported greater lactic acid production than fermentation with CBS which produced three times more acetic than lactic acid. Fermentation and resulting tissue acidification will occur in the absence of the yeast culture. The exact role of acid-forming bacteria in synergism with yeast during this heterofermentation process is unclear. Controlled comparative studies of lactic versus yeast fermentation are necessary to quantitate differences in the two processes.

No Escherichia coli, Salmonella typhimurium, Newcastle disease virus or infectious bursa disease viruses were recovered from fermented carcasses 12 hours post inoculation. Both Bacillus subtillis and Staphylococcus aureus survived a 48 hr. fermentation. Pasteurization may be required of any product to comply with direct refeeding requirements. The semi-liquid with undigested feathers has a yeast/vinegar aroma with a proximate analysis similar to fresh fermented carcasses. A crude fractionation of this product using a rotary screen (10 mesh) yielded 62% liquid, 38% solids. The liquid fraction has high digestible protein content. Amino acid levels (lysine and methionine in particular) in this fraction are equal or superior to comparative values in poultry by-product meal. Actual feeding value has not been demonstrated.

An on-farm prototype fermentation unit was evaluated at University of Delaware. The 5'h x 5'l x 5'w stainless steel shell housed a temperature controlled 300 gal. poly tank. Paddles constantly agitate/aerate during fermentation. The unit is designed for but did not include a top mounted grinder. Modifications including tank size, energy efficiency and CHO metering would enhance the economics/practicality of the unit. Both fresh and partially deteriorated carcasses have been effectively fermented yielding a surprisingly pleasant smelling product.

SUMMARY

Fermentation of mortality may offer a safe, efficient, and environmentally sound means of recycling and eliminating a "waste" product. Optimization of lactic or yeast fermentation inputs and equipment may require further refinement in developing this "systems approach" to carcass recycling. Processing procedures for the silage and its markets must be determined. The greatest potential for success in this total systems approach will likely involve poultry company participation. Last, but not least, consumer perception of refeeding "mortality" will likely always be a delicate subject.

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COMPARISON OF MORTALITY DISPOSAL SYSTEMS

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Every turkey and broiler production facility is faced with the reality of farm mortality. A flock of 30,000 turkeys averaging 0.5% mortality each week (9% total mortality), will produce approximately 13.9 tons of carcasses during an eighteen week growing period. For a flock of 50,000 broilers grown to 49 days of age that averages 0.1% daily mortality (4.9% total mortality), then approximately 2.4 tons of mortality will occur (Blake et al., 1990). These losses represent a tremendous amount of organic matter.

As the poultry industry expands, so also will the amount of on-farm generated wastes. Therefore, the poultry industry must aggressively pursue efforts to protect the environment while maintaining a good public image.

METHODS OF DISPOSAL

Burial

Burial is the original method of disposal which is usually the most convenient.

Burial involves several variations which may include pits, Utah "cookers", sanitary landfills and inverted feedbins. A properly constructed disposal pit is convenient, sanitary, and a practical method for handling poultry mortalities. Disposal pits have been used with varying degrees of success by the poultry grower. An "approved" burial pit can be fabricated from concrete block, monolithic concrete, or treated wood (Sweeten and Thornberry, 1984; Collins and Weaver, 1974). Pre-cast open-bottom septic tanks can be delivered to the site and 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 PVC pipe at the center that is capped off with a tightly fitted cover.

Although a disposal pit is convenient and economical, it should be located where ground water level is well below the pit bottom, and where soil type permits good filtration of effluent. The decline in ground water quality where an open-bottom pit is located is of concern, and the remaining residue after years of use is another reason for alternative methods of disposal. Ritter and Chirnside (1990) stated that disposal pits should not cause any more ground-water contamination than an individual septic tank and soil absorption bed. However, future research may implicate burial pits with ground water contamination and restrict their use to specific soil types.

Incineration

Incineration is recognized as one of the biologically safest methods of disposal. Wastes can be disposed of as 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.

In general, incineration tends to be slow, expensive, and often generates particulate air pollution. An increased number of nuisance complaints are generated from incineration than any other method of disposal (Murphy and Handwerker, 1988). After initially purchasing an incinerator, the average poultry grower will spend approximately $3.50 to cremate 100 lbs. of carcasses above installation, based on a propane cost of $.61/gallon (Donald, 1991). Studies indicate that certain maintenance costs are also incurred with incinerators. Grates need to be replaced every 2 to 3 years and in some instances the entire unit may require either refurbishment or replacement every 5 to 7 years. In some states, a permit may be required to install and operate an incinerator.

Composting

Composting is a controlled, natural process in which beneficial organisms (bacteria and fungi) reduce and 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 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 mortality is sequentially layered into the primary bin with used or caked litter, wheat straw, and water at a ratio (weight:weight) of 1:2:0.1:0.25, respectively (Murphy, 1988. A one-foot layer of caked or used poultry litter containing pine shavings, sawdust, peanut hulls, or rich hulls is first placed on the concrete floor of the bin. A layer of straw is added to aid in aeration and supply an adequate source of carbon. 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 is covered with manure for subsequent layering. As mortality proceeds, successive layers of manure cake, straw, carcasses, and water are layered into the primary bin. Once full, a final cover of manure is placed over the carcasses.

Temperature of the compost increases rapidly as bacterial action progresses, rising above 130 F 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 bins, 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 farm mortalities, it is paramount that the compost process completely inactivates pathogenic (avian and human) microorganisms prior to land application. Studies by Murphy (1990), Conner and Blake (1990), and Conner _et_ _al_. (1991 a,c) indicated that two-stage composting effectively inactivates poultry-associated bacterial pathogens. Aeration of the compost, simply turning of the pile from the primary to secondary bin to produce a second heat cycle, ensures effective inactivation of human and avian pathogenic microorganisms.

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.

Rendering

Rendering is one of the best means for converting 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.

Central Pick-up: 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. Central carcass disposal sites have been placed on trial in Minnesota and North Carolina (Poss, 1990; Parsons and Ferket, 1991). Transportation costs have made this method expensive, approximately $.15/lb, in comparison to other alternatives such as burial, incineration or composting which cost less than $.03/lb (Poss, 1990).

Refrigeration: Freezing carcasses for short-term storage prior to transportation to a rendering facility is effective. However, this method has also proven to be expensive. Large capacity units are usually required because 100 or more lb of carcasses at near body temperature (105 F) may be encountered daily. Electrical costs for the operation of high capacity refrigeration equipment have been estimated to be approximately $.11/lb for carcasses stored and picked up at weekly intervals (Poss, 1990; Donald, 1991).

Acid 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 while pathogenic microorganisms were effectively inactivated. Processing and feeding of the resulting by-product meal indicated no detrimental effects when compared to 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. Although organic acids such as acetic, propionic, and formic show promise, they are prohibitively expensive.

Fermentation: Lactic acid fermentation of poultry farm mortalities prior to transportation stabilizes carcass deterioration, but minimizes pathogen threat. Information on fermentation of poultry carcasses is limited. Initial studies conducted by Dobbins (1988) described methods for preserving poultry carcasses by lactic fermentation. Successful fermentation is enabled by the combination of prescribed amounts of farm mortalities with a fermentable carbohydrate source (i.e. sucrose, molasses, whey, ground corn). In order for effective fermentation to occur, carcasses must be ground. Lactic acid-producing bacteria 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), Conner et al. (1991b), and Parsons and Ferket (1991).

Pathogenic microorganisms associated with the carcasses are effectively inactivated during the fermentation process (Dobbins, 1988; Murphy and Silbert, 1990; Conner et al., 1991b). Presumably, fermented material can be stored and will remain in a stable state for several months (Dobbins, 1988; Conner et al., 1991b). Therefore, fermentation could be initiated and continue on-farm until carcass amounts are sufficient to warrant the cost of transport.

Disposal facilities have been constructed on two Alabama broiler farms to demonstrate the feasibility of on-farm endogenous fermentation of poultry carcasses (Blake and Donald, 1992). A prototype grinding unit was specifically designed to allow for the simultaneous addition of the carbohydrate source during grinding (Autiomatic Model 601, Dixie Grinders, Inc., Guntersville, AL). On a daily basis, broiler mortality is ground and ground corn (20%) was utilized as the carbohydrate source. The mixture (mortality and carbohydrate) was directly fed into sealed storage tanks (approximate capacity 1600 lbs).

Weekly pH measurements were obtained from the fermentation tank(s) at approximately 12 inches below the surface. All pH values of the ferment decreased below 5.0 within a 10-day period. Resulting ferment obtained at the end of a typical 7-week growout cycle was subjected to conventional rendering.

Unlike routine pickup of "fresh" mortalities, fermentation and subsequent storage of poultry carcasses reduces transportation costs by 90% and eliminates the potential for transmission of pathogenic microorganisms through poultry via rendered products.

<u>Extrusion</u>: 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 flow back against itself. Due to the forces of friction and pressure within the barrel, product is cooked to a preselected temperature of 115 to 155 C 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.

Haque <u>et</u> <u>al</u>. (1987) successfully incorporated whole ground hens into an extruded broiler diet. Feathers, whole carcasses, processing plant wastes and hatchery wastes have each been extruded into acceptable feed ingredients (Tadtiyanant <u>et</u> <u>al</u>., 1989; Miller <u>et</u> <u>al</u>., 1990; Blake <u>et</u> <u>al</u>, 1990). Poultry feeding trials indicate that extrusion of poultry carcasses is a viable alternative to conventional by-product rendering.

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

As the poultry industry expands, the amount of on-farm wastes increases. With present concerns for the environment, the poultry industry needs to continue to aggressively pursue efforts in protecting the environment. Therefore, all methods that allow for the environmentally safe and biosecure disposal of poultry carcasses should be considered. No single method will completely solve the problem.

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ENSILING CAGE LAYER WASTE

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In 1975, TWJ Farms started using cage layer waste mixed with corn stover and corn silage or oat straw ensiled in a trench silo. Calculations were made so 1 lb per day of non-protein nitrogen could be consumed with 30 lbs of dry matter when fed to Polled Hereford cattle. The calculations made indicated one manure spreader load would be needed for each four loads of silage. The manure was applied with a manure spreader on top of the previous four loads of silage that was leveled and packed.

The problem incurred was in obtaining a uniform distribution of the manure with a fairly small particle size. After trial and error, we found a rapid movement of the spreader and beaters is the most desirable method.

There was no problem with the cattle consuming the mixture except that they would leave the larger manure chunks in the feed bunk. When corn stover or oat straw was used, the roughage had insufficient energy for a winter diet.

The challenges that had to be overcome were stopping the tractor and spreader part way thru the silo and getting high centered. After the first time, we loaded the spreader half full and were sure we had enough speed to get through without stopping.

Water had to be added to the straw or corn stover in order to have sufficient moisture for good packing. The straw did require an excessive amount of water and made it undesirable.

Another producer near Columbus, ME had the following field experience. This farm had 180,000 cage layers and they had built a 40 by 200' compost building with a stirring device for composting. Since then they have had good experience mixing corn screenings with the fresh manure as it comes off the manure belts. They mixed a ratio of 30% corn screenings and 70% fresh manure by weight. They also tried ground corn and ground cobs, but the screenings work the best since they absorb moisture better.

After blending, it is turned with their stirring device and goes through a heat. After 30 days, this material smells like silage and is gradually accepted by the cattle.

From their experience, they have found that you do not need extra protein or mineral for an ample amount is contained in the manure. The energy of this is mixture too low to finish cattle.

Table 1. As Feed Analysis of Ensiled Cage Layer Waste

Measurement	Analysis (%)
Moisture	40
Crude Protein	10 - 12
Calcium	.8 - 1.4
Phosphorous	.4 - .5
TDN	40 - 45

Table 2. Feeding Results for 128 Head During a 274 Day Period

Beginning Weight	520#
Finish Weight	1309#
Average Gain/Day	2.88#
Feed Cost/Lb.	33.9¢

Table 3. Consumption and Cost Per Lb. of Gain

	Average lbs/day	Max. lb fed/day	Lbs per lb gain	Cost per lb	Total per lb
Silage	10.8	17	3.74	2.4	9.0
Hay	7.0	12.5	2.44	4.37	10.7
Corn	9.5	22.1	3.29	4.24	13.9
Mineral[1]			.009	31.0	.3
Grand Total					33.9

[1]Fed before silage was started.

With the above feed cost, one wonders why more cattle are not fed this material.

There are two reasons. The first is to have the chickens next to the cattle. Secondly, you need a cattleman that likes chickens or a poultry grower that knows cattle. So far the acceptance has been slow and will continue to be that way, especially with the low cost of other feed ingredients.

It can be used as a cost effective ingredient when it is done right.

TURNING MANURE FROM A LIABILITY INTO AN ASSET

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We became interested in composting poultry manure about 15 years ago. We thought there should be some method of producing a fertilizer for retail sales that did not have an objectionable odor and could be used in urban areas. We became familiar with a composting bacteria that was sold by the Pfeiffer Foundation, Spring Valley, NY 01977. They supplied me with a great deal of material on the composting of animal manure using their bacterial cultures.

Following are some general rules:

1. Use manure that has a moisture content of about 40 to 60%.

2. Use a mixture of about 40% manure and 60% sawdust.

3. Use more organic matter in higher moisture manure and less in drier manure.

4. Place manure and organic matter in layers when making your compost pile.

5. Make a workable pile of about a 24 yard mix, not over 4 foot high (less pressure, more air pockets).

6. Activate 1 to 2 oz. of composting bacteria by mixing in lukewarm water and let sit for 12 to 24 hours.

7. Drill six holes in compost pile with a bar and pour diluted bacteria into holes (four to five pails).

8. Stir with bucket loader about two times a week to cool pile and incorporate air.

9. Pile should be digested in about 5 weeks. Final color looks like rich, dark brown soil.

Our dried manure and sawdust are stored in a 40'x80' shed 14' high. The entire operation takes place under cover. Usually the finished product will store indefinitely when it contains 25% moisture or less.

The compost is bagged in 4 mil plastic that is made to hold 35 lbs. The analysis is roughly 3-6-3 (N-P-K). Our farm name, analysis and uses are printed on the bag. The compost increases the humus and thus the water holding capacity of the soil. It is an excellent fertilizer for lawns, gardens, flowers and shrubs.

We figure that the total cost of a bag is about 55¢ with the 4 mil bag costing 35¢. We sell each bag for $4.95, three bags for $12.95. Bulk compost sells for $25.00 per yard. We sell most of the compost at the farm. We have also developed sales through local nurseries and garden centers.

PRACTICAL IMPLICATIONS FOR THE COMPOSTING OF POULTRY MANURE

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Composting of poultry manure has been studied for at least three decades. Tinsley and Nowakowski(1959), Galler and Davey (1971), Bell (1970), Bell and Robinson (1971), Henry and White (1990) and Bonazzi et al. (1990) have looked at the process. In The Netherlands, Kroodsma et al. (1987) found that composting of broiler litter with a dry matter content of 0.57 resulted in 4.47 kg of NH_3 emission per 1000 kg of litter compared to 1.68 kg of NH_3 per 1000 kg of litter when the dry matter content was 0.70. Several papers address treatment of ammonia emission. Sweeten et al. (1988) reported on the use of a soil filter field to control odor from a poultry manure composting plant in Texas. Witter and Lopez-Real (1988) compared the effectiveness of clay soil, zeolite, and compost as adsorbents for volatilized ammonia. A layer of zeolite captured 90 percent of the ammonia while clay soil captured 60 percent. A layer of compost product was ineffective.

For large poultry operations, a side benefit of composting manure is the disposal of dead birds. Murphy and Carr (1990) have shown that batch composters are capable of processing 16 kg of dead birds per cubic meter of compost reactor feed consisting of broiler litter, straw, and water.

Government legislation and environmental concerns are leading to more and more regulations concerning where and how poultry producers may dispose of wastes. A properly designed composting facility that avoids excessive ammonia emissions would offer producers the opportunity to reduce manure mass and volume, while at the same time stabilizing odor, before exporting or marketing the material. Transportation costs would be reduced and marketing would be facilitated.

COMPOSTING PROCESS EVALUATION

Composting, as for any other industrial process, has to be established and controlled on the basis of many choices and decisions (Table 1). Mixture recipe, processing equipment settings and batch size are examples of choices to be made. A series of poultry manure composting tests was conducted by Hansen et al. (1989a) using pilot-scale 208 L reactor vessels with forced ventilation.

Table 1. Controllable Factors for Composting

Organic amendment	Moisture control
Carbon/Nitrogen ratio	Aeration
Particle size	Ambient temperature
Percent recycled compost	Retention time
Mixing equipment	Depth
Reactor vessel size	Percent recycled air
Turning frequency	Type of process
Chemical pH moderating agent	Curing time
Initial moisture content	Inoculation
Temperature	Bulking agents

Results for percent reduction in compost mass, dry matter, nitrogen, and mass of poultry manure processed (dry weight basis) are presented in Figure 1 for Series I tests. The type of amendment, the mixing method, and initial dry solids content had the most significant impact on compost mass reduction and dry matter destruction out of seven controllable factors tested. The carbon/nitrogen (C/N) ratio of reactor feed, turning frequency and particle size had the greatest impact on nitrogen retention. The C/N ratio of the reactor feed of course had a significant effect on the quantity of poultry manure processed. These conclusions were based on the two levels that were tested for each factor.

Upon completion of the Series I tests outlined above, a second series of tests (Series II) were run (Hansen et al., 1989b). In these tests, the effects of a C/N ratio=15 were compared to a C/N ratio=20. Also mixing methods were re-evaluated along with a comparison of the addition of 5 and 25 percent recycled compost. Results for the same measured responses as Series I are shown in Figure 2.

The Series II tests results show a relative increase in compost mass reduction as the C/N ratio increases from 15 to 20. In contrast Series I tests show a decrease in compost mass reduction as C/N ratio increases from 20 to 25. Therefore, these results point to a possible optimum C/N ratio somewhere close to 20. As expected, nitrogen losses increased as C/N ratio decreased for both series of tests. Finally, more poultry manure could be processed per batch with low C/N ratios.

Compost often is used as "recycle" to reduce the amount of organic amendments that must be purchased. Results illustrated in Figure 2 show that recycling of compost had a negative effect on compost mass reduction when the proportion of recycled compost in the initial compost mixture was increased from 5 to 25 percent. A positive effect was observed for nitrogen retention. The foregoing reveals that the recycled compost was stabilized enough so as to decompose slowly. Recycling of compost for a poultry manure composting system therefore should be reduced to that volume required as inoculum for the process.

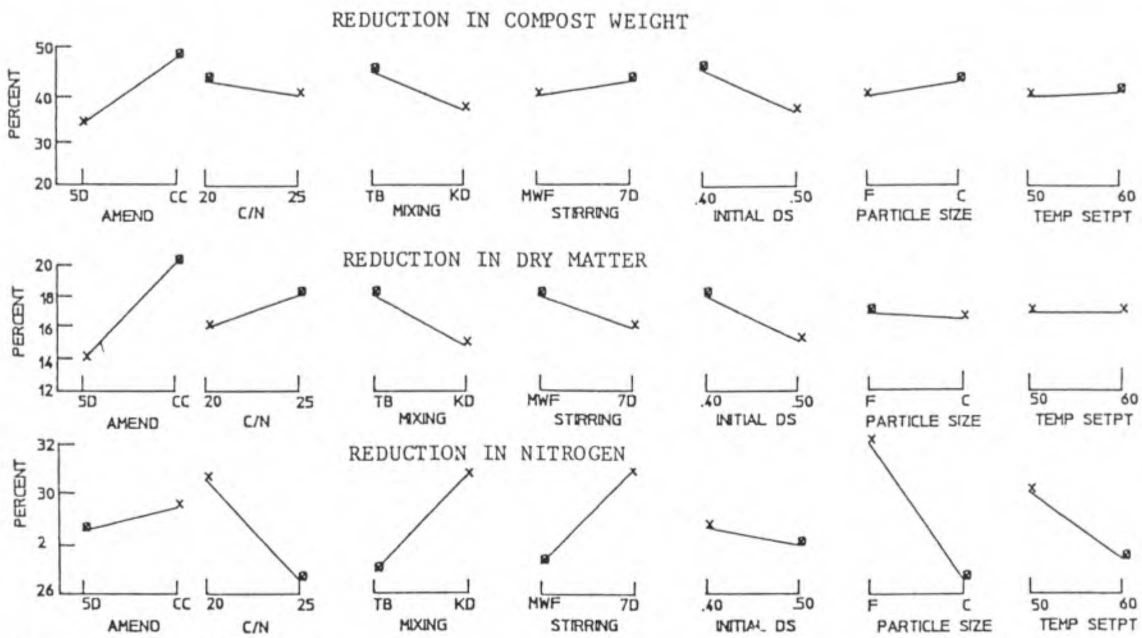
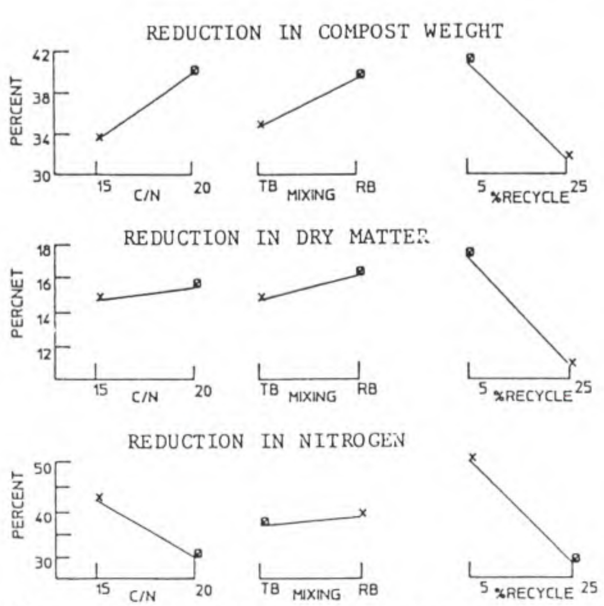


Figure 1. Response curves--composting process/Series I tests. (x Best combination of levels for factors tested.)



LEGEND

C - Coarse
CC - Corncobs
DS - Dry solids
F - Fine
KD - Kelly-Duplex paddle mixer
MWF - Monday, Wednesday, Friday
RB - Ribbon blender
SD - Sawdust
TB - Tumble mixer
7D - Seventh day

Figure 2. Response curves--composting process/Series II tests. (x Best combination of levels for factors

PRACTICAL IMPLICATIONS

The effect of C/N ratio on reduction in nitrogen concentration during high rate composting of caged layer manure mixed with ground corncobs is illustrated in Figure 3. Addition of a carbon organic amendment increases the potential for retention of ammonia through microbial protein synthesis. As a result, the ammonia released from uric acid in manure will more likely be incorporated into protein, thus increasing the amount of nitrogen retained in the finished compost. These results encourage the idea of increasing the C/N ratio to 30 as is typically recommended in most composting literature. However, note the consequence of increasing the C/N ratio on the proportion of poultry manure processed per ton of initial compost ingredients (See Figure 4) ... 1184 lbs for C/N=15 down to 519 lbs for C/N=30. While significantly less manure is being processed, the requirements for corncobs and water almost double. These results were determined on a wet basis using the following analyses (Hansen et al., 1989c):

	Moisture Content %	Nitrogen Content %
Cage layer manure	60.0	4.0
Ground corncobs	15.0	0.5
Corn stover	15.0	1.1
Initial compost mixture	60.0	---

The proportions of manure, amendment, and water that would be required for each C/N ratio were determined by using a computer program which was developed to analyze mixture requirements based on the moisture, carbon and nitrogen contents of the ingredients (Hansen et al., 1988).

A comparison of material requirements for C/N=15 versus C/N=20 is shown below using the same ingredients as described above. This comparison is based on the quantities of ground corncobs and water that would be required per ton of cage layer manure composted.

Ingredient	C/N=15 lbs	C/N=20 lbs
Cage layer manure	2000	2000
Ground corncobs	646	1228
Water	726	1382
Total	3372	4610

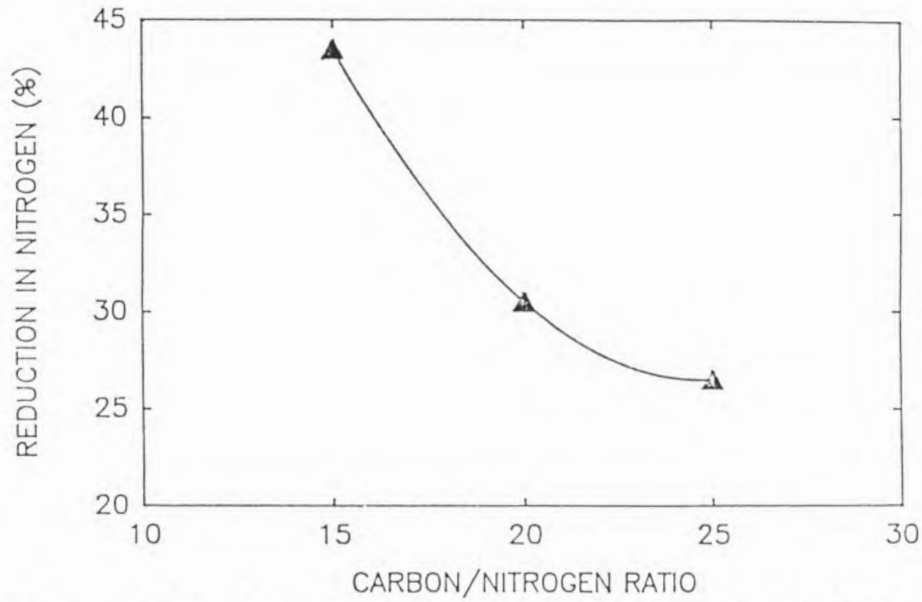


Figure 3. Reduction in nitrogen content of original compost mixture as a function of C/N ratio.

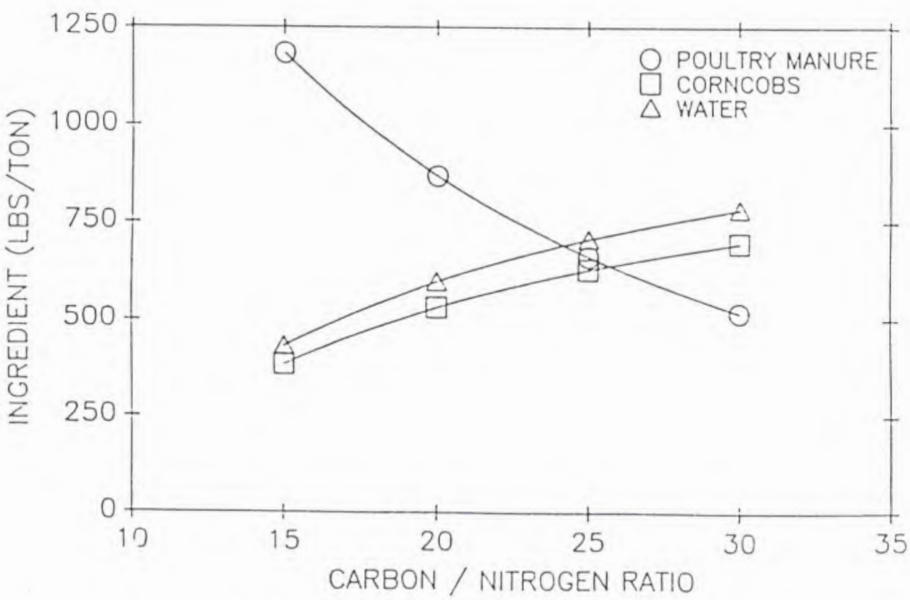


Figure 4. Initial compost ingredients as a function of C/N ratio (wet basis).

For C/N=15, about one-half of an organic amendment such as ground corncobs is required for composting compared to the requirement for C/N=20. A similar comparison is evident for water required. Also, 1238 lbs less material would need to be handled and processed. Throughput for a given compost system size would be 37 percent greater. These advantages for C/N=15 would need to be compared to the requirements for dealing with higher magnitudes of nitrogen losses and ammonia emissions (discussed in the next section).

Another practical implication for composting cage layer manure is the matter of finding a source of organic amendment, and then transporting, storing, processing (e.g., grinding), and eventually mixing it with the manure. Figure 5 illustrates the number of acres of corn that would be required to produce corncobs and/or corn stover per 1000 layers as a function of C/N ratio. The estimated production of corn stover and corncobs per acre was based on results reported by Johnson and Lamp (1966) for a shelled corn yield of 120 bu/acre. For C/N=20, the analysis suggests that a 100,000 caged-layer operation would require 2110 acres of corn to supply a sufficient quantity of corncobs for composting the manure produced in one year. Only 650 acres would be required if corn stover were harvested and processed as an organic amendment for composting the cage layer manure. But, an extra harvesting process would be required. As a part of contemporary shelled corn combine harvesting, the cobs are already harvested. Some method for capturing and transporting them to storage would be required.

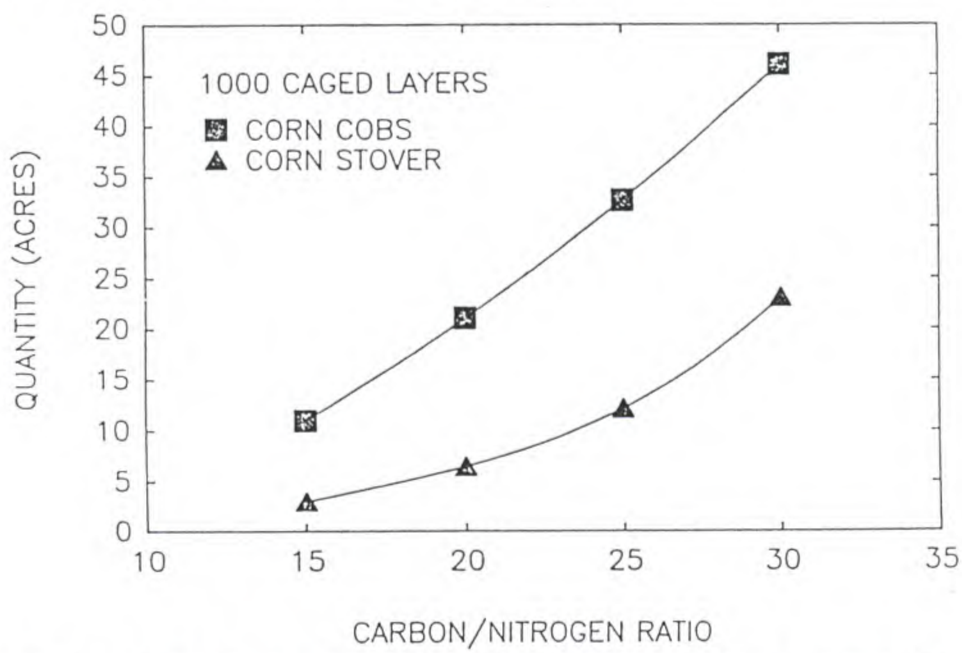


Figure 5. Acres of corn required annually to provide sufficient corncobs and/or corn stover for composting poultry manure per 1000 caged layers as a function of C/N ratio.

Other practical implications for composting cage layer manure include water requirements and a composting site of sufficient size with environmentally acceptable drainage characteristics and odor management capabilities. For a C/N=20 mixture as described above, a 100,000 cage layer operation would annually require approximately 600,000 gal of water just for the initial wetting of the compost to reach 60 percent moisture content. A composting site 5 to 10 acres in size would be required for windrow composting.

AMMONIA EMITTED

The emission of ammonia during composting is undesirable because it represents loss of nitrogen from the final product and ammonia is a major component of any odor generated. Figure 5 compares nitrogen emitted in the form of ammonia for C/N=20 versus C/N=15 during composting of cage layer manure amended with ground corncobs. For C/N=20, over one-half of the cumulative ammonia produced occurred within the first 24 hours while 85 percent of the total was emitted during the first four days of composting. For C/N=15, the ammonia produced was over three times greater than for C/N=20 (Hansen et al., 1989c).

The results illustrated in Figure 6 compared favorably to work reported by Sikora et al. (1983) and Witter and Lopez-Real (1988). However, their work involved composting of sewage sludge with a woodchip mixture in the first case and with wheat straw in the second. In both research efforts, the reactor vessels consisted of small laboratory composting simulators.

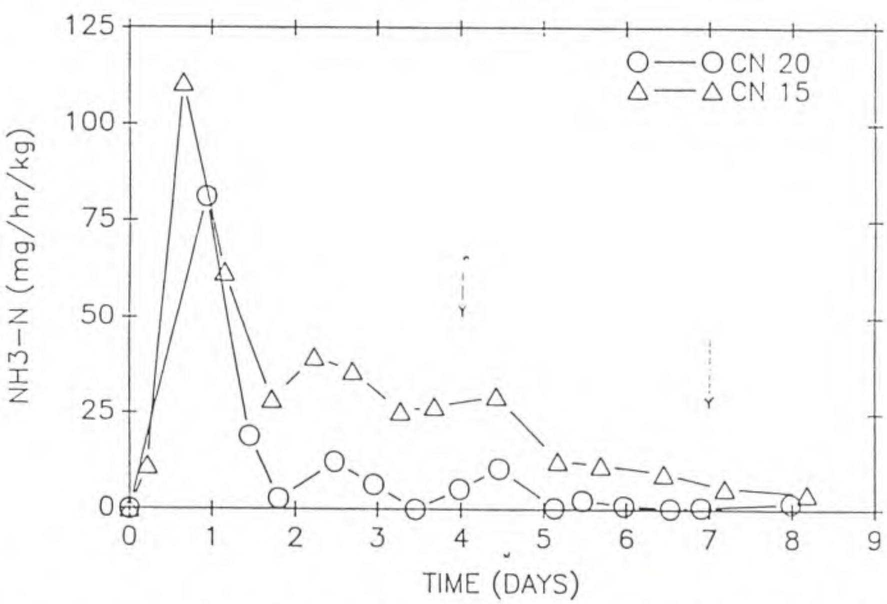


Figure 6. Specific mass rate of NH_3-N emitted while composting cage layer manure for C/N=20 compared to C/N=15. (Arrows indicate when turning occurred.) (Hansen et al., 1989c)

MOISTURE RETENTION, AMMONIA CAPTURE AND AERATION CONTROL

Aeration control is a key element of any aerobic, high-rate composting system. Along with supplying oxygen, aeration is required for removal of CO_2, NH_3, moisture and heat. A 30° to 60°C temperature gradient for a compost depth of 60 cm was found to be typical for poultry manure composting (Hansen et al., 1989a) A moisture gradient was also typical. Air was directed upward which always lead to evaporative cooling and drying in the lower half of the compost. In an attempt to alleviate this problem, composting tests using reversed-direction airflow were conducted (Hansen et al., 1990).

Reversed-direction airflow (RDAF) is a process where airflow can be reversed periodically during composting. One compost reactor was equipped with a RDAF unit which was set to reverse airflow every 12 hours. Test results indicated moisture retention was successfully increased with RDAF leading to more uniform rates of decomposition throughout the 14-day test period compared to two tests using one-direction airflow (ODAF) (temperature set point = 45°C for one reactor; 60°C for second reactor). However, the cumulative NH_3-N emitted (See Figure 7) during the 14-day composting run was greater for RDAF than for either test using ODAF. Since additional moisture created more ideal conditions for microbial decomposition for longer periods of time, the processes led to more NH_3-N emitted. During turning operations, the compost from the RDAF reactor emitted more noticeable malodorous odors and NH_3 odors than was noticed from ODAF reactors. The extra moisture may have contributed to more numerous sites of anaerobic activity throughout the 14-day test period. The use of RDAF to capture ammonia or encourage cell synthesis by microorganisms did not appear to be successful.

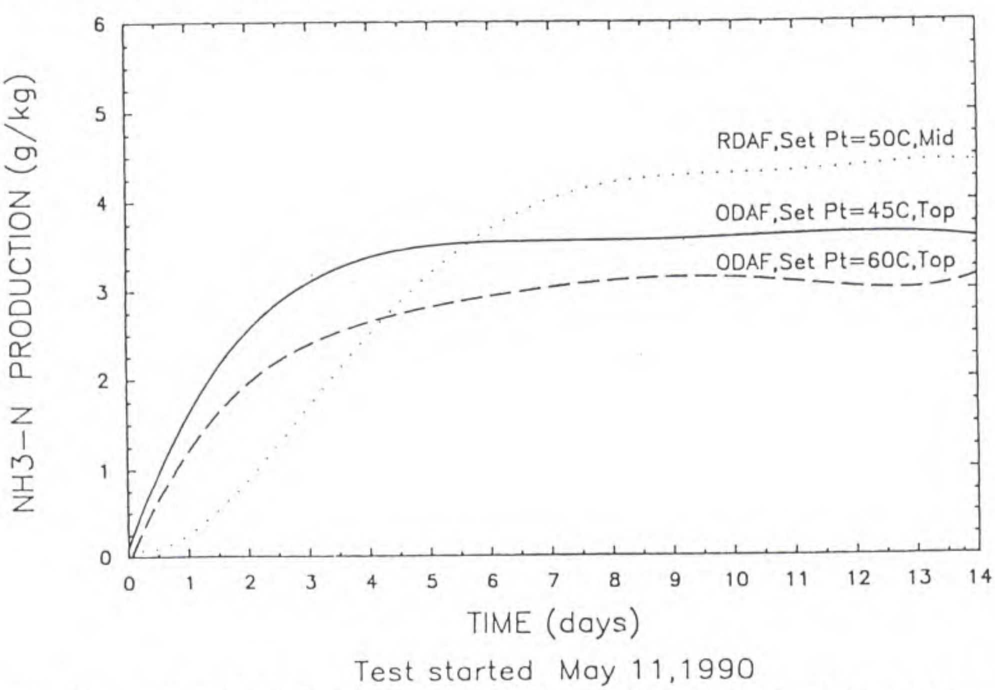


Figure 7. Cumulative NH_3-N emitted during 14-day tests as a function of three airflow conditions. Results were based on the initial mass of compost in the reactors (dry basis). (Hansen et al., 1990)

In addition to concerns for excess NH_3 emitted during composting are concerns for excess moisture production. Hansen et al. (1989c) found that over 75 percent of the original water content of mixtures of poultry manure and ground corncobs were volatilized during a 14-day composting run. The results demonstrated that 880 pounds of water would have to be removed from an enclosed structure via ventilation for each 2000 pounds of the mixture that was to be composted. Kip (1988) added water to mixtures of poultry manure and ground corncobs every third or fourth day during a 14-day composting run. The water was added to maintain ideal 60 percent moisture conditions during the process. These results indicated nearly 1500 pounds of water would be volatilized per 2000 pounds of original mixture during a 14-day composting run. By adding water during the composting process, total dry matter disappearance increased from 25 percent to over 40 percent. While extra dry matter disappearance may be a desirable result, the trade-off requires management of larger quantities of volatilized water and a compost product that retains more moisture.

Since 85 percent of the ammonia emitted occurs during the first 4 or 5 days of high-rate composting (when using ODAF), a practical solution may be to scrub or capture the ammonia in sulfuric acid traps (Hansen et al., 1990). For a 100,000 cage layer operation, an estimated 5000 lb of dry solids would be produced daily requiring 189 lb of sulfuric acid (See Table 2). An advantage of capturing the ammonia as ammonium sulfate is the potential to add the nitrogen back to the compost towards the end of the process. Based on composting results for C/N=20, the final nitrogen content could be raised as much as 0.6 percent.

Table 2. Amount and Cost of Sulfuric Acid Required to Capture Ammonia During Poultry Manure Composting, C/N=20

Number of birds	TDS* (lbs/day)	Required H_2SO_4 (lbs/day)	Cost** ($/day) Bulk	Cost** ($/day) Drum	Compost TDS Produced*** (lbs/day)	Cost ($/ton)
10,000	500	18.9	2.80	2.28	921	6.08
100,000	5,000	189	8.64	22.70	9,210	1.88
250,000	12,500	471	21.00		23,000	1.83
1,000,000	50,000	1,890	83.70		92,100	1.82
5,000,000	250,000	9,430	416.00		460,526	1.82

*Based on 3.5 lb birds, 0.2 lb manure/bird/day, 0.25 percent dry matter.

**For sulfuric acid alone, delivered in northeast Ohio.

***0.38 lb TDS manure per lb of compost TDS; 0.30 percent TDS disappearance during composting.

CONCLUSIONS AND RESEARCH NEEDS

Successful composting of poultry manure was found to be very dependent upon availability of suitable, high-carbon organic amendments. Amendment options also depend upon the ultimate use or potential market for compost end-products. Research is needed to determine not only which amendments to use but also how to specify associated compost parameters such as particle size, carbon/nitrogen ratio, initial dry solids and degree of mixing. While poultry manure can be successfully composted using any one of many composting systems such as in-vessel reactors or windrows, much research is required to resolve problems with odor control, ammonia emitted, and nitrogen lost. The effects of turning frequency and moisture addition also need additional study.

Approximately 85 percent of the ammonia emitted during high-rate composting of caged-layer manure occurred within the first four to five days of composting. Capture of the ammonia via scrubbing with sulfuric acid was studied as a possible way to return the nitrogen to the compost as an ammonium sulfate fertilizer. An attempt to capture ammonia and retain nitrogen during composting by reversing airflow direction was not successful. More research is needed in order to develop design parameters for ammonia capture and odor reduction.

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COMPOSTING EQUIPMENT AND PRODUCT QUALITY

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Salmet Poultry Systems is the representative of Salmet Deutschland poultry equipment for North America. Salmet Deutschland manufactures laying cages with fully-automated drinker & feeder systems, egg collection, and manure composting systems for the egg laying industry. Salmet Deutschland systems are installed world-wide in Europe, North America, Asia, and Africa.

Salmet Poultry Systems thanks the program committee for the invitation to participate in this symposium. The focus of this participation will be on the composting system developed and manufactured by Salmet Deutschland.

THE PROBLEM

A single 4 lb. laying hen will produce $\pm$0.21 pounds of fresh manure every single day. This equals 3.5 cubic feet in volume per 1,000 laying hens with a water content of 74.8 % and a weight density of 60 lbs. per cubic foot (Rynk et al., 1992).

Consider that in 1990, poultry industry estimates put the United States layer population at approximately 229 million layers. Calculate further; 229 million laying hens produced over 11 billion pounds of fresh manure every single day, over 800,000 cubic feet daily.

The egg producer of today is faced with increased regulation and cost in handling this manure generated by the laying hens. The producer of tomorrow must have a solution to the management of layer manure.

THE SALMET SOLUTION

Salmet recognized the need to provide the layer industry with a method of composting the caged layer manure. For over 6 years Salmet has designed, tested and successfully marketed a composting machine. As of this writing, there are presently four Salmet Deutschland Composting systems operating in North America.

The composting process begins at the layer cage when the fresh manure is deposited, by the hen, on the Salmet "Whisk" manure belt system. The "Whisk" is an exclusive feature of Salmet whereby air is circulated and directed onto the manure located on the manure belt. Systematic removal of the manure allows the manure to be "pre-conditioned" by drying, thus removing moisture in the manure to a level of approximately 50-55% water.

The systematic removal of the manure takes place in conjunction with transporting the manure by conveyor to the composting building which is in close proximity to the laying houses. Once in the composting building, the manure is placed in composting lanes in volume quantities up to 880 cubic feet per lane.

The following day, per the operation schedule, the Salmet "digester" begins passing through the compost lane. The "digester" begins at the rear of the lane mixing, aerating, and re-depositing the compost in the lane. The system is designed such that the advanced compost (the particles of manure that have biologically decomposed) is in the rear and is advanced in batch form down the lane with each pass of the "digester".

The "digester" will travel the entire length of the compost lane in one day reaching the fresh manure previously deposited. The "digester" then mixes, aerates, and moves the manure toward the rear of the lane making room for another deposit of manure.

The procedure of removing, depositing, and passing through the "digester" is repeated in a scheduled cycle. The cycle can be altered to a degree depending upon several variables such as building dimensions and laying hen population. On the average, the digester will pass through a single compost lane twice in 7 days. The compost is moved down the lane from the time it is deposited as manure to removal as a finished product in an average period of 50-55 calendar days.

SUMMARY

The Salmet composting system for caged layer manure does not require an addition of an amendment for use as a carbon source. This unique feature eliminates additional labor and material handling/storage requirements found with other systems.

The compost is removed at 20% water or less and is in a granular form. Marketing is done at the choice of the producer in either a bulk or bagged approach. A typical analysis (though each producer may experience differences due to breed of hen, feed ration, etc.) yields product containing 4% nitrogen, 3% phosphoric acid, and 3% potash. One individual producer has a multi-year contract with an organic fertilizer firm that purchases the compost for $30.00 per ton F.O.B. the producer's farm.

Salmet is committed to providing the egg producer with quality in product and performance. For 30 years, Salmet has proven this commitment by the cage systems and accessories developed to maximize egg production.

The future in the egg laying industry is manure management and Salmet is providing the responsible and environmental leadership that will reward the producer that chooses Salmet.

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UPDATE ON FEDERAL WASTEWATER REGULATIONS

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The quantity and quality of water have received much public attention. As a result, lawmakers are considering, or have already passed, environmentally conscious legislation such as the Clean Water Act (CWA). Poultry processors must address the technological and economic impact of these issues on their future.

Poultry processing operations use large volumes of water. Water is important to the poultry industry. It is used for washing products, making brine, cooking, cooling, cleaning, conveying, and sanitation. As the water is used in the plant, parts of the poultry product being processed are deposited in the water, and this wastewater must be properly handled to prevent pollution. Because of these and other related factors, water related regulations are of both great interest and concern to the poultry industry.

THE CLEAN WATER ACT

Historical Perspective

In 1972, Congress put the basic framework for federal water pollution control regulation in place by enacting the Federal Water Pollution Control Act (FWPCA). In 1977, Congress renamed the FWPCA the Clean Water Act (CWA) and changed the regulatory focus to rigorous control of toxic water pollutants. In 1987, Congress passed extensive amendments to improve water quality in areas where compliance with nationwide minimum discharge standards was insufficient to assure attainment of the CWA's water quality goals.

Prior to 1970, the water quality standards were set by the states. These standards established allowable concentrations of pollutant parameters for various water bodies. These standards were supposed to be used to formulate individualized permit limitations for each discharger. Although this approach was theoretically attractive, it worked badly in most states. Major problems included:

- Inability to determine precisely when a discharge violated applicable standards;
- Inapplicability of federal-state water quality standards to intrastate waters;
- Lack of state initiative in making load allocations required to set enforceable discharge standards;
- Cumbersome enforcement mechanisms and the requirement of state consent for federal enforcement.

Although a few states made the water quality approach work, it was clear by 1970 that an effective nationwide approach required a permit program based on federal minimum "end-of-pipe" effluent criteria enforceable directly against the discharger. In late 1972, Congress finally passed such legislation, Public Law 92-500. This statute made the Environmental Protection Agency (EPA) responsible for setting nationwide effluent standards on an industry-by-industry basis and required EPA to set such standards on the basis of the capabilities and costs of pollution control technologies to the regulated industry as a whole.

The act continued requirements for water quality standards so that more stringent discharge standards could be imposed where effluent standards were insufficient to assure that the quality of receiving waters did not deteriorate to, or remain at, unacceptable levels. States could take over the administration of the permit program when state control programs met rigorous federal standards.

The basic framework of the 1972 act--national effluent limitations, water quality standards, the permit program, special provisions for oil spills and toxic substances, and a POTW construction grant program--proved reasonably sound and remains so today. Congress significantly amended the act in 1977 in an effort to focus technology-based standards more effectively to control toxic pollutants, and to resolve numerous definitional and policy issues raised by court and EPA decisions. Over President Reagan's veto, Congress passed significant amendments in 1987. These amendments brought the act full circle: discharge standards are now to be tightened beyond technology-based minimums to assure that water quality standards for toxic pollutants are met. The 1990 Oil Pollution Act moved the CWA oil and hazardous substance discharge requirements into the modern era by making prevention, removal, and restoration high priorities of the program, with potent enforcement tools and adequate funds to make these priorities felt by the regulated community.

Areas of concern for the poultry industry include: (1) the availability of enough water of sufficient quality for the intended use, (2) the depletion or loss of water associated with this use, (3) the disposal of industrial wastes--both processing residuals and wastewater treatment process residuals,and (4) the pretreatment/treatment of wastewater. Each area has technological, economic, regulatory, and image factors. These factors combined, make these areas of concern critical to the location and continued operation of many poultry plants.

Wastewater Regulations

The regulatory program established under the Clean Water Act, as amended, has two basic elements--a statement of goals and objectives and a system of regulatory mechanisms calculated to achieve those goals and objectives.

<u>Goals and Objectives</u>
The Act states the objective (Section 101) is to "restore and maintain the chemical, physical and biological integrity of the nation's waters." To achieve that objective, the act establishes as "national goals":

Achieving a level of water quality which "provides for the protection and propagation of fish, shellfish, and wildlife" and "for recreation in and on the water" by July 1, 1983; and "Eliminating the discharge of pollutants into United States waters by 1985."

Mechanisms for Achieving These Goals and Objectives

The principal means to achieve the act's goals is a system to impose effluent limitations on, or otherwise to prevent, discharges of "pollutants" into any "waters of the United States" from any "point source." This system includes six basic elements:

(1) A two-stage system of technology-based effluent limits establishing base-level or minimum treatment required to be achieved by direct industrial dischargers (existing and new sources) and publicly owned treatment works (POTWs) and a complementary system of pretreatment requirements applicable to dischargers to POTWs.

(2) A program for imposing more stringent limits in permits where such limits are necessary to achieve water quality standards or objectives.

(3) A permit program (the National Pollutant Discharge Elimination System--NPDES) requiring dischargers to disclose the volume and nature of their discharges, authorizing EPA to specify the limitations to be imposed on such discharges, imposing on dischargers an obligation to monitor and report as to their compliance or noncompliance with the limitations so imposed, and authorizing EPA and citizen enforcement in the event of non-compliance.

(4) A set of specific deadlines for compliance or noncompliance with the limitations so imposed, and authorizing EPA and citizen enforcement in the event of non-compliance. Citizen enforcement actions have become an important factor in recent years.

(5) A set of specific provisions applicable to certain toxic and other pollutant discharges of particular concern or special character (e.g., storm water discharges, spills of oil or hazardous chemicals). These oil spill provisions were dramatically revised and penalties and cleanup obligations made far more severe by the Oil Pollution Act.

(6) A loan program to help fund POTW attainment of the applicable requirements. This loan program replaces the previous grant program as a result of the 1987 amendments, though Congress continues to appropriate more money for the program than the Administration requests.

The CWA mandates a two-part approach to establishing effluent limitations for industrial discharges: (1) nationwide base-level treatment to be established through an assessment of what is technologically and economically achievable for a particular industry; and (2) more stringent treatment requirements for specific plants where necessary to achieve water quality objectives for the particular body of water into which that plant discharges.

Wastewater from poultry processing plants is regulated by federal (EPA) and state statutes. Plant managers with direct discharges or land application of wastes and wastewater must get the required permits and file the necessary reports. Many food plants discharge to municipalities and are being regulated by local, state and federal regulations through the EPA Pretreatment Program.

During the mid-seventies the environmental regulatory program expanded to cover virtually all discharges to surface waters, with a focus on oxygen demanding pollutants (which degrade water quality when assimilative capacity is exceeded) and also toxic and hazardous pollutants (which threaten health and environment when discharged to water, even in minute concentrations and quantities).

Most of these changes became mandatory with the Clean Water Act amendments of 1977. In 1987, the Act was again extensively amended to include changes that tightened the focus on toxic dischargers. Also, water quality permitting strengthened to include discharges such as storm water, which were largely unregulated in the past. These amendments also served to strengthen the Act's enforcement mechanisms.

Enforcement

The CWA, especially after the 1987 amendments, provides a number of enforcement options to EPA and the states as well as a heavily-used citizen suit provision. As companies' potential exposure under these enforcement and penalty provisions can be staggering even for infractions causing little actual harm, it is important for regulated entities to understand what their potential exposure is under the CWA's criminal, civil, and administrative penalty provisions as well as for citizen suits.

EPA regulatory officials have developed and tested all the regulatory tools, gadgets, and mechanisms for the Clean Water Act Program. They, along with the Attorney General's Office, have a long and reasonably distinguished enforcement history. This combination of standard limits and enforcement is having an ever-increasing impact on enforcement actions taken, fines paid, and compliance expenditures undertaken by the regulated community.

Section 309 of the CWA makes the Act's enforcement provisions quite formidable. A chief attribute of the CWA enforcement philosophy is the extent to which individual criminal prosecution, or the threat thereof, is relied upon as a deterrent. Under the amendments, purposeful or negligent violation of any of the Act's major requirements, failure to obtain a permit, failure to give notice when required, failure to monitor properly, and failure to report thereon, is a crime attributable to the corporation, as well as to the individuals responsible. Inaccurate monitoring through negligence, or the intentional falsification of reports, are actions dealt with severely. The Act's criminal enforcement provisions are supplemented by an increased civil penalty authority, a provision for administrative penalty proceedings, and an expansive provision for citizens' suits.

<u>Criminal Penalties</u>

Section 309(c). "Negligent violations" are subject to criminal penalties of not less than $2,500 or more than $25,000 per day as well as a years imprisonment per day of violation.

Section 309(c)(2). "Knowing violations" are subject to fines of not less than $5,000 nor more than $50,000 per day of violation.

Section 309(c)(3). "Knowing endangerment," where a person knowingly violates a permit or other requirement "and who knows at that time that he thereby places another person in imminent danger of death or serious bodily injury. The penalty is imprisonment for 15 years and a fine of $250,000 for an individual such as a poultry plant manager or in the case of a poultry company, a fine of $1,000,000.

Section 309(c)(4). Strengthened criminal penalties for anyone who files false reports or who knowingly falsifies, tampers, or renders inaccurate any monitoring device or method. Violations are now punishable by a $10,000 fine and imprisonment of up to two years.

Penalties double for second offenses. Because negligent violations are potentially criminal, the scope of potential criminal violations under the amended CWA is extremely broad, and provides reason for diligent attention to compliance. Poultry processors are particularly susceptible to certain of these offenses.

Pretreatment violations are common with POTW dischargers. Obviously if a plant has received violation notices for the last five years, there is a "knowing" violation. Most people are unaware that such violations carry the potential for the above penalties. Several knowing endangerment prosecutions have now been prosecuted for pretreatment violations. The statute allows criminal action not only against the companies involved, but also against "responsible corporate officers." Moreover, circumstantial evidence may be used to prove violations of the knowing endangerment provision, including evidence that an officer deliberately shielded himself from knowledge of such violations. States also provide criminal penalties for violations of their statutes implementing the Clean Water Act.

<u>Civil Enforcement Options</u>
Under the Clean Water Act as amended in 1987, EPA acting through the Department of Justice, has a number of civil enforcement options to address violations of the act, the implementing of regulations, and NPDES and other permits. Penalties include $10,000 up to $25,000 per day of violation. Section 309(d) includes a number of factors for the court to consider in assessing the appropriate civil penalties including:

- the seriousness of the violation;
- the economic benefit (if any) resulting from the violation;

- any history of such violations

- any good faith efforts to comply with applicable requirements;

- the economic impact of the penalty on the violator;

- such other factors as justice may require.

Administrative Orders and Penalties

Administrative compliance orders are used against persons in violation of their Clean Water Act obligations. The order may require compliance with an interim compliance schedule or an operation and maintenance requirement; permanent compliance is to be required in a time that EPA determines is reasonable under the circumstances. The issuance of an EPA compliance order is a serious matter for a discharger, since failure to comply or at least to make good faith efforts to do so may be the basis to initiate a criminal prosecution for "knowing" violations, to initiate a civil penalty.

EPA has proposed a number of administrative penalties since passage of the 1987 amendments. The agency frequently proposes the maximum penalty, thereby shifting the burden to the defendant to show factors mitigating the violation and thus reducing the level of penalties assessed. EPA has used administrative penalties extensively in pursuing pretreatment violations.

Citizen Suits

Section 505 of the act provides an additional impetus to vigorous criminal enforcement of the act's provisions. It authorizes any person "having an interest which is or may be adversely affected" to commence civil actions against a discharger, for violation of any effluent standard or limitation of the act, or against EPA for failure to proceed expeditiously to enforce the act.

Actions against Food Processors

The current climate is one of increased litigation and cost. Examples of actions against food processors include:

- Citizens' Suits

  Chesapeake Bay Foundation vs. Gwaltney
  $1,300,000 fine proposed against meat processor

- Discharge Violations

  Nabisco Plant - Washington State
  $300,000 fine
  $250,000 reserve trust
  $ 5,000 fine/one year jail for plant manager

Ocean Spray - Middleborough, CN
$2,800,000 corporate fines proposed--fines and incarceration for officers considered.

- Sampling/Reporting

Ore-Ida - Portland, OR
Environmental Supervisor given three year sentence (given probation with house arrest and community service) and $5,000 fine for altering a wastewater sampling device and filing false reports.

Pollution Prevention Audits
EPA now utilizes pollution prevention audits in most non-compliance activities. A major turkey plant is now being subjected to a multi-media pollution prevention assessment because the POTW into which they discharge has been in non-compliance with its NPDES Permit. Both the state and EPA are involved in this case. The pollution prevention concept is discussed elsewhere in this paper.

Pretreatment

Pretreatment and sewer use ordinances can impose significant restrictions on poultry plants. The costs for pretreatment processes are expensive, and economically available technology may not yet be available to meet the new restrictive limits on nitrogen and phosphorus to be imposed for POTWs discharging to "nutrient sensitive" waters.

Pretreatment Regulations
The United States Environmental Protection Agency (EPA) in 1978, issued the federal pretreatment regulations. The objectives of the pretreatment regulations are to prevent the pass-through of pollutants that interfere with treatment systems. This assures treatment efficiency, protects treatment system workers, and improves or enhances recycling and reclamation processes. Amendments subsequent to 1978 includes those passed in 1981, 1987, and 1988, and in 1990. Plant specific permits are now being rapidly developed throughout the country to replace sewer use ordinance limitations. Most plants have found significant compliance problems with this process. The only way for an industry to guarantee that the pretreatment requirements placed on its discharges are reasonable is to take an active role in the development and implementation of the POTW's program.

General requirements are imposed under 40 C.F.R. Part 403 and requirements specific to particular industries, so-called categorical standards, are developed and imposed together with other effluent limitations governing each such industry.

The first part of the general pretreatment regulation focuses primarily on preventing the discharge into POTWs of pollutants which will interfere with the proper operation of the receiving treatment works. This "protection" standard prohibits the introduction into any publicly owned treatment works of:

(i) Pollutants which create a fire or explosion hazard in the POTW, including but not limited to, waste streams which meet the RCRA test for characteristic inflammable waste;

(ii) Discharges with a pH lower than 5.0 unless the works is specifically designed to accommodate such discharges;

(iii) Solid or viscous pollutants in amounts which obstruct the flow in a sewer system;

(iv) Discharges, including discharges of conventional pollutants, of such volume and concentration that they upset the treatment process and cause a permit violation (e.g., unusually high concentrations of oxygen demanding pollutants such as BOD); and

(v) Heat in amounts which will inhibit biological activity in the POTW resulting in interference, but in no case heat in such quantities that the temperature influent at the treatment works exceeds 40 degrees C (104° F) unless the works are designed to accommodate such heat;

(vi) Petroleum oil, nonbiodegradable cutting oil, or products of mineral oil origin in amounts that will cause interference or pass through;

(vii) Pollutants which result in the presence of toxic gases, vapors or fumes within the POTW in a quantity that may cause acute worker health and safety problems;

(viii) Any trucked or hauled pollutants, except at discharge points designated by the POTW.

Pretreatment requirements are directly enforceable by EPA and states with NPDES permit issuance authority, but the EPA regulations contemplate eventual delegation of primary enforcement responsibility to individual POTWs with EPA and the states receding to a backup role. There are a number of areas of concern for poultry company management.

<u>Ordinance</u>
The purpose of a sewer use ordinance is to give the POTW the legal authority to carry out the various functions required by the general pretreatment regulations.As part of industry's role in the pretreatment program, a plant should participate

in the local process of sewer use ordinance modification. When sewer use ordinance modifications are on the agenda, management should obtain a copy, and complete a thorough review of the draft.

Local Limits

As part of the development of a pretreatment program, each POTW must develop specific local limits in accordance with 40 CFR 403.5(c). In some cases, towns have found it easier to determine their local limits by conducting a poll of other POTWs and adopting the most common limits. As long as these limits are stringent enough to protect the WWTP and the receiving stream, they are approved by the approval authority. If the limits are too stringent, the approval authority usually assumes that the POTW is reserving capacity for future use. Therefore, the first request that an industry should make when reviewing its permit or the sewer use ordinance limits is to see the calculations on which the limits are based.

If the POTW has adopted local limits derived from site specific information, they are said to have technically based local limits. The process for developing technically based local limits involves determining the maximum amount of each pollutant acceptable to the influent (or headworks) of the WWTP, while still protecting the receiving water, the WWTP itself, and the POTW's sludge disposal options. This process is called a headworks analysis.

The headworks analysis can be divided into three sections: pass through calculations, interference calculations, and sludge calculations. An allowable influent load is calculated for each of the three sections. The three allowable influent loads are then compared and the most restrictive calculation is used as the basis for the final local limits.

Recent Developments

Program Revisions. The most recent revisions to the pretreatment program are now being implemented. These revisions were to assure that hazardous wastes discharged under the RCRA Domestic Sewerage Exemption were adequately controlled to protect human health and the environment.

The provisions of these rules include the following that may impact poultry processors:

--POTWs will be required to test their effluent for toxicity...POTWs may impose more stringent limits on industrial users.

--POTWs must determine whether their SIUs need a spill or slug plan, and when such plans are needed, must evaluate the effectiveness of the plans.

Compliance Study. A recent study of industrial dischargers into POTWs indicate that new criteria for non-compliance will dramatically increase non-compliance. The study indicates that 54 percent of dischargers would have been in non-compliance using 1990 data. Poultry processors were not specifically identified but such changes could greatly impact plants.

Summary

The only way to implement a fully effective pretreatment program is for federal and state regulators, local POTWs, and industrial users, to cooperate toward achieving a mutual goal: the protection of the receiving water and the town's wastewater treatment investment. In order to maintain the best possible cooperation, all parties involved must have a thorough knowledge of the general pretreatment requirements and an understanding of how these requirements helped to develop the POTW's site specific pretreatment program. Industries must take responsibility for understanding the pretreatment program and, in some cases, for educating the POTW in alternative ways to implement its pretreatment program. Industries that do take an active role in the development and implementation of their POTW's pretreatment program, may find that local pretreatment standards and requirements are more stringent than those required by federal regulation, or those needed to protect the WWTP and the receiving water.

Storm Water Permits

EPA published Final Storm Water Regulation in the Federal Register on November 16, 1990. EPA had exempted uncontaminated discharges from light industries such as poultry plants. A recent court decision may require EPA to mandate NPDES storm water permits from these facilities. Poultry plants that do not have enclosed live haul holding areas will need a permit anyway. There is still much speculation over technologies that might be required to control such discharges.

The Clean Water Act Reauthorization

Congress, EPA, and many environmental groups are expecting the Clean Water Act to be reauthorized soon. The impact of this process could affect the poultry industry. Some studies have approached the issue of applying market-based approaches to pollution abatement. These and other considerations require the poultry industry to proactively address these proposed changes.

MANAGING WATER AND WASTEWATER

Management and Process Changes
The four factors directly related to pollution that would induce a food processing plant manager to incorporate management and process changes designed to reduce waste load, are the following:

- Public image
- Cost reduction
- Efficiency
- Regulatory requirements

Public Image
Most food processing plant managers are very concerned about public image. They do not want to be seen as responsible for harming the environment.

Efficiency
Food plants that reduce wastes, often find they also increase plant efficiency. As wastes are eliminated, and more byproduct is recovered, there is often more product packaged for sale.

Cost Reduction
Costs for water, sewer, surcharge, and waste disposal are becoming significant expenditures for food processing plants. These costs have risen almost 10 fold over the last several decades, possibly more than any other cost for food processing. A recent survey by Arthur Young, led George Rafetelis to conclude that water costs could increase as much as 500 percent in the next five to ten years.

Regulatory Requirements
External restraints are another factor that can influence a food plant to consider water and waste reduction programs. These restraints can include effluent restrictions on selected wastewater parameters such as BOD_5, chemical oxygen demand (COD), fats, oils and greases (FOG), total kjeldahl nitrogen (TKN), and flow. These restrictions can adversely effect poultry plants.

Methods of Reduction
There are three proven ways to reduce water use, wastewater discharge, waste loads, and product loss. One method is to operate the plant more efficiently. The second method is to institute process changes proven to reduce water use, product waste, and waste loads. The third method is to install conventional pretreatment technologies such as clarifiers, separators and/or dissolved air flotation (DAF) units to remove pollutants.

Pollution Prevention Pays Concept
Although many scientists and technical people have practiced pollution prevention, Dr. Joseph T. Ling of the 3M Company can

be credited with first using the 3M Pollution Prevention Pays (3P) program.

Dr. Ling concluded that government, industry, and the public are beginning to become aware of the shortcomings of conventional pollution controls, not to mention their cost. "Pollution Prevention Pays" utilizes the concept that the conservation approach should be used to eliminate the causes of pollution before spending money and resources for clean up afterward. Dr. Ling defines the conservation approach as the practical application of knowledge, methods, and means to provide the most rational use of resources to improve the environment.

Dr. Ling believes that the pollution prevention approach is hindered or precluded by many rigid environmental laws and regulations. One current example is municipal pretreatment ordinances with specific limits on the concentration of pollutants in wastewater discharge. For food processing plants, maximum concentration limits on compatible pollutants, such as BOD_5, often preclude water reuse and recycling.

Pretreatment of food plant wastewater does not really solve a pollution problem. Instead, pretreatment generates secondary nutrients (biosolids) that must be disposed of properly to prevent moving the pollution to another location. As pretreatment or treatment requirements increase, resources are consumed, and residues are produced--the costs incurred rise exponentially. Dr. Ling defined this environmental paradox as follows: "It takes resources to remove pollution: pollution removal generates residue; it takes more resources to dispose of this residue and disposal of this residue also produces pollution."

The poultry processing industry has an opportunity to increase plant efficiency, reduce pollution, conserve water (one of our most vital resources), and increase profitability. Knowledge, management commitment, thorough understanding of the processes, and employee education, are the key components of a successful program.

EPA is seeking to integrate pollution prevention as an ethic throughout its activities, in accordance with the national policy expressed in the Pollution Prevention Act of 1990. The concept of pollution prevention is broadly applicable--a tool to accomplish many environmental tasks. Pollution prevention requires a cultural change--one which encourages more anticipation and internalizing of real environmental costs by those who may generate pollution, and which requires EPA to build a new relationship with all of their constituents to find the most cost-effective means to achieve those goals.

The EPA "Statement of Definition" is a formal embodiment of what has been the Agency's working definition of pollution prevention. The Definition is consistent with the Pollution Prevention Act of 1990 and the Agency's 1991 Pollution Prevention Strategy. It makes clear that prevention is EPA's first priority within an environment management hierarchy that includes: 1) prevention, 2) recycling, 3) treatment, and 4) disposal or release.

An internal EPA memorandum notes that while the definition is subject to further refinement, it provides a common reference point. Agency personnel were directed to please keep the following points in mind:

- As always, whether the pollution prevention option is selected in any given situation will depend on the requirements of applicable law, the level of risk reduction that can be achieved, and the cost-effectiveness of that option.

- Accordingly, the hierarchy should be viewed as establishing a set of preferences, rather than an absolute judgement that prevention is always the most desirable option. The hierarchy is applied to many different kinds of circumstances that will require judgement calls.

- Drawing an absolute line between prevention and recycling can be difficult. "Prevention" includes what is commonly called "in-process recycling," but not "out-of-process recycling." Recycling conducted in an environmentally sound manner shares many of the advantages of prevention, e.g. energy and resource conservation, and reducing the need for end-of-pipe treatment or waste containment.

Henry Habicht noted that as EPA looks at the "big picture" in setting strategic directions for the decade ahead, it is clear that prevention is key to solving the problems that all our media programs face, including the increasing cost of treatment and cleanup. In the common-sense words of Benjamin Franklin, "an ounce of prevention is worth a pound of cure."

Poultry Industry Must Change Attitude About Water Use

Water is becoming an increasingly scarce and costly commodity. Increased domestic demand fueled by a growing population, increased industrial and agricultural demand, and degradation of many water sources have combined to bring an end to the era of cheap, high-quality water. Recent droughts have underscored the fact that there are now greater numbers of people competing for less high-quality water. Poultry processors need clean, pure water and should be concerned about water availability.

However, the people at the top of the management structure in the poultry industry should be concerned about more than just the short-term availability of water of sufficient quality for food processing. Those who are responsible for the future of the industry should also be concerned about the depletion or loss of water resources and about the effect on water resources of the disposal of industrial wastes including both processing residuals and wastewater treatment process residuals. Each area has technological, economic, legal, regulatory, and image concerns. These factors combine to make water supply and waste disposal issues critical in the location and continued operation of poultry processing plants.

Over the last two decades, the public has become increasingly vocal about maintaining the quality of our groundwater and water in our streams, rivers, estuaries, and oceans. Public concerns about water quality have prompted new economic, regulatory, and political changes that necessitate a change in attitudes about water use in the food industry.

PROACTIVE COMPLIANCE

Compliance with the Clean Water Act requirements outlined above would be difficult and costly under the best of circumstances. These difficulties are complicated by inconsistencies in EPA (and state) enforcement policies, EPA's tardiness in developing standards, and the periodic congressional review of program. Consequently, the questions of how the law will be interpreted and enforced are often not amenable to predictable answers. Participation in the development and revision of standards and continuing contact with officials responsible for permitting and enforcement is necessary if industrial dischargers wish to operate in a consistent and predictable regulatory environment.

Negotiation of Permit Conditions

Whether a company's authorization to discharge is in the form of an NPDES permit for direct discharge into a waterway or a plant specific permit with a municipality for use of its treatment facilities, the terms and conditions of that permit or contract may be every bit as important: in terms of impact on profit, as a major corporate contract. Moreover, the addition of the anti-backsliding provision by the 1987 amendments make it especially important that the initial permit or contract be correct, as costly errors can be very hard to fix.

These requirements can be the subject of negotiations. Accordingly, pollution control managers should determine the areas in which the act and regulations leave room for negotiation and based on a careful assessment of the company's long-term interests, should negotiate actively, in an effort to obtain favorable permit terms and conditions. These negotiations will be more important and much more complicated if toxic pollutants are involved.

Discussions With EPA Regional Office, State, and/or Local Officials

No matter how good the standards are or how carefully permits are drawn, there will inevitably be situations where companies are forced to make major investment decisions which are affected by significant uncertainties in determining the applicable environmental control requirements. In these circumstances, serious consideration should be given to obtaining advance guidance from the appropriate EPA regional office and/or state enforcement personnel.

State and Local Planning

Industry would also be well advised to give considerable attention to the substantial planning requirements which are imposed by the act on state and local governments, especially the numerous water quality planning requirements imposed by the 1987 amendments. The state and regional water quality implementation plans, continuing planning processes and area-wide waste treatment management plans may well be as important as federal rules and regulations in determining a company's future costs. If properly followed, these planning processes can be of immeasurable aid to management in predicting and planning for the future.

Conclusion

Both the implementation of and compliance with the Clean Water Act have been and remain complex, difficult, and expensive for all concerned. The increasing focus on toxic pollutants and water quality improvement, while environmentally sound, increases the complexity of regulations, the costs of compliance, and the difficulty of monitoring. Under these circumstances, it is obvious that the development and implementation of a workable and effective program will require the best efforts of regulators, environmentalists, and the regulated community. The EPA must establish priorities and allow both industry and its own enforcement concentrate efforts and attention for resolving the problems which are most significant in terms of impact on human health and the environment. It does little for the environment to spend time, money and effort identifying and monitoring pollutants which are present in inconsequential amounts and to which significant portions of the population are not exposed.

Achievement and maintenance of a regulatory climate which facilitates cooperative and intelligent planning is the best, and perhaps the only way of achieving the pollution control objectives announced by Congress when it passed the 1972 act and has been repeatedly ratified by Congress since. These goals will best be met when all parties avoid unnecessary confrontations, focus on the real regulatory issues, and develop a program which reasonably and cost effectively achieves essential water quality objectives without major economic or social dislocation.

CONCLUSIONS

The Clean Water Act will effect the poultry processing industry by making environmental issues prominent in the 1990's. Management must plan now to comply with new environmental regulations, as well as minimizing costs and insuring the delivery of safe, nutritious poultry products to the consumer.

Top management is responsible for a firm's accomplishments in the environmental field. Management's attitude is responsible for water use reductions and waste elimination. The lowest cost control measures usually are those that attack the problem at its source. No change for a food plant can be implemented successfully without continuing interest by management.

Many note the sufficient supply of quality water as an impending national crisis. Drought conditions, together with the increasing demands of an expanding population, and growing industrial needs, underscore the importance of adequate supplies of high quality water. Conservation and industrial water use are inextricably linked with other state and national concerns for environmental quality, energy conservation, agricultural production needs, industrial development, municipal requirements, recreational, and wildlife needs.

Specific recommendations and concerns to the poultry industry include the following:

1. Control of runoff from "animal units" may impose severe restrictions on the growing of poultry.

2. Disposal of poultry litter and dead birds will receive increased attention.

3. Water conservation in processing plants needs more attention because:

   - Water used in the plant becomes wastewater which must be disposed of properly.

   - Water costs will continue to escalate.

4. Storm water permits will be required for all facilities. The nature of these permits and remedial action required for discharges remain a question.

5. Environmental regulations and costs will continue to increase.

6. Both direct and indirect dischargers will be impacted by both "nutrient sensitive " designations and the imposition of TMDLs (Total Maximum Daily Loads).

7. Toxicity concerns may force many changes including discontinuance of chlorine.

8. Non-discharge permits (such as land application systems) will receive greater scrutiny and permit renewals may require significant changes.

9. Costs for permit maintenance by regulatory agencies will continue to escalate.

10. Enforcement actions will continue to escalate as will the fines and sentences for corporate officials.

11. Spending money on environmental problems will not make many of the problems disappear nor will it assure compliance.

12. There is a need for more information and informed action. Every company must develop an effective compliance strategy.

PROCESSING WASTEWATER EFFICIENCY FOR BROILERS

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Many of you have seen my presentations in the past on efficiency of water use in processing. The basics have not changed. They are:

1. Use the least amount of water possible to produce a high quality bird.

2. Add the least amount of organics possible to the waste stream.

During the 1990's, the thrust will be to improve manufacturing efficiency so that US industries can be competitive in world markets. All industries, including poultry processing, will feel pressure to increase efficiency. Because the cost of water and wastewater treatment is increasing more rapidly than any other processing cost, it makes good economic sense to minimize these costs. Table 1 shows the economic impact that efficient water use can have on broiler processing. The table assumes an average water use of 5.5 gallons per bird and a water and wastewater cost of \$3.00 per 1000 gallons at the present time. By the year 2000, water and wastewater costs will rise to \$7.00 per 1000 gallons and broiler production will increase from 6.2 to 8.0 billion birds per year.

Table 1. Economic benefit of water and wastewater efficiency

	1992		2000	
Gals./bird	Billion Gals.	Million Dollars	Billion Gals.	Million Dollars
5.5	34.1	102.3	44.0	308
3.5	21.7	65.1	28.0	196
2.75	17.0	51.1	22.0	154

Broiler processors have an opportunity to reduce water and wastewater costs by approximately $100 million per year by becoming as efficient as the most water efficient processors at the present time. A water use reduction to 2.75 gallons per bird will be worth an additional $40 million per year at the turn of the century.

To reduce water costs, three things are necessary:

1. Commitment to management.
   Management must take a long term, continuous commitment to efficient water and wastewater use. Without this commitment little will be done to control these costs.

2. Knowledge of water use and waste loading patterns.
   With some basic technical knowledge, data can be gathered to determine those times and operations where excessive water is used and where excessive organics are added to the waste stream.

3. Continuous management commitment.
   Unless management continuously emphasizes this aspect of processing efficiency, little will be done to save the $140 million per year.

MANAGEMENT COMMITMENT

The method that management uses to make the commitment will vary from company to company. Two speakers at this symposium, Carl Galey, Tip Top Poultry, Marietta, GA, and Kevin Almand, Gold Kist, Athens, Ga, are examples of two types of management commitment made to reducing water and wastewater costs. Other types of management commitments can be establishment of water conservation teams or a corporate water conservation/waste minimization specialist who works on a multiple plant circuit to reduce the water costs at each plant. The method of commitment is not as important as the continuous commitment.

KNOWLEDGE OF WATER USE EFFICIENCY

1. Conduct a 24 hour water use profile.

   To conduct this profile, read incoming water meters at hourly intervals over a 24 hour period. At the same time, record flow discharges through a flow measuring structure. Data gathered by reading incoming water meters can determine the water use patterns over a processing day. These data can show if water is being turn off at breaks, meal periods and during shift changes. It can also show water use patterns during processing shifts and sanitation. Hourly reading of incoming water meters over many days is such a tedious chore that few processors will be willing to commit to this effort. To simplify this process, there are water meters that send a use signal to a computer so that water use can be tracked continuously. The data base will not only determine average hourly water use but also can determine variation in water use over time.

Measuring discharge flow continuously can determine discharge patterns so that the efficiency of pretreatment systems can be maximized. A recent study of wastewater discharge patterns of a processing plant by recording the flow through a "V" notch weir showed that flow varied from 150-650 gallons per minute over a 8-10 minute cycle. This type of "plug" flow can cause loss of efficiency in DAF units, clarifiers and gravity separation tanks. Another study showed a variation of 0-1000 gallons per minute over a 20 minute cycle during the sanitation shift.

2. Install water meters to segregate water use.

Installation of water meters to determine water use by ice making, mechanical equipment, evisceration, slaughter and picking operation, cut-up and further processing will determine the water use efficiency of each operation. It can also be cost effective to install water meters on major pieces of equipment. The cost of a water meter will be recovered in about 17 days if the flow to a piece of equipment can be reduced by five gallons per minute. (Table 2.)

Table 2. Cost Recovery of a Water Meter Through Water Conservation

Gallons/min reduction	Gallons/hour	Dollars/hour
2.0	120	$0.36
5.0	300	0.90
10.0	600	1.80

Water and wastewater cost = $3.00 per 1000 gallons.
Water meter cost = $250.

A study of inside/outside bird washers in one plant showed that the annual water cost of two washers varied by $17,000 per year. In this case, the cost of a water meter would be recovered in four days. In few, if any, situations will installation of a new piece of equipment pay for itself in four days.

3. Measure and regulate small flows.

Small flows such as hand wash stations (goosenecks), leaking hoses, holes in pipes, leaks, etc. can be measured using a container and a stopwatch. These small flows can waste significant amounts of money. Variation of gooseneck flow for two workers standing side by side cost a months wages more per year for one worker than the other.

Holes drilled into pipes and water rails to wash surface waste water. One plant study used $68,000 of water per year to wash 42 feet of side pan by using a water rail. It would not be considered cost effective to hire a person whose only job was to wash 10 feet of side pan, yet multiple holes in water rails have the same economic impact. In a double shifted plant, one foot of water rail with holes on one inch centers can use 400,000 gallons of water per year. At $3.00 per 1000 gallons, a foot of water rail can cost $1200 per year.

4. Regulate pressure.

Reduction of incoming line pressure has been shown to be the most beneficial single thing that can be done to reduce water use. A plant can usually process with incoming line pressures of 35-40 psi. Incoming line pressures of 60-70 psi will cause equipment to waste water. Municipal line pressure can increase, especially at night when the town is asleep and water consumption is reduced. A pressure regulator will control the incoming pressure and reduce water consumption.

5. Use new eyes and imagination.

As in many things people can be so close to situations that common things are overlooked. Step back a bit and look at everything with new eyes. Every little leak should be seen as money going down the drain.

A university bird test facility had a water rail installed to wash manure from the concrete floor under the cages. The water rail ran constantly 24 hours per day, 365 days per year. A study of this water flow showed that the water rail used 20 gallons per minute. In a years' time, this water rail used 10,500,000 gallons of water. This volume of water would meet the needs of Athens, Georgia for about 2/3 of a day per year. At Athens industrial water and sewer rates, $2.75/1000 gallons, it cost $28,875 per year to wash manure from the floor. This is a little less than one half of my annual salary and benefits cost to the University of Georgia. University administrators would be hard pressed to justify to state legislators an associate professor where half of his duties would be to scrape manure from the floor of a 300 bird test pen. Yet this is the way it had always been and nobody's eyes saw the cost.

CONTINUOUS MANAGEMENT COMMITMENT

Water use should be seen by management as a method of increasing efficiency in the same way that line speeds, downgrades, percent of shackles hung and other ways that plant efficiency is measured. The commitment must be continuous. As water and wastewater costs increase, the need for greater commitment will be necessary to improve efficiency and reduce costs.

PROCESSING WASTEWATER EFFICIENCY FOR TURKEYS AND DUCKS

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With the increase in awareness of the detrimental effects of water pollution on the environment, both reducing water use and waste pollutant concentration in wastewater should be a priority with food processing companies. Not only will there be benefits to the environment by such reductions, but economic benefits to the company as well. Although turkey and duck processors produce only compatible pollutants which are easily treated, these reductions also benefit the communities in which such plants are located as societal costs for water supply and wastewater treatment are reduced.

Wesley (1985) reported that about 11% of the 1982 total processing costs in poultry processing plants was associated with water use and treatment. He speculated that these costs would escalate in the future. In a survey conducted by Simon (1985), fifteen turkey and broiler processing plants were surveyed nationwide for water usage. It was reported that between 500,000 to 700,000 gal of water were used (including sanitation) per day in the surveyed plants. The average water and wastewater treatment costs were $0.55 and $1.80 per 1,000 gal, respectively. Turkey processing plants were found to use from 11 to 23 gal of water per bird processed. Wesley identified the four major sources of wastewater generated in poultry processing plants as the scalder and chiller overflow, viscera carriage flume, handwash stations and evisceration trough rinses, and plant sanitation program (Wesley, 1985).

In a study by Morris (1965), two Long Island, N.Y., duck processing plants were monitored to evaluate and measure process wastewater loads and make recommendations for reducing water use. The study was conducted for four consecutive days. Based on weighted averages, 23.6 gal of water were used per duck processed. Suspended solids and BOD were 0.0289 lb and 0.0419 lb, respectively, per duck processed.

As a further extension of the work of Wesley (1985), Simon (1985), and Morris (1965), the purpose of this presentation was to characterize the organic waste load distribution and volume of processing water used at various stages of processing in turkey and duck processing plants. The data presented in this manuscript was tabulated from several studies including a 1982 study of two turkey processing plants conducted by Merka and two studies conducted by the three authors of this manuscript in 1988, one involving a turkey processing plant and a second involving a duck processing plant.

MATERIALS AND METHODS

Merka (1982) Turkey Study

Wastewaters from two Texas turkey processing plants were evaluated in two phases. The first phase evaluated wastewaters discharged over a 24 hour period. Final plant effluent samples were taken at hourly intervals and analyzed for contaminant concentrations. Concurrent with sample collection, hydraulic volume discharge was measured. The concentration and mass of contaminants discharged during processing (7:00 am to 3:00 pm), cleanup (4:00 pm to 11:00 pm) and downtime (12:00 pm to 6:00 am) were evaluated. The second phase of the study evaluated organic contaminant concentrations and pollutant mass discharged by nine process unit operations. Unit operations evaluated were the killroom, scalder overflow, dressing operation, evisceration room, chiller overflow, gizzard cleaning, viscera truck drain, further processing, and the final plant effluent. These data were obtained by sampling each plant twice for both diurnal and unit operation studies. Plant A processed approximately 13,000 birds daily whereas plant B processed 8,000 birds.

Each wastewater sample collected for organic contaminant concentration analysis consisted of four one liter subsamples taken at one minute intervals. The subsamples were then mixed together to form a composite sample and 1 liter withdrawn and blended in a Waring blender jar at moderate speeds for two min. Aliquots of this blended sample were taken and analyzed for BOD_5, COD, TSS, VS, FS, and FOG according to standard methods (APHA, 1986). Hydraulic volumes discharged during the three diurnal phases at Plant A were evaluated by quadruplicate measurements of flow volumes taken at hourly intervals for duplicate 24 hour periods. Velocity of flow was measured by an Ott meter. Cross sectional area of flow was calculated according to recommended procedures. Area of cross section of flow multiplied by flow velocity determined the volume of flow per unit time and converted into gallons per minute. Hydraulic volumes discharged by Plant B during duplicate 24 hour sampling periods were calculated as the volume of water flowing into the plant as measured by city water meters.

Volumes of wastewater discharged by unit operations were measured at duplicate periods concurrent with sample collection for organic analysis. Volumes were determined by either recording the time required to fill a measured volume or calculating the volume of water flowing through a flume.

Raeford (1988) Turkey Study

A North Carolina based turkey processing plant was used as the site for this study. Processing began at 7 am and ended at 5 pm followed by cleanup which lasted from 5 pm to 7 am of the following day. The morning break occurred at 10 am and lunch was from 12 pm to 1 pm. An average of 31,115 turkeys per day were processed during the three day sampling period (3/8-10/88).

Twenty-one sample locations from throughout the plant were selected from which process wastewater samples were taken. Chemical oxygen demand and/or water flow measurements were taken at each location during the morning and afternoon processing hours. Duplicate COD values (mg/l) per 2 ml of blended sample were determined using the two hour reactor digestion method of Hach and DR 21000 spectrophotometer.

Water flow at sample locations were obtained from direct measurement (volume-time), by calculations using flume dimensions, or by reading water meters. Flowrates at each location were taken at approximate steady state processing conditions. Hourly plant water use readings over 24 hours were determined by monitoring water meters. Hourly wastewater samples were collected from the plant's final effluent discharge line (post DAF) using a 24-h ISCO sampler with COD analysis performed on individual hourly samples.

A final effluent composite sample based on hourly water use volumes relative to the 24-h total water use was formulated and analyzed for COD, TS, VS, FS, FOG, TSS, and BOD_5. Final effluent wastewater samples were collected with the ISCO sampler set to take a sample at 15 min intervals with four samples per hour composited into 24 discrete hourly samples. Total water use for each sampling day and the average water use over a three day period were used in calculating water use and wastewater percentages generated at each sample location or when expressed on a per turkey basis. Both well and city water sources were used by this processing plant.

Concord (1988) Duck Study

A North Carolina based duck processing plant was used as the site for this study. Processing began at 7 am and ended at 4 pm followed by cleanup which lasted from 5 pm until 7 am of the following day. Processing is interrupted by a 15 min morning break at 10 am and a 30 min lunch break at noon. A total of 24,888 ducks were processed on the test day (3/11/88). The average live weight (LW) of the ducks were 7.3 lb. and the average eviscerated weight (EW) was 5.4 lb.

Sixteen sample locations were selected from which process wastewater samples were taken. Flowrate measurements and/or COD analyses were taken at each location in the morning and afternoon following the procedures outlined under the Raeford turkey study. A wastewater composite sample was formulated and analyzed as described in the Raeford study. Due to differences in the two sampling procedures (ISCO and composite), distinction between these methods has been indicated in the text.

RESULTS AND DISCUSSION

Merka (1982) Turkey Study

Of the two plants studied, Plant A used 474,000 gal of water to process 13,000 turkeys per day or 36.5 gals per turkey. Of this amount, 323,000 gal or 68% of the total daily water usage was consumed during processing; 89,000 gal or 19% during cleanup; and 61,000 gal or 13% during downtime (Table 1). Plant B used 274,000 gal of water to process 8,000 turkeys per day for an average of 34.2 gal per turkey. Processing consumed an average of 186,000 gal (68%) whereas cleanup and downtime water usage averaged 40,260 gal (15%) and 46,890 gal (17%), respectively (Table 1). Both plants discharged about 70% of their waste loads during processing, 25% during cleanup, and only 5% during downtime. Maximum processing phase organic load concentrations were attributed to washdown of the processing plants during the morning break. Initial cleanup of the turkey processing plants increased the concentrations of organic contaminants to the highest level of the diurnal period.

Analysis of organic contaminant concentrations indicate that the viscera truck drain, killroom, gizzard cleaning operation, and further processing operation discharged effluents with the highest contaminant loads (Table 2). These four process functions contributed 50% of the BOD_5 in the final plant effluent (414 kg) during the processing phase yet these four functions discharged only 11% of the hydraulic volume. The feather flowaway and processing operation wastewaters accounted for the largest volumes of wastewater discharged.

However, the feather flowaway wastewater was not considered as a true measure of discharge since it is a recirculation of wastewater to flow away feathers discharged by the mechanical feather pickers.

Table 1. Characteristics of the Final Plant Effluent of Plants A and B During Three Operational Phases (Merka Study)

Operational phase	BOD	COD	TSS	VS	FS	FOG	Water volume
	kg discharged/operational phase						gallons
Plant A							
Processing	939	1630	349	1086	891	122	323,329
	73.0%[a]	77.7%	74.4%	74.2%	66.8%	74.3%	68.1%
Cleanup	327	429	116	332	295	38	89,611
	25.4%	20.4%	24.8%	22.7%	22.1%	23.5%	18.9%
Downtime	21	38	4	45	148	4	61,583
	1.6%	1.9%	0.8%	3.1%	11.1%	2.2%	13.0%
Plant B							
Processing	626	867	270	670	425	81	186,900
	71.3%	72.5%	71.7%	72.0%	42.8%	64.4%	68.2%
Cleanup	131	167	68	164	244	30	40,260
	14.9%	14.0%	18.0%	17.6%	24.6%	23.9%	14.7%
Downtime	121	162	39	97	323	14	46,890
	13.8%	13.5%	10.3%	10.4%	32.6%	11.5%	17.1%

[a]Percentage figure represents percentage of total diurnal discharge associated with each operational phase.

Raeford (1988) Turkey Study

In this second study, water use was calculated to be 26 gallons per bird with an average daily water use of 801,233 gal. Total water use was greatest during processing (52.5%). The cleanup phase consumed 47.5% of the daily water use although some of this water is used for filling the scalder and chillers or in further processing which extends into the cleanup operation phase. The COD load discharged during processing accounted for 52.5% (5680 lb/day) of the total 24 h organic load (10,812 lb/day). Cleanup activities which included some further processing generated 5132 lb of COD per hour or 47.5% of the daily COD load. These amounts translate to 348 lb of COD per 1000 birds processed. The wastewater characteristics of the 24 h composite sample taken from the plant effluent drain were as follows: COD-1.5; TS-1.1; BOD_5-0.7; and FOG-0.3 kg/1000 liters of water. These values correspond to an annual waste load of 1.14 million kg of COD, 0.834 million kg of TS, 0.531 million kg of BOD_5, and 0.228 million kg of FOG.

Table 2. BOD_5 in the Wastewater Taken From Selected Unit Operations of Two Turkey Processing Plants (Merka)

Process function	Plants A	Plants B (mg/l)	Plants Combined	Kg/hr discharge Plant A
Killroom	2137[a] (22.5)[b]	2575 NA	2356 (22.5)	11.7
Scalder overflow	386 (26.0)	328 (6.8)	357 (16.4)	2.2
Gizzard cleaning	1227 (33.3)	5539 (2.1)	3379 (19.9)	9.0
Chiller overflow	230 (29.6)	331 (25.0)	277 (27.3)	1.5
Feather flowaway	924 (517)	346 (380)	676 (448)	108.5
Processing operation	347 (234)	543 (146)	445 (190)	18.5
Viscera truck drain	10687 (9.8)	1480 NA	6084 (9.8)	23.6
Further processing	534 (13.3)	2181 NA	1358 (13.3)	1.7
Final plant effluent	695 (581)	675 NA	685 (581)	91.7

[a]Mean of 8 observations.
[b]Values in ( ) represent volume of water discharged in gal/min.

Of the 21 plant locations monitored, the eviscerating room drain, picking room drain, and gizzard defatter had the highest daily COD waste loads (794, 651, 662 kg/day, respectively, Table 3). Besides cleanup, which accounted for 47.5% of the COD load (calculated from the hourly final plant effluent samples), 16.2% and 13.3% of the daily COD load was contributed by the eviscerating room drain and picking room drain, respectively. Evisceration, further processing, and cleanup operations consumed 2.5, 1.5, and 12.2 gal of water per bird processed, respectively. Although the volume of wastewater generated at the offal and feather truck drains and gizzard line represent only 3.5% of the total wastewater produced, these locations accounted for 17.6% of the total COD load. Diversion of these wastewaters from the DAF unit might be desirable to reduce the overall organic burden on this pretreatment system.

Concord (1988) Duck Study

Daily water use was determined to be 1,945 gal/1000 lb of live weight or 14.2 gal/duck. A total of 354,900 gal of water was used daily. Processing accounted for 52.9%, whereas cleanup utilized 47.1% of the daily water volume. Waste loads were BOD_5 (5.25), COD (19), TSS (5.25), and FOG (4) lbs/1000 lb live weight, respectively, as calculated from the 24 h final plant effluent composite sample. A total of 3,661 lb of COD was discharged daily or 0.147 lb COD per duck processed. Approximately 58.8% of the total daily COD load was discharged during processing with cleanup accounting for 41.2%.

Table 3. Daily Waste Loads Generated and Water Volumes Consumed at Several Process Locations (Raeford study)

Sample location	COD (kg/day)	Percent of sample total	Daily water use (gal/day)
Chiller 1	98	3.0	20,991
Chiller 2	82	2.6	26,199
Feather truck drain	229	7.1	8,408
Offal truck drain	189	5.9	1,606
Evis. room drain	794	24.7	75,886
Final bird wash	108	3.4	23,087
Truck wash drain	18	0.6	2,434
Picking room drain	651	20.3	65,396
Giblet/heart chiller	188	5.9	38,144
Gizzard line	190	5.9	5,019
Gizzard defatter	662	20.6	12,045

The eviscerating drain discharged 138,624 gal/day (288.8 gal/min) or 39.1% of the daily water use and generated 0.037 lb COD/duck processed (Table 4). The eviscerating drain emptied water from several locations including the eviscerating trough, whole bird washer, final bird wash, gizzard cleaning trough, gizzard elevator water, and heart overflow water. Water usage was based on an eight hour processing day. The eviscerating trough and feather screen had the highest water use levels and flowrates (16.9% and 10.5% of daily water use, respectively). The highest COD (lb/day) loads were found at the feather screen, eviscerating drain, and picking drain. Although a water flowrate measurement was not taken on the feather wash, a high COD (lb/1000 gal) value was obtained. Five sample areas were ranked on water usage and COD loads generated. These rankings indicate that particular attention should be directed to these five areas because of high water usage and COD loads generated in the wastewater.

Table 4. Daily Waste Loads Generated and Water Volumes Consumed at Several Process Locations (Concord study)

Sample location	COD (lb/day)	Daily water use (gal/day)	Ranking Water (gal)	Ranking COD (lb/day)
Feather screen	1003	37,440	3[a]	1
Evis. drain	915	138,624	1	2
Picking drain	631	12,576	5	3
Prechiller	37	3,696		
Final chiller	104	15,936	4	5
Heart/liver chiller	24	1,344		
Gizzard chiller	11	4,080		
Heart/liver chiller separator	61	4,320		
Gizzard chiller separator	3	5,472		
Whole bird wash	8	1,694		
Gizzard cleaning trough	9	11,520		
Eviscerating trough	162	60,000	2	4
Feather wash	22.1 lb/1000 gal			

[a]Ranked in order with respect to all sample areas (1=highest).

The water use and waste load information presented in this manuscript on turkey and duck processing can be used by other poultry processors in identifying key problem areas in their own plants. Plant managers must begin their water and wastewater reduction programs with a positive attitude. Plant managers should emphasize the importance of conserving water as a way of reducing water and sewer costs. Waste loads from turkey and duck processing plants comes from components (feathers, fat, blood) that are lost to the plant's sewers. Blood, soluble proteins, and fat are the major contributors to waste load. Blood alone can be as much as 17.4 lb BOD/1000 broilers processed - more than 30% of the plant's total waste load. A similar relationship probably exists in turkey and duck processing plants. Possible ways to reduce waste loads are summarized in Table 5.

Table 5. Waste Reduction Options.

1. Reduce water use; most water used in processing will become wastewater.
2. Utilize screens and efficient solids recovery systems.
3. Improve on blood collection through ensuring that all birds are properly stunned and installing a blood collection system.
4. Install dry systems for offal collection.
5. Collect solids from floors and equipment by sweeping and shoveling prior to washdown. Do not use hoses as brooms.
6. Management must adopt the attitude that waste load reduction is a must business decision.
7. Train employees in the concept of pollution prevention and how to perform their jobs to maximize pollution prevention.

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STARTING A WATER CONSERVATION PROGRAM

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There are many reasons for conserving water in the poultry industry. Three major reasons are:

A. To reduce cost incurred by processing facilities in the production of poultry products. An average processing facility uses 5.75 gallons of water per bird and pays $3.10 per 1000 gallons (water and pretreatment combined). If the same plant processes 1,250,000 head a week, the annual water cost would be approximately $1,115,000. If this plant reduced it's water consumption by 1.75 gallons per bird, then the total annual water cost would be approximately $775,000. Thus, producing a gross annual savings of approximately $340,000 at the current water rate. It is apparent that a water reduction program can be a valuable aid in producing greater company profits.

B. To reduce and control the amount of raw sewage processed at municipal sewage plants. This will reduce the necessity for the expansion of municipal sewage plants and keep rates at a minimum not only for the processing facility, but for the residents of the surrounding community as well.

C. To aid in the conservation of a natural source. The natural supply of potable water is being depleted daily.

Water conservation, in the poultry industry, can be defined as; "The reduction or elimination of nonessential water usage in the production of high quality poultry products for human consumption". Some examples of nonessential water usage are:

- Leaks.
- Large volumes of water generated from hose systems.
- High flow rates from goosenecks at wash stations.
- Excessive amounts of water generated for belt washers.
- Water used in the removal of by-products, which could be disposed of more efficiently with squeegees, shovels, brooms, etc.
- Excessive overflow from cooling condensers.
- Overflow from bird stunners.

The list is endless. Distinguishing between essential and nonessential water usage is an important part of reducing water consumption in poultry processing.

In some cases, water reductions can be achieved by simply improving upon a technique or method of execution in an established process. For instance, using squeegees and shovels to dispose of large debris instead of water hoses. Ever heard of chicken hockey? This phenomenon occurs when employees are allowed to use water hoses for the removal of large material from the floors to the drains. A typical chicken hockey game can take several minutes to play and there are generally several games per night. These so called "games" can cost a company large revenues annually.

TOTAL COMMITMENT FROM MANAGEMENT

In order for a water conservation program to be successful, it must have full commitment from management. Upper management must recognize the importance of water reduction and it's effect on reducing cost. They must be willing to invest in personnel and equipment necessary to promote the program. A one year return of $340,000 on a $34,000 investment is a substantial return.

Department Manager Responsibilities

Department managers should realize that reduced water usage will be coming directly from within their own areas of production. They should be aware of potential areas of savings such as decreasing water demands for equipment during breaks and between shifts. Department managers must also communicate the importance of water reduction to supervisors. Managers must constantly monitor each area in their department for possible reductions and employee participation. Supervisors will have to convey the importance of reducing water usage to the hourly employee.

Employee Awareness

Most employees have no real conception of the volume of water utilized for processing, nor the cost generated annually from the purchase of such a volume. Some employees believe that the water is free, while others base their opinions on a monthly residential water bill.

Interaction with USDA Inspectors

USDA inspectors should be aware of a company's efforts to reduce water consumption. In most cases, they will accommodate a water conservation program. Often, inspectors will suggest areas of potential reductions and advise on areas where water usage is critical. Individuals responsible for implementing water reductions should form a solid competent relationship with USDA inspectors. Proper communication with USDA inspectors in charge will increase the likelihood of a successful water conservation program.

PLANT WATER SYSTEMS AND EQUIPMENT

In order to reduce consumption, knowledge of the plant's water systems and municipal supply lines is recommended. Also, knowledge of current water usage of equipment and manufacturer's suggested water consumption are beneficial. A water conservation program will achieve maximum results when it is subject to the detailed supervision of one individual. Knowledge of system installations and principles will enable this individual to summarize operating conditions and trends for an immediate appraisal and decision regarding water reduction.

Occupational Tools

Two primary tools of a water conservationist are a container, of known volume, and a stop watch. Detailed and accurate measurement of water usage throughout the facility will help determine areas of extreme usage and potential waste. This data can be used for comparison once a water reduction program is implemented. Flow levels recorders, flumes, and weirs are helpful in determining the volume of water pretreated and returned to the municipal sewer, but are not a necessity. Due to wet nasty working conditions, obtaining a pair of rubber boots is advisable.

Flow Meters

Flow meters are extremely useful in analyzing flow rates for various areas during different intervals of time. Flow meters, installed on municipal supply lines prior to entering the processing facility, can be monitored periodically (start and finish of each shift) in order to determine how much water is allocated to production and sanitation. Weekly totals, of daily meter readings, can provide an accurate measurement of the number of gallons of water consumed per bird during processing.

Pressure Regulators

Water pressure can have a profound effect on water usage. Decreasing water pressure will automatically limit the volume of flow through nozzles and unrestricted orifices. A better understanding of this theory can be achieved from the following relationship between volume (gpm) and pressure (psi):

$$GPM_1 \ / \ GPM_2 = \sqrt{PSI_1} \ / \ \sqrt{PSI_2}$$

Table 1. Volume and Pressure Relationships

Pressure (psi)	Volume (gpm)
5	2.1
10	3.0
20	4.2
30	5.2
40	6.0
60	7.3
80	8.5
100	9.5
200	13.4
300	16.4
500	21.0

The relationship between volume and pressure is equally true for any orifice size. However, the larger the orifice size the greater the reduction in volume with respect to decreases in pressure. Pressure regulators will reduce the total volume of water utilized in all phases of production. Thus, maximizing water efficiency and minimizing waste.

Benefits of Pressure Regulator Installations

Reducing and maintaining a constant lower pressure, through pressure regulator installations, forces the processing facility to conform to the procedures and expectations of the water conservation program. Pressure regulators lessen the wasteful effects of unseen leaks, oversized nozzles, unrestricted goosenecks and water rails.

Case History

A poultry processing facility, in their efforts to stay abreast of future trends and advancements within the poultry industry, implemented a strict water conservation program. This poultry processing facility installed pressure regulators at two of their four municipal water supply lines. Thus, reducing their operating pressure from 60-80 psi to a constant 40 psi. The installation of pressure regulators on the municipal supply lines proved to be the single most successful procedure in their efforts to reduce water consumption. The installation, of the two pressure regulators, reduced water usage by three quarters of a gallon per bird immediately.

SUCCESS OF A WATER CONSERVATION PROGRAM

Implementing a water conservation program does not guarantee tremendous instantaneous results. Water reductions are acquired through trial and error, cooperation among all parties involved, and sheer persistence on behalf of the water conservationist. Superficial savings can be obtained rather quickly from a water reduction program. However, acquiring and maintaining maximum results can take several months, as noted in Table 2.

Table 2. Actual Monthly Water Reductions

Date	Average Monthly Usage (gallons per bird)	Monthly Low/High (gallons per bird)
07/91	5.62	5.51/5.78
08/91	5.58	5.49/5.71
09/91	5.58	5.54/5.68
10/91	5.52	5.40/5.85
11/91	5.49	5.23/5.51
12/91	5.19	5.08/5.24
01/92	5.15	5.00/5.19
02/92*	4.39	4.16/5.10
03/92	4.19	4.16/4.21
04/92	4.06	3.98/4.12
05/92	4.22	4.02/4.42
06/92	4.16	3.99/4.26

*Pressure regulators installed on two municipal water supply lines.

Note: Monthly figures reflect total water usage in the processing facility. Monthly lows and highs are based on one week intervals.

With an accurate measurement of the incoming water supply accompanied with a detailed synopsis of equipment and area water usage, a water conservationist can determine which areas are appropriate for water reductions. Some areas which are generally suitable for practical and immediate reductions are:

- Medium and high pressures hoses.
- Belt washers.
- Water rails and nozzles in equipment.
- Bird stunner overflow.
- Chiller operations (both carcass and giblet).
- Flow rates (>1gpm) from goosenecks at wash stations.
- Transportation of product via flotation.

A Water Conservation Program Monthly Synopsis

The following information is a summary of an actual evolving water conservation program. This program was initiated in August of 1991 and is currently still in effect. The initial pressure and volume, of water entering the processing facility during production, were approximately 70 psi and 1150 gpm, respectively. Ten months later, pressure has been reduced to 40 psi and an average incoming volume of 875 gpm during production.

August - September (1991): Introduction to department managers and USDA inspectors. Cognizant of plant plumbing systems. Water usage data collected throughout the facility. Eliminate overflow from bird stunners. Installation of flow regulators to; house inspection area, evisceration trim trays, liver and gizzard pumps.

October - November (1991): Installation of flow regulators to gizzard de-fatters, neck scalders, hock cutters and giblet chiller supply lines. Replace spray jets in all shackle washers, bird washers, lung vacuum machines, croppers, pac-man machines and all medium pressure hoses. Install spray jets in product transport tubes. Install quick connects in the giblet harvest area in order to gauge water pressure.

December (1991) - January (1992): Install flow regulators to all belt washers and wash stations. Restore float valves in ice machines. Replace spray jets in both the gizzard and vent machines. Installation of high pressure spray guns to all high pressure hoses.

February - March (1992): Installation of pressure regulators to municipal water supply lines. Hold first water conservation committee meeting. Replace water rail type belt washers in the further processing area with spray jets. Reduce water usage on the sanitation shift through improved cleaning methods.

April - June (1992): Construction and installation of new shackle washers in the further processing area. Restoration and adjustment of float valves in cooling condensers. Implementing squeegees, shovels and brooms during wash-down periods. Terminate water supply to evisceration equipment and carcass chillers during 30 minute breaks. Replace spray jets on the medium pressure hoses. Installation of foot-pedal valves at salvage stations. Incorporate Y-type strainers and water filters in supply lines at various locations throughout the processing facility. Place computer monitored water meters in every department of the processing facility.

The prior monthly journal is not a complete and detailed account of every aspect and procedure in a water reduction program. However, the journal does contain a rough outline of significant water reducing installations and processes.

Water Conservation Success

New installations and equipment modification are essential in the reduction of water utilized in the production of poultry products. However, do not underestimate the importance of employee awareness and USDA inspector participation. A water conservation program is not a device that can be installed and forgotten. It is a never ending process which requires constant monitoring and alterations. Water reductions are achieved through management commitment, employee education and participation, appropriate installations and routine inspections. Water conservation has to become an involuntary impulse for every individual within a processing facility in order to obtain complete success and to endure.

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IN-PLANT WASTE MINIMIZATION

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The guiding principle of in-plant waste minimization is, "If you don't put it into the waste stream, you don't have to pay to take it out". With waste treatment costs increasing there will be increasing economic pressure to reduce the amounts of organics added to the waste stream.

To reduce the waste load it is necessary to determine those times and operations that add excessive organics to the waste stream.

The benefits of waste load reduction include:

1. Reduction of waste loading will reduce the amount of DAF float material produced. Handling DAF float material is a major concern of poultry processors. Because the flocculation process removes organics from the waste stream, reduction of organics loading will reduce the amount of DAF float material produced, thereby reducing handling costs.

2. Flocculation chemical costs can be reduced. A Georgia poultry processor installed a small clarifier (detention time less than one minute) to receive evisceration wastewater. Even with this limited detention time, the clarifier was able to skim away enough fat so that DAF and belt press chemical flocculent costs were reduced by about 20 percent. As this material contained no flocculents the renderer could treat this material as poultry fat rather than DAF float material.

3. Land application of DAF float material costs can be reduced. Those processors who land apply DAF float material can reduce application costs by producing less float material. A processor who land applies DAF float material reports that it cost 6 cents per gallon to apply the material. A reduction of 3000 gallons per day of float material would reduce land application costs by approximately $50,000 per

year. By excluding this amount of material from the waste stream, an additional 350 tons of material would be available for rendering each year.

4. Reduction of biological treatment costs. Reduction of the waste load will reduce the cost of biological treatment by reducing aeration requirements, size of detention ponds and the need for land for spray irrigation.

CONDUCT A 24 HOUR WASTE LOADING STUDY

Studies of waste loading from processing plants have shown that waste loads can vary from 0.03 to 0.12 pounds of BOD_5 per bird. This variation represents 9,000 pounds of BOD_5 per 100,000 birds. If capital and operating costs to treat a pound of BOD_5 is five cents, the processor discharging 0.12 pounds per bird has an additional $450 per 100,000 birds for wastewater costs than the processor discharging 0.03 pounds of BOD_5 per bird. Total volatile solids (TVS) is a measure of the amount of organic matter in the waste stream. Volatile solids average about 90 percent of BOD_5. Using this ratio, a plant discharging 0.12 pounds of BOD_5 per bird is discharging about 4 tons more organic matter per 100,000 birds than is the plant discharging 0.03 pounds of BOD_5 per bird.

To conduct a 24 hour waste loading study three things are required:

1. A flow measuring structure such as a Parshall flume or a "V" notch weir.

2. A flow recorder to measure and record flow through the flow measuring structure.

3. An automatic wastewater sampler.

Using these devices, flow can be determined and wastewater samples based on flow volumes can be collected.

To determine per bird waste loading, equipment is available that will collect wastewater samples based on a preset volume flowing through the flow measuring structure. For example, the flow measuring device signals the sampler to collect a wastewater sample after every 10,000 gallons of flow. After 24 hours of sampling, this flow composite sample is analyzed for each desired contaminant and the loading per bird calculated based on the number of birds slaughtered that day.

Example problem:
Head Slaughtered = 200,000
Gallons discharged during 24 hours = 1,250,000
BOD = 2000 mg/L

1. Determine the number of pounds of BOD_5 discharged using the following equation:

$$\frac{\text{Gallons of flow}}{1{,}000{,}000} \times 8.34^a \times \text{concentration of contaminants in mg/L} = \text{Pounds}$$

[a]gallon of water weighs 8.34 pounds

$$\frac{1{,}250{,}000}{1{,}000{,}000} \times 8.34 \times 2000 \text{ mg/L } BOD_5 = 20{,}850 \text{ pounds of } BOD_5$$

2. Divide pounds of BOD_5 by number of head slaughtered.

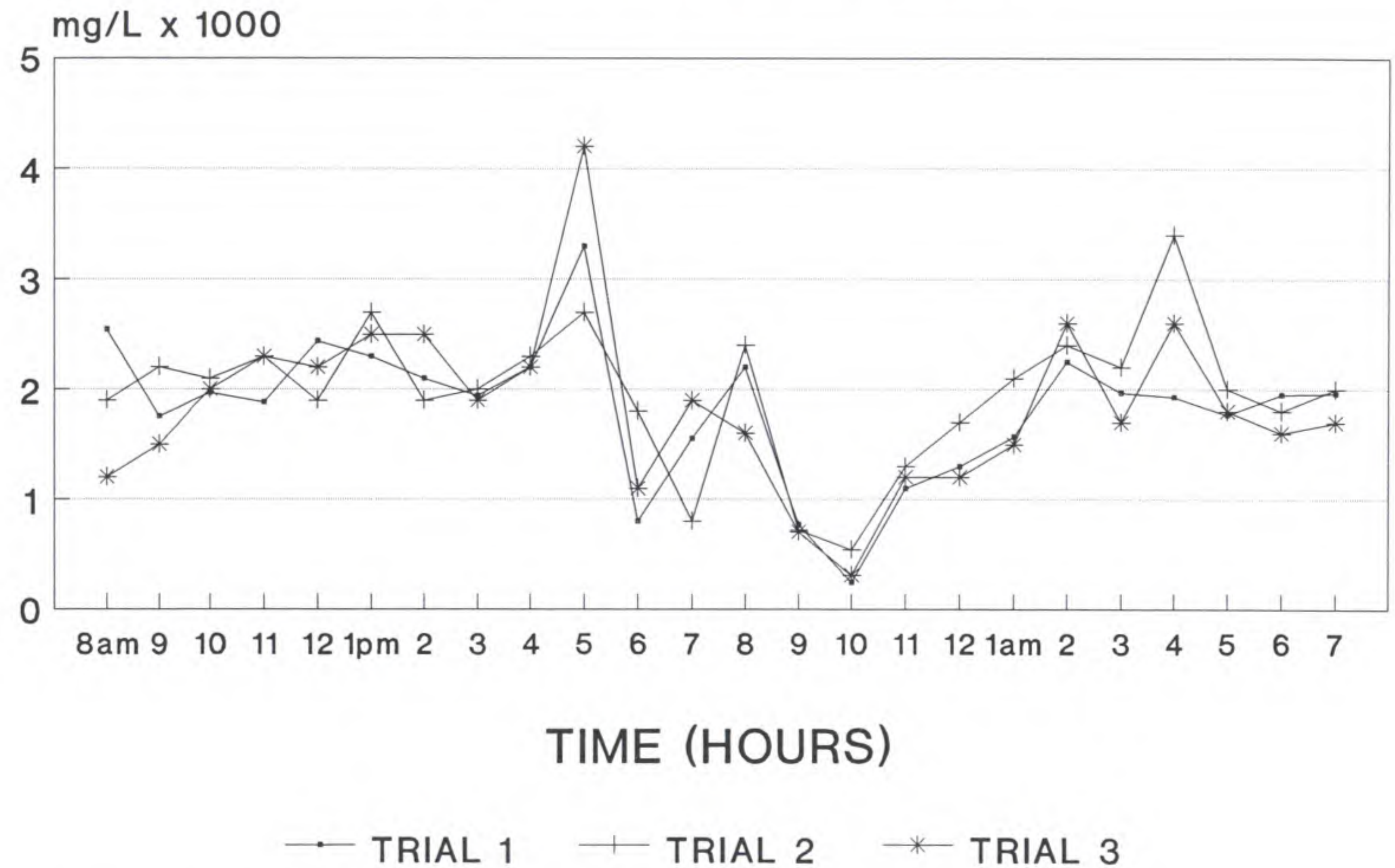
$$\frac{20{,}850 \text{ pounds } BOD_5}{200{,}000 \text{ head}} = 0.104 \text{ pounds } BOD_5 \text{ per bird}$$

This equation is appropriate for all contaminants where analytical results are reported in mg/L or ppm. In water, mg/L and ppm is the same unit.

A more detailed study can be conducted by programming the sampler to take samples on a timed interval and measuring the flow during that time interval. One method is to program the sampler to draw samples 6 times per hour at 10 minute intervals and to collect the samples into 24 individual hourly samples based on 6 samples per hour. Hourly flow volumes are recorded so that hourly discharge of contaminants can be calculated. Based on this hourly profile, those time periods where excessive contaminants are being added to the waste stream can be determined. Figures 1 and 2 are examples of a 24 hour profile for total volatile solids (TVS) and total Kjeldahl Nitrogen (TKN). It is easy to see that the most concentrated wastewater is being discharged during initial sanitation (4:00-6:00PM). Much of this high strength waste is in the nitrogenous form. If nitrogen loading is a problem, then initial sanitation is probably where minimization is effective. More attention should be paid to cleaning the killroom and to dry clean up of manure of the live haul and hanging areas.

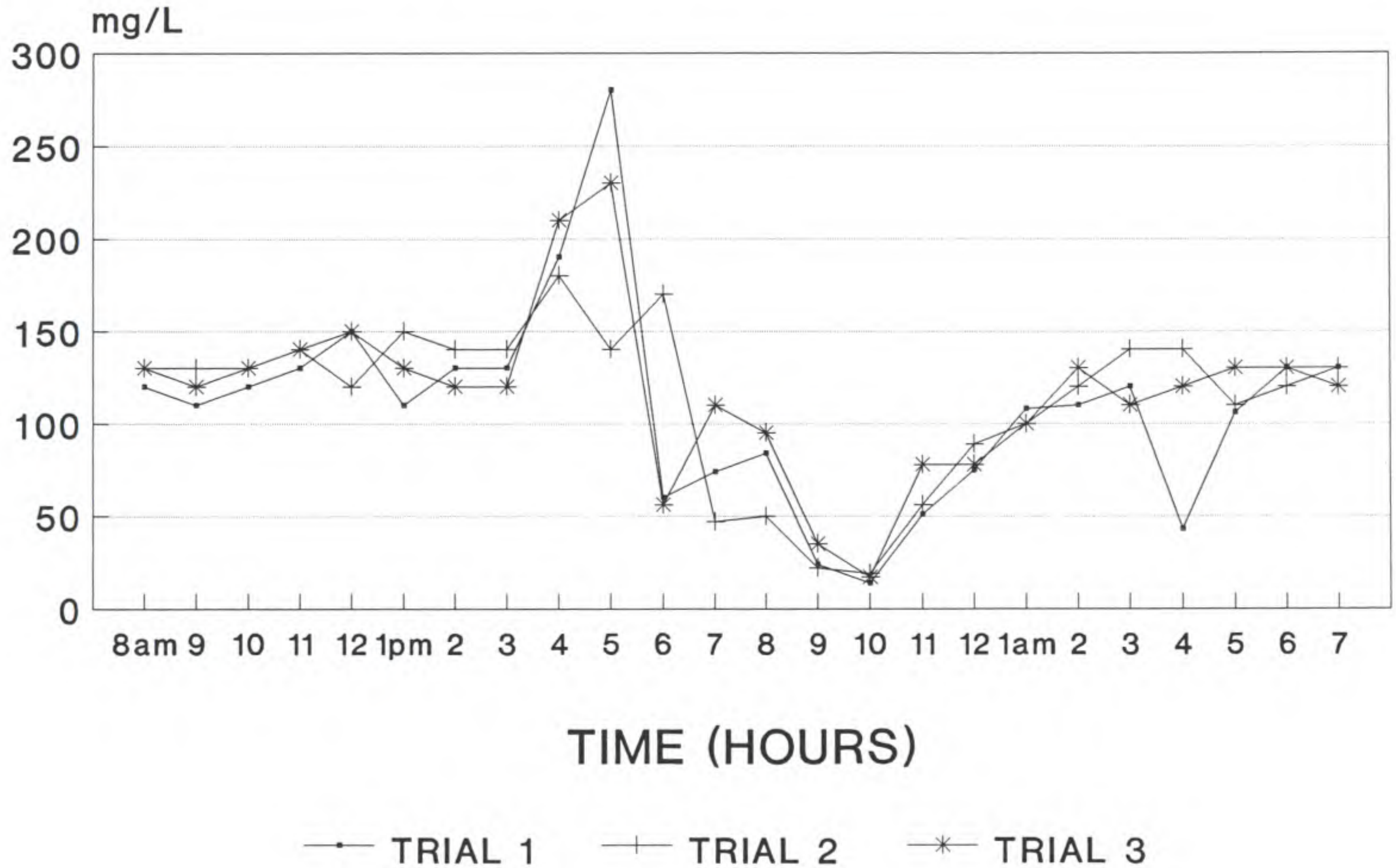
This type of profiling is beneficial in reducing waste loads by studying the characteristics of the waste stream.

Figure 1. Wastewater from a broiler processing plant



TVS-TOTAL VOLATILE SOLIDS

Figure 2. Wastewater from a broiler processing plant



TKN-TOTAL KJELDHAL NITROGEN

WATER CONSERVATION IN A HEAVY FOWL PLANT

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Water conservation at Tip-Top is especially cost effective because we pay high water and sewer rates. The cost of water and sewer in Cobb County, Georgia, is $4.53 per 1000 gallons. Each gallon of water wasted costs Tip-Top almost a half cent. The cost of water and sewer service has also increased rapidly. In 1986, that cost was $2.35 per 1000 gallons. Over the past five to six years the cost has doubled and there seems to be no cost increase relief in sight. We are forced to become water efficient just to hold our own.

About three years ago, we saw an opportunity to control our processing costs by being water efficient. In 1989, our water use averaged 10.5 gallons per bird. In 1991, using our water conservation program, we averaged 6.46 gallons per bird.

Our 1992 water use has averaged 5.60 gallons per bird. This water use is weekly for everything over a seven day period. Table 1 shows the cost savings of reducing water by four gallons per bird.

Table 1. Cost Savings Due to Water Conservation

10.5 gallons per bird		6.5 gallons per bird
95,290,000 gallons		58,625,000 gallons
	@$4.53 per 1000 gallons	
Annual Cost		Annual Cost
$431,660		$265,570
	Cost Savings	
	$166,090	

Tip-Top is a small plant compared to many of today's processing plants, yet we were able to significantly reduce our processing costs by being water efficient. Through further water conservation efforts, I believe that we can process with 5.0 gallons per bird. Reduction of an additional 1.5 gallons per bird will reduce our processing costs an additional $66,000 per year.

HOW WE DID IT

The first and most important thing was to determine that water conservation was cost effective for our time. An opportunity to reduce our processing costs by $225,000 per year, could justify some of my time. To make sure that I stayed committed, I set a goal with my boss to process with 5.0-5.5 gallons per bird and explained the benefits to him. The $225,000 possible cost reduction made sure that I stayed interested. Each month, I go over our water use with him and have to justify each day's use. To include my supervisors in my commitment, I sent written memos to each one to explain the cost reduction benefits of water conservation. We then had meetings to determine ways to reduce water use. Some of the methods we found to be successful are:

1. **Read incoming water meters at the end of each shift.**
   The processing and sanitation shift each have water allocation based on what we know is efficient. Supervisors are expected not to exceed their allocation. We have not installed pressure regulators because, as our name says, we sit on the top of a hill. Our problem can be low water pressure rather than excessive water pressure.

2. **Install water meters on individual pieces of equipment.**
   We installed water meters on the bird washers, the scalder, the chiller and the high pressure sanitation systems. We read them at the end of each shift to determine whether nozzles are wearing or if there are leaks. We also use the meters to determine the effect of changes. By reading the water meters for the sanitation shift, we can monitor if workers are leaving the bird washers and the chiller and scalder on to flush the floor drains.

3. **Segregate the line with valves.**
   We installed valves into our water supply lines so that short sections of the lines could be turned on or off. In this way, fifty to 100 feet of line would not be using water with no chickens at stations.

4. **Just in time water use.**
   As we worked together in ways of saving water, we noticed that sometimes equipment was turned on 30-45 minutes before the birds arrived and continued to run during breaks and lunch. By training workers to turn on water only when the birds were at a station and by segregating the lines into small sections so that small portions of the line can turned on at a time, we use water only when birds are present at a station.

5. **Flow restrictions.**
To control the flow of goosenecks, I used the following method. When we upgraded the plant, I had goosenecks installed on the water rail by welding the coupling onto the water rail. Instead of drilling a hole in the water rail the diameter of the gooseneck, I drilled only 1/8 inch hole into the water rail. This restricts the flow to the output of a 1/8 inch hole. To further restrict the gooseneck that would deliver the amount of water needed at that station, I placed a plastic plug with a drilled hole in the gooseneck. The hole size will deliver the volume of water required at that station. For example, the draw hands in a fowl plant need more water because of the egg yolks in the viscera. The hole in the plastic plug of their gooseneck is slightly larger to deliver a little more water. When we started on water conservation we had a lot of holes drilled in pipes to wash surfaces such as drip pans. We have replaced these with nozzles which use much less water to wash the same area.

6. **Constant attention.**
Like many things plant managers do, there must be constant attention to water conservation. When I go around the plant, I always look for leaks and water being wasted.

IRRIGATION AS A TREATMENT FOR POULTRY PROCESSING WASTEWATER

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A spray irrigation soil-plant filter is a vegetated land area on which waste water is uniformly applied with spray irrigation equipment. The waste water is partially renovated by filtration and microbiological action in the first several inches of soil depth. Renovation by soil adsorption and plant uptake occurs in the first several feet of soil depth.

Soil-plant filter management must achieve effective renovation of the applied waste water. Unfortunately, much of what occurs is under the surface of the soil. A system is judged as satisfactory as long as the water disappears. This judgement may be faulty and an operator must understand what occurs in the soil and how to keep the soil-plant filter effective. Changing waste production processes without considering the effect on the soil-plant filter or operating the soil-plant filter without regard to the condition of the soil or the crop can cause a failure of the waste water renovation system. This paper provides insight into the requirements for waste water renovation and the management needed to keep the soil-plant filter functioning.

WASTEWATER CONSIDERATIONS

The quality and quantity of waste water have an impact on the effectiveness of the soil-plant filter. The greater the concentration of waste water contaminants per unit of filter area, the less effective the treatment process. The greater the waste water quantity exceeds plant water needs, the greater the probability of crop failure followed by failure of the treatment process. Normally, a waste water discharge permit or operations manual outlines the allowable levels of waste water contaminants, the required frequency of analysis and the maximum quantities of waste water that can be applied to the soil-plant filter.

Chemical Characteristics

Poultry processing waste water usually does not contain chemical contaminants at concentrations that would be toxic to the soil-plant filter. However, long term irrigation mismanagement can result in adverse changes in soil properties or productivity which will allow increased movement of contaminants to the groundwater.

High concentration of total dissolved salts (TDS) can cause problems with some crops. Abnormally high concentrations of TDS can come from process brine discharges or from water softening equipment. Salinity is usually not a problem in a soil-plant filter where normal rainfall is sufficient to leach the salts out of the plant root zone. However, if high TDS concentrations are applied to a limited area the leaching of soluble salts to groundwater may be a concern.

The pH of waste water will usually be of little significance in the soil-plant filter. Because waste water is not buffered and most soils are buffered, the soil resists changes in pH and may be unchanged by the irrigated waste water. Waste water with extreme pH values (less than 4.5 or greater than 9.0) could be expected to contain other constituents that may adversely affect soils or plants. Soil pH changes in response to changes in hydrogen and hydroxyl concentrations in the soil solution as a result of organic decay and other processes associated with the renovation of contaminants in the waste water.

Waste waters contain varying quantities of plant nutrients including nitrogen, phosphorous, potassium, calcium, magnesium, boron, copper, iron, manganese, and zinc. The function of the soil-plant filter is the removal of these nutrients by growing plants. Different crops require different levels of nutrients. Also, plants are capable of only limited uptake of each of these nutrients. The needed nutrient recipe rarely coincides with the available nutrients in the waste stream. Waste water applications are usually based on the single nutrient (most often nitrogen or phosphorous) with the greatest pollution potential.

Physical Characteristics

The most important physical characteristic of waste water is the total solids content. Excessive suspended solids can clog spray nozzles and soils. High concentrations of dissolved solids can precipitate in the soil and cause changes in the soil texture or chemistry.

Waste water odor is a problem that can develop because of high organic solids content and low dissolved oxygen. Odor can be released during the spray or from excessive solids accumulation on the soil surface. Waste water color and temperature do not normally affect the function of the soil-plant filter.

Biological Characteristics

Poultry processing waste waters can contain high levels of bacteria. Normally these bacteria are not pathogenic to humans and are unable to survive in the soil-plant filter. Salmonella bacteria from poultry product processing can become air-borne in irrigation spray drift. Potential problems can be avoided by segregation and disinfection of the source stream before mixing with the total waste water system. Spray irrigation soil-plant filters must have sufficient perimeter land area buffer to contain expected spray drift.

SOIL CONSIDERATIONS

Soil properties highly influence the renovation of waste water applied to a soil-plant filter. Agricultural soils are dynamic and must be maintained in an aerated condition to produce optimum plant growth and to obtain the best treatment of organic, inorganic and possible pathogenic organisms in the waste water.

Physical Characteristics

The important physical properties of soils are texture and structure. These largely control the rate of water entrance into the soil surface (infiltration) and the rate of water movement through the soil (percolation) and the air-water storage space within the soil.

Coarse textured soils (sands, loamy sands and sandy loams) have large void spaces between soil particles and rapidly accept large quantities of water. However, coarse soils also drain rapidly, which reduces the water residence time and subsequently the treatment time in the the plant root zone.

Fine textured soils (clay loams, silty clay loams and clays) have smaller soil particles and consequently more but smaller void spaces than coarse textured soils. The small void spaces impair free water movement resulting in slow infiltration and percolation. These soils easily become saturated and produce runoff or ponding. The slow percolation rate may allow long periods of insufficient soil aeration causing reduced plant stands. However, the slow percolation allows a long period of soil and plant contact for waste water renovation.

Soil structure is the arrangement of soil particles in combination with organic matter, plant roots, air spaces, insect tunnels, etc. and modifies the influence of soil texture. Excessive wetness, poor plant stands and vehicular traffic compact the soil. As soil compaction increases the water infiltration and percolation capacity is decreased.

The first few inches of soil depth act as a physical filter for waste water suspended solids. The void space between soil particles can become clogged with waste solids which will seriously reduce the infiltration rate. The resulting surface ponding reduces soil aeration and eventually kills some of the plants. The loss of plants allows further loss of soil structure and the situation continues to deteriorate as long as water is applied. Soil-plant filters must be regularly "rested" to allow microbes sufficient time to break down the trapped organic solids. Severe problems require drying, tillage and the establishment of a new crop.

Soil structure breaks down when sodium concentrations are high compared with those of calcium and magnesium. Over a period of time the infiltration and percolation capacity of the soil declines to seriously restrict water movement. Fine textured soils are affected sooner and more drastically than coarse textured soils. Soil sodium loading must be balanced by applying magnesium and calcium as lime.

Soil structure is improved by growing crops, pH maintenance, the addition of organic matter, and proper cultivation timing and methods. Annual soil analysis followed by maintenance or remedial activities is necessary to keep the soil-plant filter at optimum operating capacity.

Chemical and Biological Characteristics

Waste water renovation occurs in the soil through biological and chemical processes as well as through physical filtering. Nutrients are removed from the waste water by growing plants and microbial growth. The effectiveness of waste water renovation is dependent on the length of time the water stays in contact with the plant roots and microbes. For example, a coarse textured soil may accept a high waste water application rate but, the percolation can be so rapid that renovation is minimal. Waste water application must be balanced with the renovation capacity of the soil-plant filter.

High loadings of BOD and suspended organic solids can cause excessive soil surface clogging with microbial slime. The clogging will increase the occurrence of surface ponding and vegetation decay resulting in odor production and eventually total failure of the soil-plant filter.

Nitrogen in waste water as ammonium nitrogen and organic nitrogen is nitrified to nitrate in the soil. Nitrate is soluble and subject to leaching if not taken up by actively growing plant roots. Excessive soil nitrate levels can cause increased nitrate concentrations in the groundwater. In flooded soils deficient in oxygen the nitrate in the root zone is subject to denitrification which converts nitrate to nitrogen gas that may be released to the atmosphere.

Phosphorous in waste water is retained in soils through precipitation reactions and adsorption which are controlled by the cation exchange capacity and the amount of surface area and chemical nature of the soil particles. Over the long term, the accumulation of phosphorous can reach a limit which will affect the ability of the soil to provide other micronutrients necessary for plant growth and allow phosphorous movement to groundwater. However, deep soils with medium textures have a large phosphorous retention capacity.

Soils have a fixed capacity for the capture of salts in solution including Ca^{++}, Mg^{++}, NH_4^+, K^+, H^+ and other cations. Without cation removal by plants and microbes, the cation exchange capacity may eventually become saturated after which the soil contributes little toward the renovation of these constituents. Soluble anions such as Cl^-, $SO_4^=$, PO_4^{-3}, HCO_3^-, $CO_3^=$ and NO_3^- are not removed from the effluent by the soil and contribute to the mineralization of the groundwater. The hydraulic character and ion exchange capacity of the soil will only influence the time to reach a state of equilibrium and not the eventual water quality. After equilibrium is reached, the percolate water from the soil will be of similar ionic quality as that of the applied waste water with the only removal mechanisms being the plants and microbes.

The release of captured nutrients to the soil solution and to plants is strongly influenced by soil pH. For example, the availability of major plant nutrients decreases rapidly below pH 6.0 and above pH 8.0. Fortunately, elements such as aluminum, which can be toxic to plants or other elements that can be cumulative and toxic in the food chain have limited availability at pH near 7.0. Soils should be periodically tested for pH followed by corrective measures to assure optimum crop nutrient uptake.

PLANT CONSIDERATIONS

Soil-plant filter vegetation is an important part of the filter system. The soil needs a crop cover for as much time as possible for protection against runoff and erosion, maintenance of soil structure, and uptake of the nutrients. Plants must be managed for maximum growth in order to maximize the nutrient uptake. Important factors include crop variety selection, disease and pest control, water management and other related cultural practices. The failure to grow a good crop means a failure of the waste water renovation system.

Plant-Nutrient Relationships

Nutrients must be managed to provide the balance necessary for optimum crop growth. Where waste water nutrient content is less than required for optimum plant growth, supplemental nutrient additions through fertilizer may be necessary. Soil analysis for plant nutrient content should be monitored annually. Nutrient content should become a regular part of the waste water analysis.

Estimated crop nutrient uptake values can be used for planning. Care must be exercised when using published data because climatic, soil productivity and other differences between regions of the country have significant effect on the quality of growth and quantity of yield of most crops. Measurement of crop yield and nutrient content is recommended to provide knowledge of the effective nutrient removal because crop quality and yield vary from year to year.

Nutrients must be removed from the soil-plant filter as a harvested crop. If the crop is mowed or the grain removed with the cuttings or stover left on the field, a major portion of the nutrients taken up by the plant can remain on the soil surface. As the plant residue decays these nutrients are released back to the soil. Over the long term without crop removal the soil-plant filter becomes only a temporary storage device for some of these nutrients. As the nutrient concentrations in the soil increase so will the release of soluble nutrients to the ground and surface water.

The production of agricultural crops (corn, soybeans, etc.) must follow a crop rotation schedule that includes winter cover crops. Because waste water application should not occur without a growing crop on the field, the use of cover crops increases the annual number of days that application can occur. Cover crops also help capture nutrients not used by the previous crop.

Rotations can be established using a combination of small grains and corn silage interseeded in a perennial grass sod. This combination provides an optimum length of soil cover and maximizes the opportunity for nutrient uptake and harvest. However, a market for the silage must exist. Grass crops can be grazed by cattle but, the nutrient loading must account for the pass through of crop nutrients in the cattle manure.

Harvest and disposal of the crop can present a management problem. The disposal of produced grain is not difficult but, there may be little opportunity to develop a market for the stover. Hay crops provide good nutrient removal but, require periods of no water application and good drying weather to allow harvest. A combination of fescue and bermudagrass provides good nutrient removal if regularly mowed. But, the grass clippings must be spread on other land for disposal or utilized in some manner consistent with environmental quality goals. Feeding forages to livestock is a means of disposal but, the forage must be monitored for nitrate because high concentrations of nitrate in feed can be toxic to animals.

Plant-Water Relationships

Good plant growth requires waste water application schedules that allow for soil drying and aeration Some plant species are more water tolerant than others. Crop selection can be based on water tolerance or on agronomic performance. Water tolerant crops should be planted where waste water storage facilities are minimal, waste water chemical concentrations are low and waste water application rates are high.

Agronomic crops grown for economic return have specific water quantity and timing requirements which may not coincide with the waste water production schedule. Crop water use, called evapotranspiration or ET, is a combination of evaporation of water from wet soil and plant surfaces and transpiration of water vapor from the plant during periods of respiration. ET is dependent on the soil moisture content, air temperature, relative humidity, wind speed, solar radiation, crop age or maturity stage, crop species and crop variety.

ET cannot be measured directly for an entire field but, can be computed using mathematical models. There are many models of varying accuracy with each depending on a series of different atmospheric or meteorological measurements. Maintenance of soil moisture can be monitored with tensiometers and other moisture measuring devices. Control systems based on soil moisture are available that can direct the application of waste water to those fields needing water. Irrigation scheduled to meet evapotranspiration needs will minimize the possibility of water and nutrient movement to groundwater.

MANAGEMENT CONSIDERATIONS

Well designed soil-plant filters fail because of lax management. The company must have a commitment from the top executive to the bottom floor sweeper to ensure that the irrigation system for waste management remains functional. A system can fail for any one of the following reasons:

* Management doesn't understand the needs of the soil plant system and therefore doesn't provide the incentive necessary to make things work.

* The lowest level employee is the waste water system operator.

* Education is not provided for the operating employee to allow optimum operation of the system.

* Water conservation efforts are not maintained or reinforced in the processing plant by employee training and middle management directives.

* Processing operations are changed without consideration of the soil plant filter.

* Adequate and timely resources are not provided for maintenance and repair of the system.

* Records of system use are not maintained.

* Continuity in knowledge of the system is not maintained when employees change jobs or positions.

* The condition of the soil plant filter is not reviewed regularly with an agronomist, soil scientist, or engineer knowledgeable of soil plant filters.

* An operations and maintenance manual is not on file where it can be found and referenced.

SUMMARY

The relationships between soils, crops, waste water quality and quantity and other environmental factors are very complex. It is recommended that a soil-plant filter manager seek the assistance of consultants knowledgeable of local conditions for system design and operation. The system will function optimally only if management provides the necessary resources.

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HATCHERY WASTE COMPOSTING

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The Delmarva broiler industry produced 537 million birds in 1991 in an area defined by the limits of the Chesapeake Bay and Atlantic Ocean to the east and west and by Dover, Delaware to the north and Exmore, Virginia to the south. Eight integrated companies operate in this region with approximately 6,000 active production houses. Broilers rank first in gross agricultural income for both Delaware and Maryland. Because of the high bird density per square mile, there are many opportunities for recycling by-products from broiler production and processing.

Estimates of the annual poultry by-product production on Delmarva are as follows:

Poultry Litter	671,250 Tons
Normal Mortality	25,776 Tons
Hatchery	12,975 Tons
Dissolved Air Flotation Skimmings .	16,110,000 Gallons

This paper will present research on composting hatchery by-products in Maryland.

Composting of organic waste has been used for centuries. Its use in sewage sludge stabilization increased in the 1970's and 80's as alternatives to landfill, ocean dumping and incineration disposal. As municipalities face disposal problems for their organic waste, so do food processors.

REVIEW OF COMPOST REQUIREMENTS

In order to generate a healthy compost process, five key elements are needed. They are as follows:

1. Proper nutrient mix - Carbon: Nitrogen ratio (C:N) very important for the bacteria to process the organic materials into compost. The C:N should be in the range of 20:1 to 35:1.

2. Moisture -- Moisture is very important for the microbial activity to process the organic material into compost. A range of 40 to 60 percent is desirable. Too dry or wet, the process will not operate effectively.

3. Oxygen -- The composting process is an aerobic process. Oxygen levels should not be less than 5 percent. If less than 5 percent, odor may become a problem. Proper aeration of the compost mix is very important. A perosity of approximately 30 percent should be planned for. (An O_2 instrument was not available for the work to be reported herein).

4. Temperature -- If the C:N, moisture and oxygen are proper, thermophilic aerobic bacteria will cause the mass to heat and generate carbon dioxide and water vapor as by-products of the composting process.

5. pH Control -- A proper C:N should keep pH in check. However, if for some unknown reason pH approaches 8, ammonia and other odors may become a problem. Adjust the pH to a lower reading. One product that has been used successfully was granular ferrous sulfate (Carr et al., 1990). Sweeten (1988) suggest a pH in the range of 6.5 to 7.2 initially as the best for composting.

COMPOSTING TECHNIQUE

The hatchery waste was composted mechanically in a 6.5' x 3' x 40' channel using an electric powered hydraulic driven compost turning machine. The channel was covered with a 15' x 50' green house to shed rainfall. Materials were pre mixed and batch loaded into the compost channel. Machine turning for aeration occurred daily at the beginning and less frequently as the end of a cycle approached. This cycle was approximately 35 days in length.

DATA COLLECTION

A compost mix was turned almost daily for the first 4-weeks. Temperature data were collected frequently at 6, 12, 18, 24, 30 and 36 inch depths in the vertical profile. Temperatures were measured before turning using long stem thermometers with a dial sensor head. The compost surface was the reference plane. Temperatures were measured at two locations in the composting channel (south end and north end). The channel's long axis was in a north/south orientation.

Bulk densities (pounds/cubic feet) were collected at the locations described above. A 5-gallon bucket, 60-pound spring loaded hanging scale and a tripod were used to determine the bulk density. Nutrient and bacterial data were determined by independent labs and the University of Maryland Soils Lab.

HATCHERY BY-PRODUCTS

Hatchery by-products in the Delmarva Region are collected and the supernates extracted by a centrifuging technique. The by-product remaining goes to a local landfill for disposal. As an alternative to landfilling, composting the by-product may be a viable alternative. For purposes of this discussion the hatchery by-products were composted mechanically as described. The centrifuged hatchery by-product was delivered to the compost site by dumptruck. The recipe for composting was as follows:

1 part ---------- hatchery by-product
1 part ---------- wood shavings
20:1 ------------ C:N (Minimum desired)

The ingredients were pre-mixed by use of front end loaders (in the rain) and placed in the compost channel.

HATCHERY COMPOST RESULTS

Table 1 shows the compost composition (Carr, 1991) before and after the process. Figure 1 is a plot of the temperatures achieved.

Table 1. Hatchery Compost Composition (wet basis - WB).						
Item	TKN %	Moisture %	Total Solids %	Carbon % (DB)*	pH	Bulk density lbs/ft^3
Wood shavings	0.01	18.62	81.38	55.29	5.5	8.36
Centri. hatchery waste	1.61	24.51	75.49	21.96	8.6	48.00
35 day-compost	1.19	25.01	75.99	31.34	8.4	22.10

*Dry Basis

DISCUSSION

The hatchery by-products and wood shavings were pre-mixed by use of front end loaders before placement in the composting channel. Moisture was not adjusted during pre-mixing because it was raining which added sufficient moisture. If it had not been raining, 417 gallons of water would have been required to achieve 58% moisture in two wet tons of the initial compost mix. This would have increased the gross weight from 2 wet tons to 3.7 tons. Nitrate concentrations for the items in Table 1 were 3,886 and 9 ppm, respectively. These data show that nitrate nitrogen was greatly reduced in the composting process. Most of this was probably converted back to stable organic nitrogen. The high pH hatchery waste was an indicator that conditions were suitable for ammonia volitization to the atmosphere but no real problems were detected. The C:N of the initial compost mix was 38:1 and 20.1:1 for the finished compost. With the high C:N ratio of the initial mix, additional centrifuged hatchery waste could have been added to the composting process at 10-14 days. Brodie et al. (1991) describes this process for crab waste using a 1:1 recipe similar to the hatchery recipe. This reduces the amount of wood products used for bulking and carbon.

The temperature profile (Figure 1) is typical of channel composting. In the turning process all the channel profile was subject to higher temperatures. Temperatures at the 24 and 30 inch depth were influenced by the heat transfer to the core of the earth. Insulation under the concrete pad would have reduced this heat transfer. Suitable insulation should be considered when constructing an in channel composting system. Salmonella tests were conducted of the finish compost and no positive indicators were found.

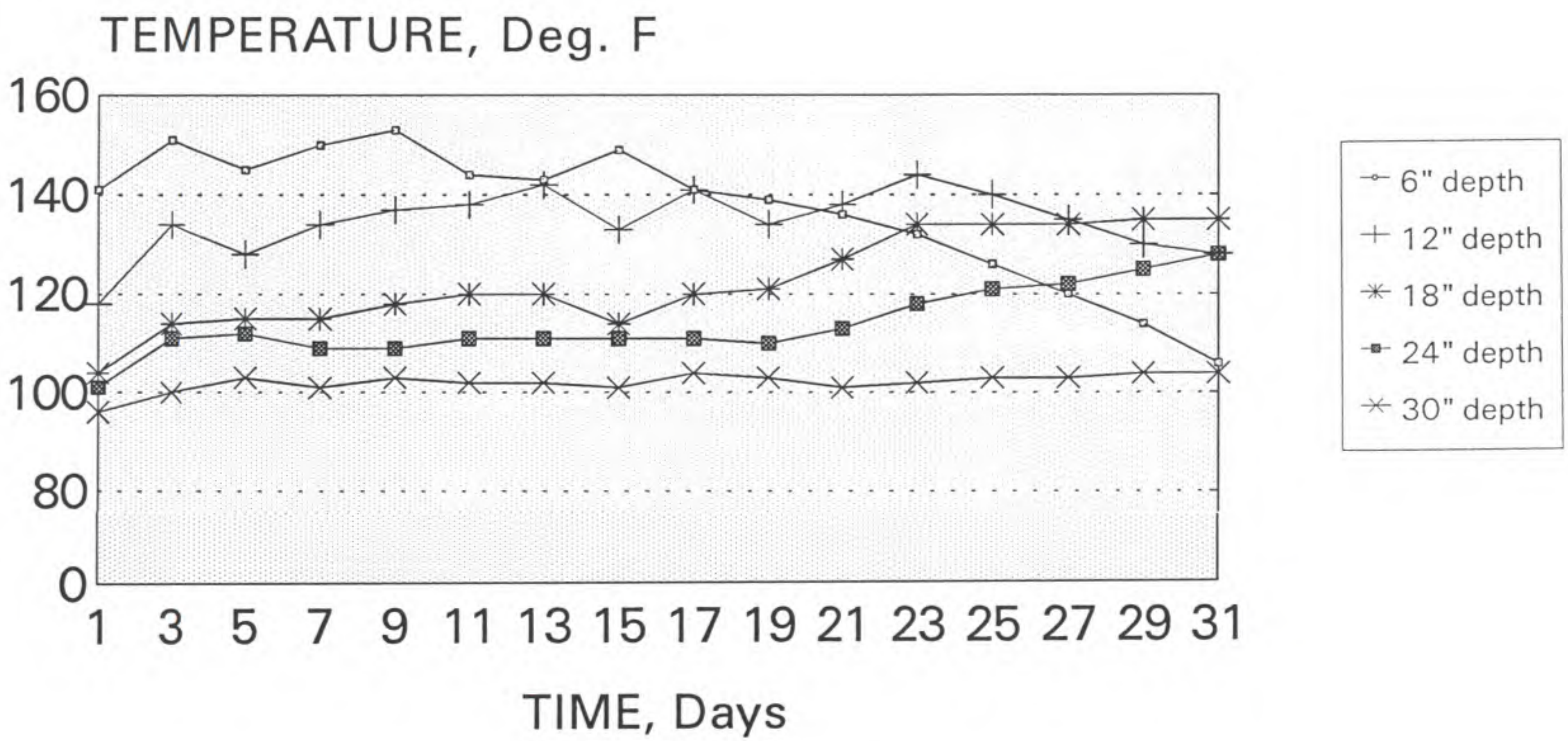

FIGURE 1. Temperature profile of hatchery waste compost.

Co-composting hatchery by-products with other organic materials should be considered. The nitrogen (TKN) in Table 1 could be increased if broiler litter had been part of the mix. The hatchery compost produced had a calcium content of approximately 26 percent. At the present time an "organic farmer" in our area is making compost from yard leaves, broiler litter, horse manure and hatchery by-products. There are many opportunities to recycle products going to landfills on Delmarva. These opportunities are not limited by region.

CONCLUSIONS

1. Hatchery waste can be composted successfully.
2. The composted product has a high calcium content (approx. 26 percent) which may make it a suitable soil buffer.
3. No positive indicators were found for Salmonella at the conclusion of a test.
4. There are opportunities for co-composting hatchery waste with other organic materials.

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MARKETING POULTRY BY-PRODUCTS

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As the owner of two poultry farms, I always had a belief that something useful could be made from the waste leaving the farm. I believed that there should be a way to process and market some form of poultry litter waste, perhaps even at a profit. Marketing processed litter products would reduce the waste by-products leaving the farm, benefiting the farmer and potentially some consumers.

This vision of taking a waste product and turning it into a useful product was shared by several Auburn University and Tennessee Valley Authority scientists. Working together, we felt we might be able to develop a way to process waste products and turn them into marketable products.

Consumers would likely be interested in one or more processed litter products. Using organic products and growing plants organically is quite popular today. There are no signs this trend is changing, only becoming more popular. Nearly all Americans are interested in protecting the environment and reducing the volume of landfill waste is one way to help maintain a high quality environment. If we could reduce the amount of litter that must be spread on crop and pasture land, non-point source pollution problems might be avoided. It seemed that at least one market was ready for additional organic lawn and garden products, perhaps more. Processed poultry waste products fit right in to the attitudes and needs of 1990's consumers.

THE FIRST PRODUCT

Our first priority was to develop a production facility to process and package products. A small composting, screening, blending, and bagging plant was built about four years ago. The first product we considered was a quality organic specialty fertilizer. The litter had some nutritive value for plants. Processing the litter and defining the guaranteed analysis for the fertilizer was the first step. We composted litter and developed an organic fertilizer.

One of our first mistakes was not totally removing the odor from the product. The odor was not a problem for the consumer so much as for the distributor and the retailer who found it offensive when stored inside a warehouse or store. A full year and many dollars were spent addressing the odor problem. After overcoming the odor problem, we were able once again to concentrate on marketing.

MORE PRODUCTS FOR THE MARKET

As we began to develop our markets, it became evident we needed to offer several products in order to interest distributors and also to help in being able to deliver full truck loads. It was much easier to deliver a truck load of five different products than it was of one product. Clearly, we needed to develop a diverse product line with more than one product for each market. Trying to run a litter based production facility with only one product to market would be very difficult.

In addition to the organic fertilizer, we added several products to the line. One product was a soil amendment which contained 100% composted litter. This was positioned as an organic material, similar to peat moss or other composted manures, that could be worked into a landscape bed prior to planting. We hoped that both the consumer market and the landscape contractor market would use this product.

A second potential product was a soilless potting mix, which contained 50% composted litter and 50% composted pine bark. This product should have more appeal in the consumer market.

We also considered repackaging brick nuggets and other non-litter products to help us fill a truck load to ship all the products more profitably.

OTHER MARKETS FOR THE PRODUCTS

We began looking at the consumer market first, not going through any commercial uses of the composted litter products.

Garden centers were one of the first retailers of the organic fertilizer. Many consumers buy plants and related products at the garden center. This seemed to be the most likely place to start. But, as we developed a number of products in addition to the organic fertilizer, we found more markets could use the products.

A second market that come to us was the landscape contractors. These people wanted to purchase the material in bulk for large-scale landscape site preparation. Evidently, they had used the product on a smaller scale, liked it, and wanted to purchase it in volume. This market had need of the product at slightly different times. It lengthened our market and enabled us to keep the plant busy a little longer in the year. On-time delivery and consistent quality are two factors of vital importance to large volume, bulk customers. Landscape contractors and retail lawn and garden centers offer potential for packaged as well as bulk products. Bulk quantities may very well offer more potential than ever realized before.

Mass marketers, such as the Wal-marts, K-marts, and supermarkets, also sell potting mixes and fertilizers. With the odor problem resolved, organic products would fit in well with their garden or floral departments. Although a more challenging market than the garden centers, this could have a potentially larger payoff. More people visit a mass marketer than a garden center, exposing more people to the products. The marketing strategy for this market would have to be different. There would not be anyone there in the store to assist with product selection. Packaging considerations may be different. Working with the buyers for these large chains is very different from working with individual garden center managers or even regional chains.

In looking at alternative markets for the processed products, we found that the market for organic and organic-based products will probably continue to grow. The more we learn, the easier the marketing becomes. But, along with the increase in need of organic products comes increased competition. We will need to be sharper and faster with our marketing plans to remain competitive in the long term.

Manufacturers should remain flexible in order to process custom blended products to meet certain requirements or specifications for individual users. Manufacturers must also be willing to explore new possibilities for products as new by-product materials become available.

The investment and commitment to processing and marketing these products is greater than most people realize. In order to develop a viable processing, packaging, and marketing organization, a big time and financial commitment needs to be made. The amount of paperwork and regulations will become more of a burden in the future. Meeting requirements with the State Departments of Agriculture is a monumental task to get a fertilizer registered. Depending on the market territory, registration will be required in many states. Each state will have slightly different regulations regarding analysis and labeling. It is not likely that this will become an easier process.

Profits will be realized only by the dedicated innovators with sound business management ability and most of all, the ability to market new products.

CONSUMER CONCERNS WITH LITTER PRODUCTS: MARKET RESEARCH RESULTS[1]

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In 1990, the poultry industry in Alabama produced 3.6 billion pounds of broiler chickens (Ala. Agri. Stat., 1990). Continued expansion of the industry could pose potential waste disposal problems. Composted broiler litter (CBL) has some nutritive value as it can be used as an agronomic fertilizer (Mitchell et al., 1990), as an alternative crude protein source for beef cattle (Donald, 1989), and can be incorporated into at least three horticultural products: (1) in a potting mix as a substitute for peat moss (Bugbee and Frink, 1989); (2) in field production of ornamentals and landscape bed preparation as a soil amendment (Gilliam et al, 1989); and as an organic fertilizer. The primary product of interest in this research was a 50% CBL amended potting mix.

Ornamental horticultural crop production is important to the U.S. economy and comprised the largest value of all plant crops produced in Alabama in 1991 at $183 million (Ala. Agri. Stat., 1990). Gardening is a popular hobby of American households as 75% participated in some form of gardening in 1991 (National Gardening Association, 1991). Since many ornamental plants are produced for American consumers and many participate in gardening activities, horticultural uses of CBL may be an alternative outlet for the waste product if future disposal is limited.

The greatest potential problem in marketing CBL amended products may be a perceived unpleasant odor. While most of the unpleasant odor is removed during composting, some still remains and some may be perceived by the consumer.

[1]This research was generously funded by AUTRC and the Alabama Agricultural Experiment Station. Research cooperators included James Donald, Charles Gilliam, Lisa Beckett, and Ginger Purvis.

Evaluating the amount of perceived unpleasant odor from a soilless potting mix tested in a real consumer environment was a logical first step in developing the marketing strategy. The ideal environment to assess a reaction to unpleasant odor was in consumer homes.

IN-HOME TESTING

The objective of the first portion of the study was to determine if an unpleasant odor emanated from plants grown in a 50% CBL amended potting mix. In order for the experiment to have a realistic setting, it was conducted in consumer homes. Dallas fern was selected as a test plant because the cultivar was suitable for use as a houseplant and because it has tolerance of low light and low humidity conditions (Gilliam et al., 1989). A potting mix containing 50% CBL (AUmix) was compared with two commercially available potting mixes.

AUmix was a potting mix amended with CBL comprised, by volume, of ten parts CBL, ten parts aged, amendment grade pinebark, and one part horticultural perlite. Two commercial growing media were used as comparisons, Hyponex and Baccto. In Oct., 1990, commercially grown, uniform 1/2-inch liners of Nephrolepsis exaltata dallasii 'Dallas Jewel' were transplanted into four inch plastic pots of the three media. The ferns were grown for one week in a fiberglass covered greenhouse.

Members of twenty-three garden and homemaker clubs in Lee Co., Ala., were requested to participate in a study to evaluate ferns. Of approximately 300 members contacted, 119 agreed to participate. An exit survey mailed to participants at the conclusion of the study revealed that respondents (67 of 112) by age group were 33-50 (28%), 51-66 (34%), and 67-85 (37%). Eighty-seven percent of the respondents had completed some college or had earned a college degree. Median per capita income was $20,833, and mean per capita income was $21,502. The mean number of persons per household was 2.5. Eighty-eight percent of the respondents were female and 12 percent were male.

Between 24 Oct. and 1 Nov., consumers randomly chose a market basket which contained three ferns. Each set of ferns contained one fern grown in each of the three media. Each consumer received an instruction sheet, six color-coded forms for weekly evaluations, and six postage-paid envelopes for returning completed surveys. In each set of ferns, pots were labeled as either A, B, or C, and media order was randomly varied. Consumers were requested to keep the three plants together in the market basket during the survey period. Water, light, and temperature instructions were provided on care tags furnished by the fern grower, Casa Flora of Dallas, Texas.

From 2 Nov. through 7 Dec., consumers evaluated each fern on four variables using a five-point scale, comparing the plant being rated to the other two plants. Fern frond color was rated as 1=light green and 5=dark green. Unpleasant odor was rated as 1=no unpleasant mix odor and 5=strong unpleasant mix odor. Overall health of each fern was rated as 1=fair health and 5=excellent health. Plant water requirement was rated as 1=little water applied and 5=a considerable amount of water applied. Ninety-four percent of the consumers completed the study. Averages over the entire six weeks of evaluation were tested at the 5% significance level using ANOVA.

Ferns grown in Hyponex received a lower average color rating (3.0) indicating plants were lighter green when compared to plants in the other two media. Ferns in AUmix (3.6) and Baccto (3.7) had similar average color ratings, slightly darker green than ferns in the Hyponex potting mix. Ferns grown in Baccto received a lower average rating for water required (2.4) when compared to ferns grown in Hyponex (3.3). Ferns grown in the AUmix required an intermediate amount of water (2.7). Ferns grown in Hyponex received a lower average rating for fern health (3.1) than plants grown in the AUmix (3.6) or Baccto (3.7) which received similar average health ratings.

Determining any unpleasant odor was the primary concern in AUmix's acceptability to consumers. When comparing the presence of an unpleasant odor emanating from the growing mix, consumers rated ferns growing in Baccto and Hyponex similarly throughout the study. Overall, ferns grown in Baccto (1.1) and Hyponex (1.1) received 2% better ratings than ferns grown in the AUmix (1.2). AUmix had a slightly more unpleasant odor than Baccto or Hyponex. The difference measured was 0.10 or 2% on the 5-point rating scale. No more than 13% of the participants rated AUmix unpleasant odor a 2 or higher for each of the six weeks of testing. Although AUmix had a slightly higher unpleasant odor than either Baccto or Hyponex, the difference, while statistically different, was not substantial and few consumers appeared to notice the unpleasant odor.

The AUmix sustained plant growth as well as one commercial potting mix and better than another with only slightly more unpleasant odor reported. Ferns grown in AUmix required more water than those in Baccto but less than those grown in Hyponex. We concluded that AUmix odor would not be objectionable to most consumers. From these results, we concluded that a CBL amended potting mix could be acceptable for use in consumer homes.

CONSUMER PERCEPTIONS

Since a CBL amended product could be acceptable in consumer homes, the objective of the second part of this research was to determine consumer perceptions of the product through their visual and olafactory examination of the product. Montgomery, Alabama, was selected as a consumer testing site due to its proximity and the availability of cooperating firms. On two Saturdays, Feb. 23 and Mar. 2, 1991, a survey was conducted in two malls and three garden centers. Consumers were asked to complete a questionnaire pertaining to their past growing mix purchases, and their perceptions and attitudes about growing mixes.

Demographic characteristics of consumers are useful in segmenting populations and in determining if a population is homogeneous. Three demographic characteristics were used to evaluate homogeneity of the samples from each location: education, per capita income, age. We considered the population homogeneous if a location was distributed the same on two of the three demographic characteristics. Mall A was dissimilar for two of three characteristics and the responses of its 57 participants were excluded from analyses. The other four locations were homogeneous and their participants totaled 198.

Respondents had purchased growing media for use both in the garden and home (46%), for use with houseplants (34%), and as an amendment to garden soil (7%). Twenty-five percent of the respondents had not purchased potting media in the past year.

The most frequent use of growing media by respondents was for growing new houseplants (67%). Multiple responses were permitted and other uses indicated were re-potting houseplants (49%), preparing beds for shrubs (25%), sowing seeds (24%), preparing beds for perennials (22%), preparing/patching lawn (9%), preparing beds for annuals (6%), and preparing vegetable beds (6%). The primary use of growing media recorded by the respondents was for potting new houseplants (48%) and 25% did not indicate a primary use.

Respondents next indicated what type of growing media they purchased most frequently in the past year. Potting mix (54%) was preferred by the respondents. Other past purchases included top soil (15%), peat moss (11%), organic potting mix (6%), composted cow manure (5%), soilless mix (3%), other (3%), and composted poultry manure (2%).

Respondents were asked to indicate from where they had made growing media purchases most frequently in the past year. Discount stores (46%) were reportedly the location of most purchases followed by garden centers (29%), nurseries (16%), and other stores (9%). Respondents did not choose drugstores or supermarkets as sources of potting media. Mass markets, primarily discount stores, likely do not have the personnel available to assist in the differentiation and selection process with consumers.

Responses were recorded for the brand of potting mix purchased most frequently in the past year. Hyponex (35%) was most preferred while store "house" brand (18%), Gardener's Choice (3%), Baccto (2%), Fertilmix (1%), and Fafard (>1%) were less preferred. Many respondents failed to recall the brand name (35%) that they had most frequently purchased. There did not appear to be a high level of brand loyalty among consumers when they selected potting mix. The generic "house brand" may indicate either an inability to differentiate between potting mix or a reliance on the retailer to supply an acceptable quality potting mix.

Respondents were requested to rate nineteen characteristics or attributes of potting media on a scale from one to five (1=least important and 5=most important). Based on average rating, the most important characteristics were texture, fertility, price, water retention, contents labeled on bag, contains organic material as an ingredient, and color. The least important characteristics for the respondents were the ability to smell the mix, pine bark as an ingredient, and the brand. Of the materials considered as ingredients of a mix, composted manure was rated less important than peat moss and organic material but more important than pine bark, perlite, and vermiculite. Respondents indicated that pleasant odor was of moderate importance when choosing growing media.

Respondents were then asked to indicate their level of agreement with seventeen statements. A five-point scale was used: SD=strongly disagree, D=disagree, N=neutral, A=agree, and SA=strongly agree (Table 1). Consumers strongly agreed that potting media differ, that bagged media are more fertile than garden soil, and that a potting mix with added fertilizer will help plants get a better start. They also strongly agreed that organic gardening is important to the environment. Regarding composted manure, the consumers strongly agreed that composted manure is a valuable addition to the home garden and that they would purchase plants growing in a potting mix amended with composted manure. When compared with cow and horse manure, poultry manure was perceived as a less desirable additive to a soilless potting mix than cow manure but similar to horse manure. When compared with cow and horse manure, poultry manure was perceived to have a similar unpleasant odor. Respondents strongly agreed that potting mix should have a rich, organic smell.

MARKETING STRATEGY

Consumers purchased growing media primarily at discount stores and this market could be targeted first. An important element in a product selection process will most likely be missing from the mass market outlet: knowledgeable personnel. The package for this market will need to be attractive and self-explanatory. There will likely be no one in the mass-market outlet to assist the consumer in learning about a new product or to assist in product differentiation and selection.

Table 1. Mean ratings for attitudinal questions relating to the consumers agreement or disagreement on a scale from 1 (strongly disagree) to 5 (strongly agree)

	Mean Rating	% Agree	% Disagree
Composted manure is a valuable addition to the home garden (n=204).	4.0	74%	5%
Composted poultry manure is desirable in a potting mix (n=179).	$3.2^{z,y}$	40%	26%
Composted horse manure is desirable in a potting mix (n=175).	3.2^{z}	39%	21%
Composted cow manure is desirable in a potting mix (n=183).	3.7^{y}	65%	13%
Composted poultry manure has an unpleasant odor (n=168).	$3.3^{x,w}$	44%	21%
Composted horse manure has an unpleasant odor (n=163).	3.2^{x}	39%	21%
Composted cow manure has an unpleasant odor (n=172).	3.2^{w}	42%	29%

Statistical comparisons using paired t-tests:

^{z} No significant difference (p=0.5465) between means.
^{y} Significant difference (p=0.0001) between means.
^{x} No significant difference (p=0.7083) between means.
^{w} No significant difference (p=0.2504) between means.

The nursery and garden center outlets are important, but secondary markets. Since knowledgeable personnel will likely be available to assist in new product introduction and product selection, in-store information and displays should be prepared with the consumer and the store employee in mind. Benefits or advantages of the product should be indicated to store personnel. Perhaps trials of the product would be an effective means of educating store personnel and potential customers simultaneously.

Package wording would be critical to successful positioning in both the mass market and nursery/garden center. "Composted organic manure" may be more acceptable terminology than composted broiler, poultry, or chicken manure. States vary in regard to their definition of "organic," thus an enterprise seeking to market this type of product would need to comply with different laws.

Uses indicated on the package should include specific mention of potting new and repotting old houseplants, since that was a primary use of packaged growing media. Other uses should be included on the package label to suggest added uses and perhaps increase purchases of the product.

Fertility was an important attribute to consumers when selecting a growing mix. If the product is positioned as a growing mix, no mention of the specfic level of fertility needs to be mentioned. However, positioning the product as an organic fertilizer would require a guaranteed minimum analysis to be clearly labeled on the package. Entrepreneurs will need to weigh the costs and benefits of including a guaranteed minimum analysis. An emphasis on the organic content, fertility, and environmental aspects of these products should improve the marketability of products containing composted broiler litter.

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ENHANCEMENT OF BROILER LITTER TO IMPROVE FERTILIZER QUALITY

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The continuing success and growth of the poultry industry in the Tennessee Valley is one of the bright spots for agriculture in the region. The Tennessee Valley Authority (TVA) is proud to have been an integral part of that growth and we are committed to working cooperatively to help that growth continue. Of course, we, along with each of you, want this growth to continue in an environmentally sound manner. We are convinced it can, and with the attitude we have seen throughout the industry and among agricultural leaders, we are convinced it will, both here and in other production regions in the United States.

HISTORY AND BACKGROUND

TVA contributions to the poultry industry began with the provisions for navigation and assistance in providing efficient and safe port facilities to support low-cost transportation of grain for feed mills located along the river. With continued growth, the poultry industry became more specialized and concentrated in specific regions. The industry required major investments in infrastructure, institutions, public and private research, and human resources for its support. The industry is a vital supplier to the economy of the region and is a vital supplier of low-cost food products. The industry provides one of a few agricultural products that earns a large value added component in the export market.

As the industry grew, the importance of litter to help develop and support an efficient cattle industry in the region became apparent. TVA, through the Agricultural Institute and the Agricultural Research Department, at the National Fertilizer and Environmental Research Center (NFERC), took an early support role to assist Auburn University to develop and organize research, prepare educational information, and provide extension leadership to utilize the litter as essentially "free goods" for feed and fertilizer to support development and growth of the cattle industry. The

Agricultural Institute and NFERC's Agricultural Research Department have supported research and extension activities at Auburn University to develop and demonstrate ways to utilize litter for feed, fertilizer, potting mixes, and in silage, and have supported efforts by at least two private firms in the state to develop processes and to begin commercial marketing operations. This work has been supported since the early 1980's with direct TVA program funds and with research enhancement funds made available by the State of Alabama through the Alabama Universities TVA Research Consortium (AUTRC), a program designed to support research to directly result in job creation and income enhancement for the people of Alabama. TVA's contributions and leadership to the industry were recognized in 1991 by the presentation of a distinguished service award by the Alabama Poultry and Egg Association to Cliff Bice of the Agricultural Institute.

TVA'S INCREASED COMMITMENTS

Due to the increasing complexity of environmental issues facing the poultry industry, TVA recently established a new program at NFERC in Muscle Shoals, Alabama. This program will broaden TVA's efforts to develop new technologies, cooperate with others to expand new product market opportunities, and help cope with the increasing environmental demands being placed on the industry. NFERC is now renovating an existing building and will develop a compost research program with facilities ranging from lab-scale to full production scale for research and testing. These program additions are intended to complement programs already in place. The additions commit TVA's scientific and engineering resources and experience from our fertilizer, agricultural research and development activities, including waste management; to problems associated with animal and solid waste. Current emphasis is on broiler litter.

The program changes also make a more national effort possible. In that regard, we are initiating cooperative projects in Arkansas, Oklahoma, Wisconsin, and Rhode Island this fiscal year and hope to develop work with other states as resources and mutual interests dictate. NFERC has also agreed to represent TVA in the Poultry Water Quality Consortium (PWQC) that Ed Schwille has already discussed. We are happy to be associated with this effort and are optimistic that it will prove to be a positive force to promote better environmental management by the poultry industry. We see a number of benefits accruing to all of us from this effort. One benefit that has not been stated is the potential to leverage funds and support from other sources for environmental work. There is an excitement among staff at TVA involved in these efforts, and we are working as an effective team to achieve our objectives.

CURRENT BROILER LITTER OBJECTIVES

There is apparently an agreement that the best course of action is to use broiler litter for feed, fertilizer, and soil amendments with minimum processing and transportation, and to do so within environmental guidelines. The TVA program is based on the premise that, despite best efforts, more poultry litter is being generated than can be utilized in many concentrated production regions in the country. Excess then becomes a waste. Solutions to the waste problem will primarily come from source reduction technologies and recycling to provide new products with value added features.

With continued industry growth, a system is developing that includes specialized waste management firms, probably drawn from the ranks of house cleaning contractors. These firms perform assembly, recycling, distribution, marketing, and sales functions. The intent of the NFERC and Agricultural Institute programs are to assist the industry to minimize waste disposal costs by developing new technologies and new high-value market opportunities that will provide year-round business opportunities to partially off-set increased investment, operating, and transportation costs. Market opportunities identified and under investigation include traditional agricultural fertilizer, beef cattle feed, products for nursery, greenhouse, professional turf, and landscape uses, as well as for the consumer lawn and garden market. These markets offer relatively high value opportunities but will be slow to develop. Financial support for the new firms will be required to offset the necessary added costs. Support may come in the form of tipping fees and/or contributions by others. Such actions would encourage efforts by the poultry industry to reduce waste at the source, and take other waste and/or cost-cutting measures. These actions would also provide incentives for waste disposal firms to adopt new cost saving technologies, to increase service income, to expand markets, to increase product value, and to become more creative in exploiting higher value consumer markets.

TVA is committed to working with appropriate agencies, the poultry industry, and waste management firms to meet the new challenges associated with utilizing litter efficiently and effectively. TVA will conduct and publicize composting/litter utilization research and provide technical assistance to improve information and technology exchange across the industry, to lower costs, and to improve products.

Initial work in compost research will concern poultry and yard waste, but in the future, other wastes derived from animal and plant sources will be evaluated. The program will encourage interaction between researchers from TVA and other organizations, as well as allow the production of composts made from different sources for greenhouse, field testing, product development, and marketing studies. Improvements in compost production/processing and characterization of compost quality as it relates to different uses will be of particular interest.

BROILER LITTER ENHANCEMENT FOR FERTILIZER

Once decisions are made to market broiler litter products on a commercial basis, it becomes necessary to provide products that consistently meet standards and consumer expectations. Processing steps are necessary to meet these requirements. Feed must be certified pathogen-free; it must consistently meet minimum nutritional guarantees and quality standards; and be competitive in the market. The same general requirements would apply to fertilizer products. Litter for feed should not be composted because it reduces feed value, but it should be pelleted and dried to meet pathogen requirements and to insure stability. Although high in crude protein content, a more balanced feed requires the addition of corn or similar material to increase the amount of available energy.

TVA's experience has shown that litter composting is required for successful marketing of all commercial fertilizer/soil amendment products. Composting is currently necessary to insure product quality, stability, and to moderate objectionable odors. Efforts with a commercial producer have shown significant improvements in quality as a result of adjusting the carbon-to-nitrogen ratio, controlling moisture content, and monitoring temperature and oxygen levels to determine turning frequency in the composting process. Test results have shown typical N-P-K levels at 2.5 to 3.0% N, 3.5-3.7% P_2O_5, and about 2.5% K_2O on a dry basis.

The composted litter, when pelleted, is a good soil amendment with some fertilizer value, but it has limitations. Even so this is the form in which most composted broiler litter is sold. Limitations include: (1) low plant nutrient analysis, (2) some odor, (3) low bulk density, and (4) a narrow range of potential markets. Enhancements can overcome each of these limitations and can provide for additional advantages as well. Enhancements could result in a number of products, but for the purposes of this paper the discussion will be limited to those amended with chemical fertilizers. This can be a disadvantage in some cases that demand a "pure" organic product. In discussions with agronomists and market specialists, it was decided that an "enhanced" fertilizer should contain a minimum of 50% composted broiler litter on a dry basis when mixed with a chemical fertilizer. Chemical fertilizers included in our tests were: urea, ammonium sulfate, ureaform and methylene urea forms as slow-release nitrogen sources. Phosphorus sources were 11-52-0 and 0-46-0 and merchant-grade phosphoric acid. Potash sources were potassium chloride and potassium sulfate. Numerous grades and ratios have been tested in laboratory scale pelleting and compaction equipment. No significant processing problems have been encountered. In all cases, enough phosphatic product was added to react with any free ammonia in the compost to further reduce odor and improve storage qualities. The grades were made by blending the required amounts of each fertilizer to form the desired formulation. This blend was then added to the compost at the 50% compost rate and remixed. The new blend was then pelleted and dried. Test results indicate that phosphoric acid is the preferred P_2O_5 source, but it would be somewhat more difficult to use. If sulfur is desired, ammonium sulfate would be the preferred nitrogen source. Urea, would be the preferred nitrogen source if no special requirements are dictated. Urea because of its higher analysis, makes the production of higher grades possible. Potassium sulfate would be used if requirements dictated chlorine-free grades or if sulfur was a desirable component. Many of these grades have been tested in our labs and are currently being evaluated in TVA greenhouse tests. We have not observed any change in release patterns or reactions as a result of the mixing and pelleting process.

Once the fertilizers are added, bulk density increases accordingly, particle hardness and consistency improves, and odor is reduced, at least partially, because of the added phosphoric acid. Grades made with urea, 11-52-0 and potassium chloride have included: 8-8-8, 8-14-8, 12-4-6, and 12-4-8. These grades compare in nutrient concentration to conventional fertilizers, which allows the producer to achieve the same transportation and handling costs per ton of product and the homeowner would apply either at the same rate.

The added sales advantages include the organic base, the consumer interest in recycled products, about 1.5% of the N is in slow-release form from the compost, and products are frankly superior in consistency and handling qualities to conventional blended products otherwise available in market outlets contemplated. A product such as this is targeted to the consumer to be purchased in lawn and garden departments of national chain stores. The line can be easily upgraded for sales in lawn and garden stores and for professional turf users by substituting a slow-release form of nitrogen for urea and potassium sulfate for potassium chloride. Both of these product lines are meeting with good price competitiveness and sales success with one firm with national marketing capabilities. Success observed this year, with very limited market promotion, suggests a solid growth potential for sales of enhanced products as well as for composted and pelleted broiler litter.

Experiments are also under way to make and test plant response to pelleted slow-release iron fertilizer made from iron/zinc crystal waste from zinc galvanizing processes. Iron sulfate quickly becomes unavailable to plants after soil contact. In this application the pelleted product is broadcast on turf, the product remains in the duff layer, and the iron remains available for a longer percentage of time. Time and market needs will undoubtedly suggest many more applications for enhanced products. For example, feather meal can be used as an organic enhancement for increased N to satisfy demands for all organic products.

We are excited about TVA's compost research program and the broiler litter program. Prospects for success in helping to solve environmental impacts of poultry wastes are good, and opportunities to work cooperatively in compost research and market utilization studies are encouraging.

HORTICULTURAL USES OF MANURE FOR BEDDING PLANTS, VEGETABLES, AND TUBERS

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Poultry manure is primarily used in horticultural crop production as an organic source of plant nutrients. Use of poultry manure can partially substitute for commercial fertilizers, primarily nitrogen, although phosphorus and potassium requirements can also be supplemented through poultry manure application. When applied over many years, another benefit of poultry manure is an increase in soil organic matter content, which in turn can improve soil physical properties. As with any manure, the low nutrient content relative to commercial synthetic fertilizers limits the distance of transport unless a higher price can be obtained. Horticultural crops offer some advantage over traditional agronomic crops for using poultry manure at a greater distance from the source because more intensive production practices are used, often requiring higher and more expensive inputs. For example, in the greenhouse-nursery industry there is a need for large quantities of organic matter to formulate various media. For turf production, a high quality medium containing organic matter and slow release of nutrients is desirable. For vegetable crops, organic production (production without synthetic fertilizers or pesticides) often commands a higher price for the produce. If managed properly, poultry manure, has the potential to be used for a wide variety of horticultural crops.

The primary objective of this paper is to summarize some of the research relating to use of poultry manure on horticultural crops. The first two sections on bedding plants and vegetable crops deal with research conducted with turkey manure compost. The third section deals with the use of relatively fresh turkey manure for potato production.

BEDDING PLANTS

The material used in this study was a compost consisting of turkey manure and wood shavings that had been windrowed outdoors for six weeks. The primary advantages of using composted material are that odor is minimized and physical properties are more desirable for potting media (Parr and Wilson, 1980). The goal of the experiment was to identify an optimum rate of turkey compost to incorporate into media.

Chemical Characterization of the Compost

The nutrient composition of the compost was as follows (O'Leary, 1989): (% dry weight basis), carbon, 15.6; nitrogen, 1.9; phosphorus, 2.5; potassium, 1.1; aluminum, 0.31; iron, 0.51; (ppm dry weight basis), zinc, 421; copper, 110; lead, <9; nickel, 11; chromium, 10; cadmium, 1. The C:N ratio was 8.2 indicating that some release of nitrogen from the compost would be expected. Other chemical characteristics include: cation exchange capacity, 27.4 meq/100g; pH (1:1), 6.2; soluble salts (saturated extract), 21.6 mmhos cm^{-1}; moisture, 40%. The biggest concern in using this compost based on the chemical properties is the high soluble salt content, which may limit usage of the material in potting media unless controlled leaching prior to planting is practiced.

Treatments and Physical Characteristics of the Media

The compost was mixed with a 1:1 sphagnum moss peat: perlite mixture at rates of 0, 10, 20, 30, and 50% by volume of the total mix. No additional amendments were added to the media containing compost. The control treatment was the 1:1 sphagnum moss peat:perlite mixture amended at the time of mixing with macro and micronutrients (O'Leary, 1989). An additional treatment consisting of a commercial bagged product, Jiffy Mix (1:1 peat:vermiculite, plus nutrients), was also included. Porosity and bulk density determinations of the media at the time of mixing are shown in Table 1.

Table 1. Porosity and Bulk Density of Turkey Compost-Amended Media and Jiffy Mix.

Medium Composition	% Pore Space		Bulk Density
%compost:%peat:%perlite	Total	Air-filled	(g/cc)
0:50:50	72.5	13.1	0.13
10:45:45	72.5	13.1	0.15
20:40:40	70.7	13.3	0.17
30:35:35	70.7	14.6	0.17
50:25:25	65.6	17.9	0.23
Jiffy Mix	69.7	11.6	0.16

The physical characteristics of the compost-amended media at all rates were similar to Jiffy Mix and resulted in good drainage and adequate water holding capacity.

Tomatoes ('Better Girl') and snapdragons ('Cheerio') were grown in the experiment. Tomatoes were seeded and snapdragons were transplanted in four-packs containing the various treatments. Plants grown in the compost-amended media were not fertilized. Plants grown in the Jiffy Mix were fertilized with a water soluble N-P-K fertilizer during the course of the experiment to simulate conventional growing practices. Tomatoes were grown for five weeks and snapdragons for ten weeks. Plant height and dry weight were recorded as an average of the four plants in each pack at the end of the experiment.

Effect of Turkey Compost on Bedding Plant Growth

Germination of tomato seeds was delayed by one day in media containing 30% compost and by four days in media containing 50% compost compared to the other treatments. The turkey manure compost initially supplied excessive amounts of nitrogen, primarily in the nitrate form (1500 ppm NO_3-N based on a KCl extract). Overall soluble salt levels were also initially above the desirable range. By the end of the experiment, nutrient levels and soluble salts were in the low range indicating that uptake by the plants and leaching out of the medium had occurred. Height and dry weight of the plants are presented in Table 2.

Table 2. Effect of Compost Rate and Jiffy Mix on Growth of Tomato and Snapdragon Plants. (means of 3 reps.)

	Tomatoes		Snapdragons	
Compost rate (%)	Shoot dry wt. (g/plant)	Height (cm)	Shoot dry wt. (g/plant)	Height (cm)
0	0.4	15.1	1.2	24.6
10	1.3	21.6	1.9	29.5
20	1.3	24.4	2.5	29.1
30	1.1	20.5	2.9	24.7
50	0.8	18.0	2.2	21.7
Jiffy Mix	2.3	27.6	6.3	43.3

Height and dry weights of tomato plants increased with increasing compost up to 20% by volume and then decreased. Dry weights of snapdragons increased with increasing compost rate up to 30% compost in the media for dry weight and 10-20% for height. Roots were darker in color as compost rate increased. Growth inhibition at the high rates of compost was probably due to initially high salts, primarily nitrate. Although poultry manure compost will vary in composition, based on this study no more than 10-20% by volume should be used in potting media for bedding plants. The greater growth of plants grown with Jiffy Mix plus supplemental fertilization suggests that additional fertilizer would be necessary in the compost treatments after the initially high salts from the compost are leached out.

Sims and Pill (1987) also reported that poultry manure (noncomposted) initially reduced tomato shoot growth compared to slow release fertilizer treatments when applied at high rates. They suggested that poultry manure should be applied based on a laboratory determination of its nitrogen content. Their recommendation was that poultry manure should not exceed 2 lb N per cubic yard of potting media when used as a supplemental N source and that leaching of the growth medium to reduce soluble salt concentrations may be necessary if poultry manure exceeds this rate.

VEGETABLES

Use of poultry manure for vegetable crops is common in parts of the country where the poultry industry is concentrated. The distance poultry manure can be transported from the source for vegetable crops is usually limited. Extending the distance the manure could be transported would help in recycling the waste. Studies presented here were conducted to evaluate the use of relatively low rates of turkey manure compost on yield and quality of sweet corn ('Jubilee') and snap beans ('Eagle'). One question that we wanted to answer was whether the composted manure had benefits other than simply nutrient value. Both of the crops tested are grown in fairly large acreage for processing.

Chemical Characterization of Turkey Compost

The product used for the vegetable study had different characteristics than the one used for the bedding plant study. The moisture content of the compost was 49.9%. The nutrient value of the compost is provided on a pounds per wet ton basis: nitrogen, 50; phosphate (as P_2O_5), 75; potash (as K_2O), 50; sulfur, 9; magnesium, 9; calcium, 50; sodium, 6; iron, 2; aluminum, 1; manganese, 0.6; copper, 0.1; zinc, 0.6. Treatments used were based on the total N content of the compost since the idea was to sell the compost based on its total nutrient value.

Experimental Procedures for Vegetable Crop Study

The experiment was conducted on a Hubbard loamy sand at the Sand Plain Research Farm in Becker, Minn. (Rosen and Buchite, 1987). Average soil test values prior to planting were: pH, 6.5; Bray P1, 44 ppm; ammonium acetate K, 119 ppm; organic matter 2.5%.

Treatments for the snap bean experiment were as follows: 1) Control (no added fertilizer), 2) 40 lb N/A (as urea), 3) 1.0

ton/A compost, 4) 1.5 ton/A compost, 5) 2.0 ton/A compost, 6) 1.5 ton/A compost plus 25 lb N/A (as urea). All compost and fertilizer applications were applied before planting and rototilled in to a depth of six inches.

Treatments for the sweet corn experiment were as follows: 1) 50 lb N/A preplant, 100 lb N/A sidedressed; 2) 50 lb N/A preplant, 100 lb N/A sidedressed, 100 lb K_2O preplant, 3) 1.5 ton/A compost preplant, 75 lb N/A sidedressed; 4) 1.5 ton/A compost preplant, 140 lb/A 11-48-0 starter, 60 lb N/A sidedressed; 5) 1.5 ton/A compost preplant, 75 lb N/A sidedressed, 50 lb K_2O/A preplant; 6) 1.5 ton/A compost preplant, 140 lb/A 11-48-0 starter, 60 lb N/A sidedressed, 50 lb K_2O/A preplant; 7) 2.0 ton/A compost preplant, 50 lb N/A sidedressed. All sidedressed N fertilizer was applied as urea three weeks after planting. The fertilizer potash source was potassium chloride (0-0-60).

Treatment Effects on Snap Bean and Sweet Corn Growth

Compared to the control treatment (no fertilizer or compost), snap bean yield and nitrogen concentrations in first trifoliate leaves were not significantly affected by fertilizer or compost application (Table 3). Snap beans are a legume and fix their own nitrogen from the atmosphere, therefore, the effect of additional nitrogen from inorganic or organic sources would not be expected to be that great. Vine yield tended to increase with compost rate and fertilizer addition, a response often observed with legumes receiving additional nitrogen. Pod maturity was not affected by treatment nor was the extent of root nodulation with rhizobia bacteria (data not presented).

Table 3. Effect of Compost Treatments on Snap Bean Pod and Vine Yield and Nitrogen Concentration in First Trifoliate at Flowering.

Treatment	Pod Yield Ton/A	Vine Yield Ton/A	Leaf N %
Control	4.35	6.40	2.68
40 lb N/A	4.66	7.78	2.75
1 Ton/A compost	4.95	7.49	2.63
1.5 Ton/A compost	4.74	8.23	2.58
2.0 Ton/A compost	4.33	8.67	2.60
1.5 Ton/A compost + 25 lb N/A	4.43	8.09	2.77
LSD (0.05)	NS	1.20	NS

Compared to inorganic fertilizer treatments, sweet corn yield was not affected by compost applications (Table 4). The use of starter and potash fertilizers also did not improve yield over the urea only treatment. Nitrogen concentrations in the ear leaf tended to be lower in the compost treatments. These results suggest that nitrogen availability from the compost is lower than from conventional fertilizer. Concentrations of potassium in the ear leaf were not affected by compost or potash fertilizer additions (data not presented).

Table 4. Effect of Compost and Fertilizer Treatments on Sweet Corn Yield and Nitrogen Concentration in the Ear Leaf at Silking.

Treatment	Green Yield Ton/A	Husked Yield Ton/A	Leaf N %
150 lb N/A	5.88	4.18	2.64
150 lb N/A + K_2O	6.10	4.11	2.52
1.5 T/A compost + 75 lb N/A	6.13	4.44	2.50
1.5 T/A compost + 75 lb N/A + starter	5.82	4.23	2.17
1.5 T/A compost + 75 lb N/A + K_2O	5.83	4.03	2.57
1.5 T/A compost + 75 lb N/A + K_2O + starter	5.83	4.35	2.22
2.0 T/A compost + 50 lb N/A	5.23	3.71	2.28
LSD (0.05)	NS	NS	0.21

Based on these results, turkey manure compost applied at relatively low rates does not appear to offer any yield or quality advantages over conventional fertilizers. These conclusions are in partial agreement with those of Montagu and Goh (1990), who reported limited availability of nitrogen and lower yields of tomato with poultry manure compost compared to other organic and inorganic nitrogen sources when applied at equal total nitrogen rates.

POTATOES

Poultry manure can be used for potato production to provide a source of nutrients for crop growth, a use similar to that for vegetable and agronomic crops. The study with potatoes presented here was part of a larger study in which an effort was being made to quantify water and nitrate movement under crops grown on sandy soils (Sexton et al., 1992). The results reported below focus primarily on the response of potato ('Russet Burbank') to turkey manure and urea as sources of nitrogen.

Chemical Characterization of Turkey Manure

The manure used for this study was mixed with pine sawdust and sunflower seed hull litter. At the time of application, it was 56% moisture and had a fertilizer value of 47.1, 17.1, and 17.8 lbs per wet ton of N, P_2O_5, and K_2O, respectively. The total nitrogen analysis was determined using the Kjeldahl digestion procedure. Inorganic nitrogen in the manure was determined following extraction with 2 N KCl. Based on this extraction, 11.7 lb N/wet ton was in the ammonium-N from and 2.1 lb N/wet ton was in the nitrate-N form. Total available N for the first growing season from the manure was estimated by assuming that 30% of the organic fraction and 80% of the inorganic fraction would be available (Sutton, 1985). The total estimated available nitrogen was 21 lb per wet ton of manure.

Experimental Procedures for Potato Study

The experiment was conducted on a Verndale sandy loam at the Irrigation Center in Staples, Minn. Average soil test values prior to planting were: pH, 6.9; Bray P1, 32 ppm; ammonium acetate K, 79 ppm; organic matter, 1.8%. Treatments included a control, three rates of nitrogen fertilizer as ammonium nitrate and two rates of turkey manure. Specific treatments were as follows: 1) control, no N fertilizer applied; 2) 80 lb N/A, 3)160 lb N/A; 4) 240 lb N/A; 5) 13.1 ton/A turkey manure preplant; 6) 19.9 ton/A turkey manure, preplant. The ammonium nitrate was applied in three equal applications at planting, emergence, and hilling. The manure was plowed in after application. Estimated available nitrogen rates from the turkey manure based on the assumptions detailed in the previous section were 282 and 425 lb N/A.

Effects of Turkey Manure on Potato Growth

Potato yield increased with turkey manure application and nitrogen fertilizer application (Table 5). Yield of potato with manure was slightly higher than with the highest fertilizer N rate. However, the rate of estimated available nitrogen applied with the manure was 40 and 185 lbs greater than the highest nitrogen rate with nitrogen fertilizer. Thus, basing the turkey manure application on estimated available nitrogen seemed to correspond well with potato yield increases due to nitrogen fertilizer. Leaching of nitrate during the growing season was lower for manure than for ammonium nitrate fertilizer (data not presented). The results of this experiment clearly show a benefit from using turkey manure as a nitrogen source for potato production, provided that available nitrogen is calculated properly.

Table 5. Effect of Turkey Manure and Nitrogen Fertilizer on Potato Yield.

Treatment lb N/A	Culls cwt/A	Marketable cwt/A	Total cwt/A
0	47	146	193
80 (fertilizer)	47	280	327
160 (fertilizer)	57	319	376
240 (fertilizer)	59	333	392
275[a] (manure)	70	339	409
420[a] (manure)	74	357	431
Standard Error	16	25	24

[a]Estimated available N from turkey manure.

In some cases, using manure for potato production has been reported to increase the incidence of potato scab. In the present study, potato scab was not observed. It is recommended that if potato scab is a problem in a particular field that manure not be used.

SUMMARY

Poultry manure can be used to provide a source of nutrients for horticultural crops. For bedding plants, care must be taken to monitor the salt and nitrogen content of the product being used. For field grown vegetables and potatoes, poultry manure application should be based on the estimated available nitrogen content. When managed properly, poultry manure can be recycled for use in horticultural crop production and can partially substitute for the use of synthetic fertilizers.

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POULTRY BY-PRODUCTS USED IN CONJUNCTION WITH BIOSTIMULANTS FOR TURFGRASS GROWTH

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In the United States, there are about 1.4 trillion head of poultry that produce over 1.5 billion tons of waste each year. In areas where poultry population is concentrated, the litter often is more than the immediate crop land can handle. Feathers from processing has also become a major problem. If these materials are not managed properly, they may become pollutants.

Ingenuity must be employed to recycle the poultry waste that increasingly is being generated. Broiler litter has been recycled as cattle feed because of its high nitrogen content. Poultry litter is also valuable as fertilizer not only because of its nutrient content, but because it reduces the impact of nitrate leaching and is an excellent source of humus.

In the past few years, there has been an increasing interest in using organic fertilizers for lawns and gardens. Fertilizers derived from litter and feathers have been developed to help meet the demand of organic based fertilizers and to provide a recycling outlet for surplus poultry waste.

We have conducted a series of experiments to evaluate fertilizers derived from poultry litter and feathers as compared to other nitrogen sources used on turfgrasses. In addition, biostimulant additive to these poultry waste fertilizers were researched. Biostimulants are hormones, or substances when externally applied influence plant internal hormone activity. Substances that we know have biostimulant activity include seaweed extract, humic acid, triazole fungicides, and synthetic cytokinins. Some of our research will be discussed in this paper.

EXPERIMENT 1

An experiment designed to ascertain the influence of fertilizer derived from chicken litter as compared to urea and urea formaldehyde nitrogen sources influence on turfgrass was conducted. A mature Kentucky bluegrass, Poa pratenses, grown

Table 1. Color ratings of Kentucky bluegrass as influenced by different N sources applied on 5 May, 19 July, 17 September, and 5 November, 1990 and on 3 June, 23 July, 10 September, and 29 October, 1991.

	1990 Rating Dates		1991 Rating Dates		
Fertilizer	29 May	15 Oct.	19 Feb.	24 June	19 Nov.
	----------------1-9=best-----------------				
Urea	7.8 a[a]	7.1 a	8.5 ac[a]	7.8	8.1
42-0-0	7.3 bc	7.1 a	6.3 ab	7.3	7.8
9-2-4	7.0 cd	7.3 a	5.8 bc	7.3	7.3
Biostimulant					
None	6.8 c	6.3 b	6.0 ab	7.3 b	7.3 b
Fe	7.8 a	7.8 a	6.3 a	7.5 a	8.1 a
FSE	77.2 b	7.3 a	5.8 b	7.4 a	7.0 b

[a]Means in the same column for either fertilizer or biostimulant parameters that have the same letter are not statistically different at the 0.1% probability.

Table 2. Clipping yields of Kentucky bluegrass as influenced by fertility and biostimulants as listed in Table 1.

	1990 Yield Periods		1991 Yield Periods	
Fertilizer	5/30 - 6/30/90	8/8 - 11/6/90	4/11 - 11/23/91	Thatch 6/11/92
	g/100 sq.ft.		g/100 sq. ft.	--cm--
Urea	213	304	311	2.4 a[a]
42-0-0	229	301	284	2.3 b
9-2-4	199	292	267	2.3 ab
Biostimulant				
None	232	317	326	2.4 a
Fe	202	290	286	2.2 b
FSE	192	293	249	2.4 a

[a]Means in the same column for either fertilizer or biostimulant parameters that have the same letter are not statistically different at the 0.1% probability.

on a Frederick silt loam at the Virginia Tech Turfgrass Research Center, Blacksburg, Virginia was used for this study. The following fertilizers were employed: (a)42-0-0 (a blend of methylene urea, methylene diurea, and dimethylene triurea that contained 20% soluble N; 57% water soluble polymer -N; 23% cold water insoluble N, 80% total polymer N, and 6% water insoluble N); a synthetic slowly available nitrogen source ideal for turfgrass production (b) urea an inexpensive source of nitrogen widely used in the turf industry (45% soluble N); and (c) 9-2-4 fertilizer derived from chicken feathers, sulfate of potash and bonemeal. The fertilizers were applied to supply one pound of N per 1000 sq. ft. in 1990, on 5 May, 19 July, 17 September, and 5 November, and in 1991, 3 June, 23 July, 10 September, and 29 October. In addition, 0.5 lb. of P_2O_5 and K_2O per 1000 sq. ft. were applied to each plot each time N was applied except the 9-2-4 treated plots.

Seaweed extract fortified with humic acid and vitamin B (FSE) and chelated iron (Ciba Geigy Fe330) were applied at 2 gal. and 1 lb. per acre, respectively on 18 May, 19 July, 17 September, and 8 November, 1990 and on 6 June, 23 June, 10 September, 1991.

Initially in 1990, urea-treated turf had significantly better color ratings than either the turf fertilized with the methylene urea or the chicken feather-derived fertilizer (9-2-4) (Table 1). However, as the season progressed, all nitrogen sources caused similar color, which continued during the 1991 season (Table 2). Turf treated with iron or the FSE generally produced better color turf than turf not so treated both in 1990 and 1991.

Clipping yields generally were lower for the turf fertilized with the 9-2-4 than when fertilized with urea or methylene urea both in 1990 and 1991 (Tables 3 and 4). This indicates that the chicken feather fertilizer source was slower to release nitrogen than the other two sources. Slower growing turf required less mowing frequency.

Fortified seaweed extract and iron treatments caused the turf to produce less clipping yields during both seasons. After two years, the plots treated with iron had developed a lower thatch buildup. Fertilization with urea was associated with the largest thatch buildup. This indicates that slower growing turf was less prone to developing thatch. Thatch buildup can be harmful to turf quality by reducing nutrient and water infiltration into the root zone.

EXPERIMENT 2

In a separate experiment, a fertilizer burn tolerance of Penncross creeping bentgrass was conducted at the Turfgrass

Research Center in Blacksburg, Virginia. Urea, the 42-0-0 and the chicken feather 9-2-4 were applied at 3 and 6 lbs. N per 1000 sq. ft on 20 and 16 of August of 1990 and 1991. Irrigation was withheld for 48 hours after treatment. Injury ratings were taken within one week after application and recovery from injury was evaluated within six weeks following fertilization.

Fertilizer derived from chicken feathers (9-2-4) was relatively safe to apply to bentgrass, which is non-tolerant of salt applied to its leaves, especially during hot weather (Table 3). Except for the 9-2-4 fertilizer, the six pound rate caused more injury than the three pound N per 1000 sq ft. rate.

Table 3. Injury caused by plasmolysis and subsequent recovery of Penncross creeping bentgrass influenced by applications of different nitrogen sources applied at 3 and 6 lbs. N/1000 sq. ft. on 10 August, 1990 and on 16 August, 1991.

Nitrogen sources	Lbs./1000 sq.ft.	Injury Rating 1990	1991	Recovery Groundcover 1990	1991
		----1-9=most----		---1-9=most---	
5-0-0	3	6.0 c[a]	6.7 d	6.7 d	6.3 d
45-0-0	6	9.0 a	9.0 a	5.3 e	6.0 d
42-0-0	3	1.3 de	6.7 b	8.3 abc	7.3 bc
42-0-0	6	7.3 b	7.7 b	6.7 d	6.3 cd
9-2-4	3	1.0 e	2.0 de	8.7 ab	9.0 a
9-2-4	6	1.0 e	3.0 de	8.7 ab	8.3 ab

[a]Means in the same column that have the same letter are not statistically different at the 0.1% probability.

Urea (45-0-0) fertilization at both the three and six pound N per 1000 sq. ft. rate caused more injury than the other nitrogen sources in 1990. In 1991, the higher rate of urea caused the most severe injury. Fertilizer derived from chicken feathers (9-2-4) was associated with the least injury and, consequently, the fastest recovery. Urea-treated turf was the slowest to recover from injury, reflecting the intensity of injury this nitrogen source caused. The methylene urea source was intermediate in injury and recovery when compared with the other two nitrogen sources.

EXPERIMENT 3

An experiment designed to determine if biostimulant activity could be ascertained in Kentucky bluegrass fertilized with processed chicken feathers coated with biostimulant materials. Plush Kentucky bluegrass was sown on a loam soil in 4 liter containers on 1 October, 1990 and fertilized with an organic 9-2-4 (derived from chicken feathers) coated with biostimulant materials as listed in Table 4 was applied. The containers were placed under a greenhouse mist system until 11 November when all irrigation was discontinued.

All grasses when fertilized with processed chicken feathers that were coated with the low dosages of biostimulants exhibited more tolerance of drought than the turf fertilized with the non-coated feathers (Table 4). Turf fertilized with the 9-2-4 that was coated with the triazole fungicide (Propiconazole or cyproconazole) wilted the least. However, turf treated with (FSE) to supply 0.6 oz. alone or with 10.4 g of Fe per 1000 sq. ft. also significantly reduced wilting when compared to the control.

Table 4. Wilting evaluation of Kentucky bluegrass generated from seed sown (1 g/sq. ft.) with a 9-2-4 organic fertilizer blended with various biostimulants to provide 2 lb. of N per 1000 sq. ft. on 1 October, 1990. Grass was kept moist until 11 November, 1990.

Biostimulant	Amount per 1000 sq. ft.	Wilt Rating, 20 Nov. 1990
		----1-9=most-----
Control	-	8.0 a[a]
FSE	.3 oz.	7.0 ab
FSE	.6 oz.	3.8 c
FSE + Fe	.6 oz. + 10.4 g	2.8 c
Propiconazole	.2 oz.	1.0 d
Cyproconazole	.2 oz.	1.0 d

[a]Means in the same column that have the same letter are not statistically different at the 0.1% probability.

EXPERIMENT 4

A study to determine the nutrient uptake and utilization efficiency of Kentucky bluegrass as influenced by fertilization and biostimulant treatment. Chicken litter obtained from layer houses had an analysis of 3-6-3 and fortified with methylene urea and sulfate of potash to obtain a 14-3-6 fertilizer was compared to urea. The 14-3-6 was 60% by weight chicken litter.

On 29 November, 1989 and 9 May, 1990 the 14-3-6 and urea was applied to separate plots to provide 14.7, 9.8, and 4.9 g N per meter squared. Urea-treated plots also received 4.9 and 4.7 g P_2O_5 and K_2O per meter squared.

One-half of the fertilized plots received 1 gal. per acre of FSE at the date of fertilization. Clipping yields from each plot were taken in the spring (March 27, 1990), dried and analyzed for N, P, K, Ca, Mg, and Fe content. Nutrient uptake efficiency (UP) was calculated:

$$UP = \frac{\text{Nutrient concentration x clipping yields}}{\text{Fertilizer level}}$$

Nutrient utilization efficiences (UE) was calculated:

$$UE = \frac{\text{Clipping yield}}{\text{Clipping yield x nutrient concentration}}$$

Turf color as a response to the fertilizer and biostimulant treatments were ascertained frequently during the experiment.

When color ratings of the turf were taken during the experiment were averaged, no significant differences between urea and the chicken litter fertilizer were obtained (Table 5). Both fertilizers improved color with rate of application.

Table 5. Color of Kentucky bluegrass grown under field conditions as influenced by different levels of urea and fortified chicken litter (14-3-6) applied on 29 November and 9 May, 1990.

Fertility N g/m^2	Average Color Rating Urea	Chicken Litter
	-------------9=best-----------------	
14.7	6.6 a[a]	6.7 a
9.8	5.7 b	5.6 b
4.9	4.5 c	4.5 c

[a]Means in same column that have the same letter are not statistically different at the 0.1 Probability level.

On 29 March, 1990 when clippings were collected for nutrient analysis, no differences in color rating between urea and the chicken litter fertilizer was obtained (Table 6). However, clipping yields of the turf were heavier when fertilized with the chicken litter than urea. Both color and yields were enhanced when the turf was treated with the fortified seaweed extract.

Table 6. March 29, 1990 clipping yield and color of field-grown Kentucky bluegrass turf as influenced by urea and fortified chicken litter fertilizer (14-2-9) with and without fortified seaweed extract applied 29 November, 1989.

Fertilizer	Clipping Yields	Color Rating
	---------g/m^2--------	-----1-9=Best-----
	No FSE	
45-0-0	23	5.6
14-2-9	31	5.5
	FSE	
45-0-0	25	5.8
14-2-9	32	5.8

Kentucky bluegrass uptake of all nutrients was more efficient with the application of chicken litter fertilizer as compared to urea (Table 7). However, the utilization of all nutrients tended to be more efficient with urea than the chicken litter fertilizer.

Application of FSE appeared to effect uptake efficiency of nutrients as well as increase the nutrient utilization efficiency for all nutrients except for nitrogen. Calcium and magnesium were the nutrients that were most enhanced in utilization efficiency when fortified seaweed extract was applied.

EXPERIMENT 5

An experiment designed to determine the effect of drought on Kentucky bluegrass as affected by chicken litter fertilizer (14-3-6) treated with biostimulants was initiated on 2 March, 1992. Four-inch diameter plugs were taken on 2 March, 1992 from a Kentucky bluegrass field established in September, 1991. The plugs were then transplanted to 4 liter containers filled with a sandy soil and placed under a mist system in a greenhouse. A 14-3-6 chicken litter-based fertilizer was blended with five different seaweed extracts and Banner, a triazole fungicide, as listed in Table 8. On 3 March, 1992, chicken litter-based fertilizer was applied to each plug to supply 1.5 lbs. of N per 1000 sq. ft. with and without the biostimulants.

Table 7. Nutrient efficiency uptake (UP) and utilization (UT) rating (the higher the number the more efficient) of field-grown Kentucky bluegrass as influenced by urea (45-0-0) and fortified chicken litter fertilizer (14-3-6) with different biostimulants applied on 29 November, 1989 and 9 May, 1989. Nutrient analysis determined on pooled clippings obtained.

Fertilizer	N		P		K	
	UP	UT	UP	UT	UP	UT
No Biostimulants						
45-0-0	32	25	3.5	235	19	44
14-2-9	45	25	4.8	229	26	43
FSE						
45-0-0	33	26	3.6	243	19	47
14-2-9	45	25	4.9	230	27	42
	CA		MG		K	
	UP	UT	UP	UT	UP	UT
No Biostimulants						
45-0-0	4.6	187	1.4	601	816	107
14-2-9	5.9	183	2.0	598	1088	101
FSE						
45-0-0	4.4	195	1.4	625	786	110
14-2-9	5.8	192	1.8	613	1035	108

Beginning on 11 March, 1992, 200 ml of a 0.2% NaCL solution was applied to one-half of the treated plugs three times a week to provide an artificial drought. The other half received 200 ml of potable water. Root development was ascertained on 21 April, 1992 by the vertical root lift technique. There was no significant root development differences between the salt and potable water irrigation (Table 8).

Evidently the soil salt concentration with the saline irrigation had not increased sufficiently to influence root growth. A longer irrigation period may have shown root inhibition with the saline treatment. When data were pooled between irrigation treatments, all grasses fertilized with biostimulant-treated 14-3-6 produced significantly more roots than the non-biostimulant control. Root development increased from 23 to 43% when seaweed extracts were blended with the fertilizer. A 20% increase was realized with the triazole fungicide treatment. These data indicate that biostimulants blended with chicken litter-derived fertilizer will further enhance turfgrass root development.

Table 8. Kentucky bluegrass root development as affected by chicken litter fertilizer (14-3-6) treated with biostimulants. Fertilizer was applied at 1.5 lb. N per 1000 sq. ft. Experiments initiated in greenhouse 2 March, 1992. Irrigated with potable and salt water for seven weeks.

		Root Development 21 April			
Biostimulant	Amt/1000 sq. ft.	No Salt	Salt	Average	% >
		Vertical root lift ($kg/180\ cm^2$)			
FSE	9 oz.	9.9	9.9	9.9 a[a]	43
SE-1	2 oz.	8.6	10.3	9.4 ab	36
SE-2	4.5 oz.	9.4	8.9	9.1 ad	32
SE-3	8 cc	9.9	8.3	9.1 ad	31
SE-4	1 oz.	8.6	8.4	8.5 bd	23
Banner	1 oz.	8.1	8.5	8.3 be	20
Control	-	6.9	7.0	6.9 f	-

SUMMARY

Fertilizers derived from either poultry litter or from chicken feathers were satisfactory for use in turfgrass production. The slow release nitrogen from these fertilizers provided a steady source of nutrition without causing excess foliar growth. These fertilizers were safe to apply, even during hot weather. Single applications to supply up to six pounds of nitrogen per 1000 sq. ft. from chicken feathers derived fertilizer (an extremely high rate) did not cause significant phytotoxicity.

Application of fertilizer processed from chicken feathers and coated with low dosages of biostimulants conditioned the turf to become more tolerant of drought. Both the triazole fungicides and the FSE treatments caused a significant reduction in turf wilting. Turfgrass nutrient uptake was enhanced when fertilized with chicken litter derived fertilizer as compared to grass fertilized with urea. Nutrient uptake as well as nutrient utilization efficiency was further enhanced with the FSE treatment. Root development increases were associated with both triazole and FSE coating of chicken litter derived fertilizer.

STATE REGULATIONS FOR WATER POLLUTION ABATEMENT IN POULTRY PRODUCTION

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State water quality programs are designed to fulfill the Federal Clean Water Act's mandate to protect and nurture aquatic life and to allow for designated activities in and on the water. Individual State standards designate water uses, i.e. drinking water, recreational purposes, etc., and contain criteria specifying the level of quality needed to protect a designated use.

Certain general water quality criteria are common to most states. Typically, states prohibit wastewater discharges that would interfere with the designated uses of State waters by creating unfavorable conditions. These conditions may include turbidity, color, oil films, floating solids, deposits, and offensive tastes or odors. In states that have not issued water quality standards, or have issued standards not consistent with the Clean Water Act, processors must comply with federal standards issued by EPA.

In addition to the general water quality criteria which must be met, processors must also meet specific criteria for point source discharges which are generally specified in a pretreatment permit issued by a municipality or a National Pollutant Discharge Elimination System (NPDES) permit issued by the EPA or a designated State. These permits typically specify allowed discharge levels for:

- Flow
- pH
- BOD
- Total suspended solids
- Oil and grease

and, in some cases:

- Total kjeldahl nitrogen
- Ammonia nitrogen
- Nitrate nitrogen
- Total phosphorus

Whereas the water quality programs have traditionally concentrated on controlling point source discharges, under the 1987 amendments to the Clean Water Act, the control of nonpoint sources of pollution has become a crucial component of each State's water quality program. As a result, processors will be required to obtain stormwater discharge permits to cover operations from processing plants and feed mills and will be subject to increasing scrutiny and regulation as relates to manure, dead bird, and wastewater pretreatment/treatment residuals management.

This paper addresses the trends in State water quality regulations, with emphasis in the following key areas:

- Pretreatment permits
- NPDES permits
- Stormwater permits
- Manure and dead bird management
- Wastewater pretreatment/treatment residuals management

STATUS OF STATE PROGRAMS

Table 1 summarizes the status of State programs as relates to NPDES permit delegation, pretreatment programs, and general permit programs, as of April, 1992. In general, where States have received delegation for programs from the EPA, the burdens on processors are somewhat reduced. Where states do not have delegation, processors are subject to the "double jeopardy" of federal and state regulations. All States have received delegation for one or more programs, with the exception of:

- Alaska
- Arizona
- Florida
- Idaho
- Louisiana
- Maine
- Massachusetts
- New Hampshire
- New Mexico
- Oklahoma
- South Dakota
- Texas

(Note: The list changes frequently. One or more States may have received delegation subsequent to April, 1992.)

PRETREATMENT PERMITS

Pretreatment permits are generally issued to processors who discharge to municipalities. The permits typically specify the quantity and quality of the following parameters which can be discharged:

- pH
- BOD
- Total suspended solids
- Oil and grease

Any processor who now discharges to a municipal system and is not controlled by a permit should expect that a permit will be required in the very near future.

TABLE 1. State NPDES Program Status

State	Approved State NPDES Permit Program	Approved State Pretreatment Program	Approved State General Permit Program
Alabama	X	X	X
Arkansas	X	X	X
California	X	X	X
Colorado	X		X
Connecticut	X	X	X
Delaware	X		
Georgia	X	X	X
Hawaii	X	X	X
Illinois	X		X
Indiana	X		X
Iowa	X	X	
Kansas	X		
Kentucky	X	X	X
Maryland	X	X	X
Michigan	X	X	
Minnesota	X	X	X
Mississippi	X	X	X
Missouri	X	X	X
Montana	X		X
Nebraska	X	X	X
Nevada	X		
New Jersey	X	X	X
New York	X		
North Carolina	X	X	X
North Dakota	X		X
Ohio	X	X	
Oregon	X	X	X
Pennsylvania	X		X
Rhode Island	X	X	X
South Carolina	X	X	
Tennessee	X	X	X
Utah	X	X	X
Vermont	X	X	
Virginia	X	X	X
Washington	X	X	X
West Virginia	X	X	X
Wisconsin	X	X	X
Wyoming	X		X

In the past, pretreatment permits have typically specified limitations which are not to be exceeded, limitations over which surcharges will be paid, or both. As effluent limitations and sludge management requirements for municipalities become more stringent in the future, processors can expect the treatment requirements to be "passed back". Specifically, future pretreatment permits will likely have one or more of the following provisions:

- Reduced BOD, total suspended solids, and oil and grease limitations designed to reduce sludge production at municipal plants and prolong and enhance overall municipal treatment plant efficiency.

- Limitations on total Kjeldahl nitrogen and/or ammonia nitrogen to facilitate municipal treatment plant nitrification/denitrification process efficiency.

- Limitations on total phosphorus to reduce municipal plant construction and operation and maintenance costs for nutrient removal.

Processors should prepare for these more stringent pretreatment limitations by beginning now to control flows and pollutant loadings at the source.

NPDES PERMITS

NPDES permits are issued by delegated states or the EPA and cover point source discharges from processors. The permits can either be technology based or water quality limited permits. Technology based permits generally apply to discharges to high flow rivers such as the Mississippi River and are less stringent. Very few processors operate under technology based permits. Water quality limited permits establish site and discharge specific limitations which are necessary to achieve receiving stream water quality standards. The majority of processors with NPDES permits operate under water quality based permits. The approach to the issuing of water quality based permits varies significantly among states. For example, in the State of Texas, discharges to streams are allowed, with typical effluent limitations being in the following range:

- pH - 6 to 9
- BOD - 5 to 15 mg/l
- Total Suspended Solids - 15 to 30 mg/l
- Oil and Grease - 10 mg/l
- Ammonia Nitrogen - 1 to 5 mg/l

In contrast, the State of Georgia discourages direct discharges and issues numerous no discharge land application permits requiring the following range of wastewater quality prior to land application:

- o BOD - 200 to 250 mg/l
- o Nitrate Nitrogen - 10 mg/l
- o Total Nitrogen - based on nutrient balance

Future trends in NPDES permits are not expected to change significantly, with one exception. Specifically, numerous processors operate biological treatment systems which meet specific Kjeldahl nitrogen and/or ammonia nitrogen limitations through biological nitrification. Many of these facilities do not have denitrification capabilities, which results in high nitrate nitrogen levels in discharges. Because nitrate nitrogen is associated with "blue babies" and can also serve as a nutrient source, processors with systems which provide nitrification, but no denitrification, should expect that future permits may impose nitrate nitrogen limitations. Any new biological treatment systems should be designed with full nitrification/denitrification capabilities in mind.

STORMWATER PERMITS

The Water Quality Act of 1987 added Section 402(b) to the Clean Water Act, which requires EPA to develop a phased approach to regulating stormwater discharges under the NPDES program. Stormwater is rain or snow runoff that comes into contact with an industrial facility or is contaminated by overburden, raw material, products, or wastes, whether the water is intentionally channeled or collected.

The EPA has determined that poultry processors must obtain stormwater permits for processing plants and feed mills. The stormwater permit must be in the form of a group permit issued to a group of plants or mills in the same industry, an individual permit applied for by a specific plant or mill, or a general permit issued by a State or an EPA Region. Many processors have elected to apply for a group permit through the National Broiler Council. Others have elected to apply for individual permits. General permits may be issued which are applicable to those processors not involved in the group permit or individual permits.

While the exact outcome of this stormwater permitting process is not known at this time, processors should understand that this regulation will impose significant monitoring, recordkeeping, and reporting requirements, as a minimum. Where processors have significant yard and drive areas which are subject to surface contamination from live haul vehicles, grain or finished product vehicles, etc., significant costs may be incurred to eliminate contamination at the source or treat contaminated runoff. Processors are encouraged to audit existing "outside" activities which can result in the potential for stormwater contamination and be prepared to take measures to eliminate or treat the contamination.

MANURE AND DEAD BIRD DISPOSAL

The State regulations for manure and dead bird disposal vary significantly across the country. On the Eastern Shore where land areas for manure application are limited and ground water elevations are near the surface, regulations have long been stringent. In Arkansas and Texas, where land areas are larger, limitations have been less stringent. However, this situation is changing. With the increased emphasis on environmental protection, particularly as brought to focus by this year's Presidential election, processors can expect increasingly more stringent regulations regarding manure and dead bird disposal.

As an example, the State of Texas has recently proposed new "Livestock and Poultry Production Operations Rules" which would drastically change the requirements associated with manure and dead bird disposal in the state. Specifically, whereas breeder and broiler farms have traditionally been exempt from Confined Animal Feeding Operation (CAFO) regulations because the regulations specify that only facilities with "unlimited continuous overflow watering systems" or "liquid manure handling systems" are covered, the new regulations would remove these phrases and require that many larger breeder and broiler farms be registered and permitted. Along with this registration and permitting would come extensive monitoring, recordkeeping, and reporting requirements which now do not exist. Additionally, the new regulations would require extensive submittals to the state regulatory agency before a new farm could be built. To date, the regulations are on hold. However, it is impossible to anticipate the future.

In any event, as a minimum, in the future it will be necessary to better control the disposal of manure and dead birds by educating growers in best management practices, or have the regulations forced upon us.

WASTEWATER PRETREATMENT/TREATMENT RESIDUALS MANAGEMENT

Wastewater pretreatment skimmings and wastewater treatment sludges have traditionally been disposed of by land application. Where adequate land exists, there is an excellent method of management which can provide beneficial reuse of the skimmings and sludges. However, land application has the potential for surface or ground water contamination if not managed properly. The EPA and many States are encouraging the development and utilization of technologies which reduce or eliminate waste materials. Recent work completed by numerous processors indicates that pretreatment skimmings can be recovered and rendered at a profit through the use of acidulation for pretreatment versus iron salts. Processors are encouraged to investigate this technology where DAR systems are being used for pretreatment. Additionally, a few processors are successfully rendering biological sludge. While this approach may not work for all, it should be looked into as a means of reducing or eliminating the volume of sludge requiring land application.

SUMMARY

In summary, processors should expect that regulations will be come more stringent in the future. The State regulations which will likely have the greatest impact on processor will be:

- o Pretreatment requirements for nutrient reductions
- o NPDES requirements for denitrification
- o Stormwater permits
- o Manure and dead bird disposal requirements

WATER QUALITY AND POULTRY PRODUCTION IN THREE HYDROLOGIC UNITS IN ARKANSAS

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Arkansas is one of the leading poultry producing states in the nation with an annual production of approximately one billion broilers, 16 million layers, and 22 million turkeys. Concerns about the impact of land application of animal manure on water quality prompted the funding of three joint USDA hydrologic projects in the state in 1990 and 1991.

HYDROLOGIC UNIT PROJECTS

Moores Creek/Muddy Fork

The Moores Creek/Muddy Fork project in Washington County was funded in 1990 as one of the highest nonpoint source priority hydrologic units in the state. Total annual poultry population in the watershed approaches 20.5 million birds per year on 47,122 acres. This amounts to over 430 birds per acre or 800 birds per acre of pastureland. Over 19 million of these are broilers. Total annual nutrients produced in the watershed for poultry, dairy, and unconfined beef cattle is about 3.7 million pounds of nitrogen and 3.4 million pounds of phosphorus. Approximately 88 percent of the N and 90.5 percent of the P is from poultry production.

Long Creek

The Long Creek hydrologic unit project in parts of Carroll and Boone Counties was funded in 1991. The total annual poultry population in Long Creek Watershed approaches 24 million birds per year on 96,574 acres. This amounts to 248 birds per acre or 315 birds per acre of pastureland. Over 18.5 million of these are broilers and over 3 million are turkeys. Total annual waste produced in the watershed for poultry, dairy, and unconfined beef cattle is about 490,000 tons. Poultry produces approximately 155,000 tons of manure per year. Essentially all is surface applied as dry litter for pasture fertilization. This is over 6 tons of animal waste for every acre of pastureland in the watershed. The safe application rate for broiler litter is approximately 4 tons annually. Poultry produces 60 percent of the N and 82 percent of the P. A third of the total N and P is produced by turkeys.

Millwood Lake

The Millwood Lake demonstration project is different from the other two hydrologic unit projects in that the water in the lake is not considered impaired for any use. The project funded in 1991 comprises 1.3 million acres in all or parts of five counties in the southwest corner of the state. Millwood Lake is a 30-year old manmade multi-purpose reservoir that serves as a source of household water for approximately 100,000 people. Half of the 4,144 square mile watershed is in Oklahoma. Land use is about 65 percent forestland, 25 percent grassland, 5 percent cropland, and 2 percent urban. Water from the three Arkansas tributaries that flow from the Ouachita Mountains to feed the Little River and Millwood Lake is of excellent quality. At the present, it meets all standards established by the Safe Drinking Water Act. However, a large increase in the confined feeding of poultry and swine has raised concerns about the protection of the water supply from plant nutrients and animal wastes. There has been a trend for increasing concentrations of total phosphorus and chlorophyll A in the lake water. Both are indicators of nutrient enrichment.

ACTION TAKEN

A full time coordinator was hired by Extension for each of the projects. The SCS assigned similar coordinators. One or two agricultural technicians were hired in each of the counties involved to collect soil, water, manure, and plant samples and conduct field demonstrations and other educational activities.

The first step in all three projects was to inventory the soil, water, plant and animal resources in the watershed. This includes the amount of animal waste generated and how it is being utilized. The next step was to determine the quality of the surface and ground water in the watersheds. A third step was to determine the major possible avenues of contamination of water from animal wastes generated by poultry production. Major avenues that were identified include: (1) poultry carcass disposal, (2) uncovered poultry manure stockpiles, (3) old poultry house pads, (4) excessive rates of manure application to the land, and (5) improper land application of manure with respect to runoff and surface water sources. Research projects have been developed at the University of Arkansas to answer some of the questions concerning these possible pathways.

The fourth step was to develop and promote best management practices (BMP's) that will protect water quality. Most of the water quality BMP's that were promoted for implementation by poultry producers are the same ones that have been promoted for erosion control.

RESULTS

Soil and Water Testing

More than half of the soil acreage in the Moores Creek/Muddy Fork HUA has been sampled by the technicians and tested for routine analysis plus nitrate-N. A lesser percentage of the acreage in the Long Creek HUA has been tested. Soil sampling in the Millwood watershed was only recently initiated. In the Moores Creek HUA only about 0.5 percent of the soils were high in nitrates. Less than 20 percent of the soils were high in phosphorus (greater than 300 lbs per acre by Mehlich III extraction). Although only about 30 percent of the soils need phosphorus fertilization for crop production according to University of Arkansas soil test recommendations, producers continue to apply poultry litter to the land. Concerns are that soils high in extractable P may contribute to pollution by streams and lakes receiving runoff from these fields. A total of 341 soils were sampled and tested for their capacity to fix phosphorus. Most had the capacity to fix much more P than was available by routine soil test extraction methods.

Nearly 250 surface or ground water samples were collected and tested for nitrates and P. Concentrations in most of the samples were well below the guidelines set by the EPA. Much of the soil test and water quality data from Moores Creek has been entered into the University of Arkansas GIS data bank for tabulation and display.

Best Management Practices

Nutrient and waste management plans are being written for cooperators by SCS in cooperation with Extension agents and technicians. Specific farms are being identified to establish demonstrations of animal waste management practices to show producers recommended BMP's for protection of water quality. Plans are being prepared for producers to balance the amount of nutrients that are land applied with plant needs. Cost-share funds are available to help producers install eligible water quality practices. Technical practices that are being installed for poultry producers include: 1) poultry carcass composters, (2) dry litter stacking sheds, (3) improvement and establishment of vegetative cover, (4) treatment of critically eroding areas, and (5) pond construction.

Educational Methods

Traditional Extension educational methods have been used to reach poultry producers. These include public informational meetings, dissemination of information through the mass media (radio, TV, newspapers, etc.), fact sheets and other direct mailings, practice demonstrations, and tours or field days. For example in the Moores Creek/Muddy Fork project alone, thirteen practice demonstrations have been established by Extension, including two whole farm demonstrations. Twenty three educational tours have been conducted, with a total attendance of over 800 people have been conducted. In the Millwood project, the SCS has established BMP demonstrations on twelve farms covering 1,579 acres. Water quality practices, such as dead bird composting, poultry manure stacking sheds, nutrient and animal waste management, and pasture management have been applied on these demonstration farms. County Extension agents will use these demonstration farms for tours and field days. Cost-share funds will be provided to other producers in the watershed to carry out the approved water quality BMP practices.

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THE EFFECT OF WATER QUALITY ON BROILER AND TURKEY PERFORMANCE

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Water quality, pollution abatement and recycling are "buss-words" at the National, State and local levels among members of government agencies, the consuming public and generally in the various agricultural industries. We have been interested in the mineral content of water and its effect on performance of poultry for a number of years. We have conducted a broiler study involving 300 farms and a turkey study involving 100 farms to determine the effect that water quality has on performance.

BROILER STUDY

This study was conducted in cooperation with three integrated poultry companies that had at least two locations in the state. Water was tested from 300 broiler farms in the state (100 samples from each company). Twenty-five top producers and 25 bottom producers were selected at each location by each company. Attempts were made to eliminate poor producers that had obviously inadequate housing or poor management practices. Performance data for the previous year were obtained from the integrated company to use in this study. Performance criteria were feed conversion, body weight, livability, and condemnation.

Since different companies produce broilers to different ages and different market weights, these data were adjusted to a 49-day body weight and 49-day feed conversion by linear regression. The livability and condemnation information were not adjusted. One company produced a significant number of all male broilers. These data were converted to mixed-sex weights and feed conversion by least square procedures.

The water samples were collected either at the well source or at point of entry into the broiler house. These mineral-analysis samples were collected in quart plastic bottles and transported to the University of Arkansas Diagnostic Laboratory for analysis. Samples were assayed for the items listed in Table 1 according to procedures listed in **Standard**

Methods for the Examination of Water and Waste Water, 1980, 15th Edition, American Public Health Association.

Table 1. Analyses Conducted on Water Samples

Cations	Anions	Other
Ammonia	Phosphate	pH
Calcium	Nitrate	Electrical conductivity
Magnesium	Sulfate	Hardness
Sodium	Bicarbonate	Dissolved oxygen
Potassium	Carbonate	
Iron	Chloride	
Zinc	Nitrite	
Manganese		
Copper		

Bacterial samples were collected either by the author or by selected personnel within these companies. The procedure for collecting these samples was to flame the water faucet with a propane torch, run a small amount of water to cool the faucet, and collect the sample in a sterile container. None of these samples were collected inside broiler houses in which birds were present. (It is the authors opinion that an aseptic sample cannot be collected inside a broiler house when birds are present). These bacterial water samples were transported to laboratories of two of the companies involved in this study and plated the same day as collected. The samples were cultured for E. coli using MacConkey's media and for Pseudomonas using Cetrimide agar. One-half milliliter of water was used for each plate.

RESULTS

In the overall analysis, nitrate was the only mineral that had a significant effect on performance. Higher nitrate levels had a detrimental effect on performance.

Simple correlation coefficients that were significant ($P<.05$) are shown in Table 2 for the overall analysis. Calcium was negatively correlated with adjusted conversion, meaning that as calcium increased conversion decreased. That is, conversion improved as calcium increased.

Magnesium was positively correlated with adjusted conversion, or, had an adverse effect on conversion.

Dissolved oxygen, bicarbonate, hardness, calcium ($P<.09$) and magnesium all were positively correlated with adjusted weight while nitrate was negatively correlated with adjusted weight.

Table 2. Overall Results

	Positive Correlations	Negative Correlations
Adj. conversion	Mg	Ca
Adjusted wt.	DO, HCO_3, Hard., Ca (.09), Mg	NO_3
Livability		Ca, K
Condemnation	Ca, NO_3	
pH	EC, PO_4, Ca, Na, HCO_3, CO_3, Cl	NH_3, Fe, Mn, NO_3
Electrical conductivity	pH, Hard., NH_3, PO_4, Ca, Mg, Na, K, SO_4, Cu, HCO_3, CO_3, Cl	
Hardness	EC, NH_3, Ca, Mg, Adj. wt., Zn NO_3, SO_4, Cu, HCO_3, Cl	
Ammonia	EC, Hard., K, Fe, Mn, SO_4, Cl	pH, DO
Phosphate	pH, EC, Na, HCO_3, CO_3, Cl	DO
Calcium	pH, EC, Hard., Mg, Adj. conv., Zn, NO_3, SO_4, Ca, HCO_3	
Magnesium	EC, Hard., Ca, Adj. wt., Adj. conv., Mn, SO_4, DO, HCO_3, Cl	
Sodium	pH, EC, PO_4, K, HCO_3, Cl	DO
Potassium	EC, NH_3, Na, NO_3, HCO_3, Cl, NO	Liva, DO
Iron	NH_3, Zn, Mn, NO_2	pH
Zinc	Hard., Ca, Fe, SO_4, NO_2	
Manganese	NH_3, Mg, Fe, SO_4	pH, HCO_3
Nitrate	Cond., Hard., Ca, K	pH, Adj. wt., HCO_3
Sulfate	EC, Hard., NH_3, Ca, Mg, Zn, Mn, Cu, HCO_3, Cl	
Dissolved oxygen	Mg, Adj. wt.	NH_3, PO_4, Na, K
Copper	EC, Hard., CA, Mg, SO_4, HCO_3	
Bicarbonate	pH, EC, Hard., PO_4, Ca, Mg, Na, Mn, NO_3., Adj. wt., K, SO_4, Cu, CO_3, Cl	
Carbonate	pH, EC, PO_4, HCO_3	
Chloride	pH, EC, Hard., NH_3, PO_4, Mg, Na, K, SO_4, HCO_3	
Nitrite	K, Fe, Zn	

Calcium and potassium were negatively correlated with livability, indicating that livability decreased as calcium or potassium increased. This detrimental effect of calcium on livability is opposite to the beneficial effect of calcium on adjusted conversion and adjusted weight. One explanation could be that calcium is interfering with water vaccination and thus affecting livability. Calcium and nitrate were positively correlated with condemnation.

The bacterial results were analyzed on a positive or negative basis using Chi Square procedures. No significant differences were found between top and bottom producers for either *Pseudomonas* or *E. coli*. The number of positive samples by company and by location is shown for top and bottom producers in Table 3.

Table 3. Number of Positive Bacterial Samples

		Pseudomonas		*E. coli*	
Company	Location	Top	Bottom	Top	Bottom
1	1	0	4	6	9
2	3	2	1	4	4
2	4	0	2	0	7
3	5	2	2	9	10

Company 1 and company 3 producers were tested at the headquarters location only, while company 2 producers were tested at both locations. Company 2 had been testing farms for quite some time and chlorinating those found to be positive. This explains why they had only about one-half the number of positive farms as companies 1 and 3.

DISCUSSION

The summary of the water quality data and the analysis of variance show that water quality was not significantly contributing to top and bottom producers in this study, except in the case of nitrate. However, in the simple correlation analysis, where all producers are compared together, significant findings have been shown that relate to adjusted conversion, adjusted weight, livability and condemnation. An examination of the simple correlation analysis, and the raw data (not shown in this report) shows that dissolved oxygen may be an important indicator of mineral water quality. Individual samples that contain low dissolved oxygen usually have increased levels of K, PO_4, Cu, FE, NO_3, or Mn, and in some cases Na, Cl and HCO_3. Individual samples that have high levels of K, PO_4., Cu, Fe, No_3 or Mn, or combinations of more than one of these minerals may have high dissolved oxygen levels. In these cases, Mg and/or Ca are at elevated levels, which offers a protective effect. This is supported by the fact that Mg and Ca were positively correlated with weight in the simple correlation analysis.

The positive correlation of hardness with adjusted weight could be explained in the same manner, since calcium and magnesium are primary contributors to hardness of water. Since Fe, Mn and NO_3 were negatively correlated with pH, this may help to explain the positive response of body weight to increasing pH.

A word of caution should be mentioned in regard to dissolved oxygen, hardness and pH. These are probably only indicators of water that affects body weight. Injecting oxygen, adding materials to increase hardness, or using a soda ash feeder to increase pH may not improve performance. Removing the underlying problem that is contributing to these indicators should be the approach to improving water quality.

SUMMARY

Water samples from 300 broiler farms in Arkansas were analyzed for mineral content and the mineral content correlated with body weight, feed conversion, livability, and mortality. Twenty-five top and 25 bottom producers were selected at each of two locations by three integrated broiler firms (100 samples from each company). Bacterial samples were collected from 200 of these farms and cultured for <u>Pseudomonas</u> and <u>E. coli</u>. No differences were found between top and bottom producers related to bacterial contamination.

Dissolved oxygen, bicarbonate, hardness, calcium ($P<.09$) and magnesium were all positively correlated with growth rate while nitrate was negatively correlated with growth rate. Calcium was negatively correlated with feed conversion while magnesium was positively correlated with feed conversion. This means that feed conversion improved as calcium went up and got worse as magnesium went up.

Calcium and potassium were negatively correlated with livability. This detrimental effect of these minerals may be related to interference of water vaccination and this affecting livability. This same possibility may exist where calcium and nitrate were positively correlated with condemnation.

It appears that dissolved oxygen may be an important indicator of mineral water quality. Individual samples that contain low dissolved oxygen usually have increased levels of K, PO_4, Cu, Fe, No_3, or Mn. Individual samples that have high levels of one or more of these minerals can have high dissolved oxygen.

In these cases, Mg and/or Ca are at elevated levels, which offers a protective effect.

TURKEY STUDY

This study was conducted in cooperation with three integrated turkey companies. Water was tested from 100 turkey farms in the state although the numbers were not equal between companies. Performance criteria were the same as in the broiler study. The performance data were adjusted to 130-day age and were adjusted for sex. The same minerals were analyzed as in the broiler study. In addition, an aggressive index was calculated for each sample and analyzed in this study. Bacterial samples were not collected in this study.

RESULTS

Significant correlations in the turkey study are shown in Table 4. Ca, Mg, HCO_3, hardness and Aggressive Index were beneficial to feed conversion. PO_4 and NH_3 were detrimental to feed conversion. Ca, Mg, DO, Zn, hardness, and Aggressive Index were all positively correlated with adjusted body weight. Magnesium was negatively correlated with livability. Magnesium and Aggressive Index were positively correlated with condemnation while K, Zn, NO_3, and PO_4 were negatively correlated with condemnation. Although fewer numbers of farms were involved in this study, the results generally support the results of the broiler study.

Table 4. Turkey Water Study

	Positive Correlation	Negative Correlation
Adjusted conversion	PO_4, NH_3	Ca, Mg, NCO_3 Hard., AI
Adjusted weight	Ca, MG, DO, Zn, Hard., AI	
Adjusted Livability		Mg
Adjusted condemnation	Mg, AI	K, Zn, NO_3, PO_4

RECOMMENDATIONS

Producers and integrators generally get around to questioning water quality after they have exhausted other possibilities on problem farms. We suggest testing the water for mineral content through our Diagnostic Laboratory or similar labs in their state.

In addition, we recommend testing the water for bacterial contamination at the same time. Chlorination will be a cheaper first treatment in trying to correct water quality related performance problems. We also ask producers if they are on a rural water system. In some cases, we suspect that high chlorine levels are interfering with field vaccinations.

Water quality will be an important area of study in future years. We certainly need to learn more about this important component of poultry production.

ANAEROBIC TREATMENT OF POULTRY PROCESSING WASTEWATERS

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Most poultry processing plants pretreat wastewater before discharge to a publicly owned treatment works (POTW), a receiving stream with a National Point Discharge Elimination System (NPDES) permit, or land treatment system. Wastewater discharged from a poultry processing operation contains relatively high concentrations of conventional pollutants shown in Table 1. To meet typical pretreatment levels for biochemical oxygen demand (BOD_5), total suspended solids (TSS) and fats, oil and grease (FOG) a reduction of 80 to 90% is required. Meeting pretreatment levels is necessary to not only comply with maximum permitted limits but also to avoid costly surcharges. The possibility of severe civil and criminal penalties exist for violating water quality standards.

In the United States, many poultry processors have installed on-site wastewater treatment systems. Among the most popular pretreatment method is dissolved-air flotation (DAF). To obtain the 80 - 90% removal efficiencies required to meet pretreatment requirements (Table 1), the DAF process has to be augmented by the addition of coagulant and/or flocculant chemicals (with pH adjustment if needed). The most commonly used chemicals for treating poultry processing wastewater are trivalent salts of iron or aluminum, often in combination with organic polymers (polyelectrolytes). To be effective, attention must be given to pH, alkalinity, physical mixing and floc removal. Generally, this combination of chemicals has been effective in reducing the pollutant concentrations to meet pretreatment requirements; however, the resultant hydroxide based skimmings are notoriously difficult to dewater.

This skimmings material is often rendered, but many renderers are becoming less willing to accept DAF skimmings because the water content is high and there are concerns over quality. Landfill disposal without dewatering is no longer an option for processors in many states because regulations for disposal of liquid in landfills have tightened. Land application of the skimmings, to utilize the fertilizer value, is sometimes an option but problems exist with odors, storage requirements during periods when it cannot be applied, and potential of groundwater contamination.

The cost of chemical addition and the associated cost of skimmings dewatering and disposal significantly adds to the capital and operating costs of a DAF based pretreatment system. This opens the door to other pretreatment technologies such as anaerobic biological treatment to provide pretreatment quality effluents with the potential for lower sludge disposal and operating costs.

Table 1. Poultry Processing Wastewater Characteristics and Pretreatment Goals

PARAMETER	AVERAGE CONCENTRATION (mg/L)	PRETREATMENT OBJECTIVE (mg/L)	PERCENT REMOVAL (%)
BOD_5	1800	250	86
TSS	1500	250	83
FOG	500	100	80

BASICS OF ANAEROBIC TREATMENT

Anaerobic biological treatment offers an alternative to traditional wastewater pretreatment (Table 2). The process is capable of providing pretreatment quality effluents from wastewater generally thought to be too high in soluble and total organics for conventional aerobic biological processes. The process uses anaerobes, bacteria that live in an environment without oxygen, to capture and digest organic materials in wastewater. The various types of anaerobes in a treatment system break down organic materials in several steps, finally yielding methane and carbon dioxide. The anaerobic reaction can be best described as a three step process:

1. Hydrolysis of suspended organics and high molecular weight soluble organics.
2. Degradation of small organic molecules to volatile fatty acids and eventually acetic acid.
3. Production of methane from acetic acid, hydrogen and carbon dioxide.

The steps in an anaerobic process are carried out by two major groups of organisms: acetogenic bacteria which primarily carry out Steps 1 and 2 and methanogenic bacteria which are primarily involved in Step 3. The specific bacteria used in an anaerobic treatment process are developed by a natural selection process that depends largely upon the wastewater substrate, the initial culture in the anaerobic seed material or inoculum, and system temperature. Most anaerobic bacteria are easily available from a number of municipal, industrial, agricultural, and natural sources.

Unlike aerobic bacteria, anaerobes require no oxygen. Because they reproduce slowly, they produce a minimum amount of sludge. For example, many anaerobic systems will only have waste solids no more than every six months. The sludge is already stabilized and ready for land application. Moreover, the methane the anaerobes produce is usually of high enough quality to be used for fueling boilers and other energy devices.

In general, anaerobic bacteria prefer stable temperatures in the 35° C (95° F) range, neutral pH (7.0), and adequate nutrients (nitrogen and phosphorus) for cell growth. These major nutrients are usually readily available in most meat and poultry processing wastewaters. Moreover, poultry processing wastewaters typically are discharged from the plant with a pH near neutral reducing the need for buffering chemicals.

ANAEROBIC TREATMENT SYSTEMS

Anaerobic digesters often have been used to stabilize municipal wastewater sludges over the last half of this century. And, as illustrated in Table 3, a variety of anaerobic systems have been developed over the years for specific wastewater treatment applications. The systems shown in Table 3 represent the more common types of systems in use today for the pretreatment of industrial wastewaters, including those from food processing operations. Each type of system has its advantages and disadvantages in the areas of control, operation and maintenance, space requirements, and capital cost (Table 4).

Anaerobic Lagoons

Traditionally, anaerobic lagoons are considered low-rate systems designed to handle low organic loading rates primarily due to the high hydraulic retention times required by their low temperature operation. Treatment takes place under these low hydraulic conditions through contact with the microbial biomass that accumulates in the sludge on the bottom of the lagoon or is suspended due to rising gas or hydraulic mixing. Treatment can be obtained at temperatures as low as 72°F (Totzke, 1990).

Anaerobic lagoons have the advantage of being easy to operate (no heating) and less expensive to build (earth removal). However, they also have the disadvantage of having poor

Table 2. Advantages and Disadvantages of Anaerobic Pretreatment[1]

ADVANTAGES	DISADVANTAGES
Low production of stabilized excess sludge	Start-up of process may take up a period of 8 weeks or more.
Production of a useful-end product in the form of methane	Anaerobic treatment is essential and only effective as a pretreatment process
Some sludge can be preserved unfed for long periods without any appreciable deterioration	There is less practical experience with the anaerobic process than with conventional aerobic processes
A high degree of waste stabilization is possible at high organic loading rates	Energy input might be required in some cases to maintain optimum operational temperature
The excess sludge has good dewatering characteristics	
Low nutrient requirements	
May be less sensitive to toxic compounds than aerobic processes	
The use of aeration equipment is not necessary	

[1]Obayashi and Gorgan, 1985

Table 3. Anaerobic Systems in Use at Food Processing Facilities Worldwide

Anaerobic System	Number in Use[1]	Typical Loading Rates[2] (kg COD/m^3/day)
Lagoons	40[3]	1-2
Contact digesters	58	1-5
Upflow anaerobic sludge bed (UASB)	80	5-10
Filter or packed-bed	25	1-15
Hybrid	5	5-20

[1]Totzke, 1990
[2]Corbitt, 1990
[3]Totzke, 1988

volumetric treatment efficiency thereby requiring large areas in which to build. Because of the lack of biomass retention, anaerobic lagoons are more prone to upset from slug loadings and slow to start up and recover from upsets with periods of one to several months not uncommon (Sneed, 1987). Organic loading of a lagoon is typically limited to 1.0 kg COD/m^3-day as illustrated in the full-scale data in Table 5. Methane content of the biogas from a lagoon is also typically lower.

Some improvements to lagoon design have shown up in proprietary designs incorporating sludge recycling, sludge mixing, and flexible gas covers (Landine and Cocci, 1988 and Brown et al., 1990). These recycled sludge designs have been able to provide COD removals of 97% with organic loading rates of 1.24 kg COD/m_3-day. As illustrated in Table 3, over 40 anaerobic lagoons are in use for food processing wastewater treatment in the world (Totzke, 1988 and Totzke, 1990).

Contact Process

Another type of anaerobic system is the contact process designed to concentrate and recycle active biomass that would ordinarily discharge or "wash-out" from the system. A sidestream of the recovered biomass is returned to mix or "contact" with the incoming influent within the reactor. This results in an increase in solids retention time (SRT) while the hydraulic retention time (HRT) can be reduced. As illustrated in Table 3, the organic loading rate of a contact process can be two to three times greater than an ordinary lagoon process.

The extra process to remove the biomass is the primary disadvantage of the system (Table 4). Biomass recovery is typically accomplished through clarification, centrifugation, or filtration. In many cases, the effluent must be degasified, typically by vacuum, for the recovery process to work properly. Contact processes have the advantage over higher rate processes in avoiding the use of specialized and costly media or granulated sludges which must be maintained internally within the system.

Anaerobic Sludge Bed System

With anaerobic sludge blanket reactors, the anaerobic bacteria attach to heavy particles of granulated sludge that settle in the bottom of the reactor to form the sludge blanket. The sludge provides a very high surface area for contact with wastewater pollutants. These reactors typically are designed so that wastewater flows upward through the active biomass for treatment. Sludge blanket reactors and similar systems (such as fluidized bed reactors) are designed to handle much higher organic and hydraulic loading rates (one to two days) than either lagoons or contact digesters.

These higher rates reduce reactor size. However, these reactors are more difficult to operate and maintain than some other types of anaerobic systems. Should a sludge bed reactor fail completely, the sludge must be removed from the reactor and replaced with a specialized granular biomass. Furthermore, to date they have not been very effective in treating wastewaters with high oil and grease levels such as those found in meat and poultry processing. Most of these systems are limited in the amount of suspended solids that can be present in the wastestream and are susceptible to upset (Lettinga et al., 1980).

Filters or Packed Bed Systems

Anaerobic filters or packed beds (APBRs) retain biomass by the development of a biofilm on or within a packing media inside the reactor. The retention of the biomass results in higher SRTs while allowing greater surface contact between the active biomass and wastewater pollutants. Anaerobic filters using support media ranging from random pack stone or plastic pall rings to modular plastic media have been used to treat a variety of industrial wastewaters ranging from wheat starch processing to landfill leachate in full-scale applications in the U.S. and Canada (Young and Yang, 1989).

Laboratory results (Table 5) have indicated the potential of providing adequate pollutant removals, BOD_5 (82%), TSS (82%), and FOG (61%), with organic loading rates of 5.20 kg COD/m^3-day with an upflow packed bed reactor treating poultry processing wastewater (Harper et al., 1989). Similar laboratory results under loading conditions of 7.0 kg COD/m^3-day have been reported by Yang et al. (1986). Pilot testing using an upflow packed bed reactor with a conventional random pack, plastic media treating a poultry processing wastewater (Table 5) provided similar removals although at a lower loading rate (2.8 kg COD/m^3-day).

A primary disadvantage of a packed bed system is the capital cost (Table 4). The packing media used to retain biomass (random pack or modular media) can cost from $3 to $10 per cubic foot installed and is estimated to account for 33% of the total reactor cost or 15% of the total APBR system cost (Ross and Valentine, 1988). This cost can be greatly reduced through the use of a lower cost support media material or simply using less packing material.

Hybrid Systems

Hybrid reactors typically are a combination of both sludge bed and packed bed technologies. These high-rate designs have made possible the anaerobic treatment of some of the more dilute industrial wastestreams (down to 800 mg COD/L) in addition to reducing the hydraulic retention time required to treat more concentrated wastestreams from 10 days to 10 hours (Ross and Valentine, 1988). A popular hybrid design is the incorporation of a fixed film media in a sludge bed process to encourage biomass settling and increase the ability of the system to recover from a major upset.

As illustrated in Table 4, high-rate processes such as filters and sludge beds have distinct advantages over lower rate systems in the area of performance and control. However, they are not without drawbacks. Temperature control is very important in the operation of most of these high rate systems. Because the temperature of most food processing and agricultural wastestreams are below 80°F, energy above that produced by the system is required to maintain mesophilic operation resulting in a net energy requirement (Valentine et al., 1988). Due to the high organic and hydraulic loading rates, pH control is much more sensitive and typically requires some form of buffering chemical addition. The mechanical systems required to maintain temperature and pH control in addition to the physical construction of the reactor and the biomass retention system results in a fairly high capital cost relative to other treatment systems (Valentine et al., 1988). Furthermore, energy costs for maintaining system temperature can be the highest operating cost of these high-rate systems.

Table 4. Comparison of Anaerobic Systems

Anaerobic System	Organic Loading	Space Require-ments	Capital Require-ments	O&G Capacity[1]	Recovery Capacity[2]
Lagoon	low	high	low	high	medium
Contact	medium	medium	medium	medium	high
Sludge bed	high	low	high	low	low
Filter or packed-bed	medium	low	high	medium	high
Hybrid	high	low	high	medium	high

[1]Capacity of system to handle high oil and grease concentrations.
[2]Capacity of system to recovery from upset or shock loading.

CONCLUSIONS

The primary impediment to the use of newer, high-rate anaerobic systems for the pretreatment of poultry processing wastewater is the higher capital cost over that for a

Table 5. Performance of Anaerobic Treatment of Meat and Poultry Wastewaters

Origin of Process Wastewater	Anaerobic System	System Size	Influent Characteristics				COD Loading (kg COD/ m^3-day)	COD Removal (%)	BOD_5 Removal (%)	TSS Removal (%)	FOG Removal (%)	Gas Quality (% CH_4)	Temp (°F)	Reference
			BOD_5 (mg/L)	TSS (mg/L)	FOG (mg/L)	COD (mg/L)								
Pork	Lagoon	Full-scale	1,572	849	330	na	0.13[2]	na	91	82	88	57	ambt[3]	Dague, et al., 1989
Beef, pork, sheep	Lagoon	Full-scale	820	520	230	1,540	0.90	38	61	46	71	na	ambt[3]	Totzke, 1987
Beef, pork, sheep	Contact	Full-scale	1,315	524	342	na	0.56[2]	na	96	87	88	na	ambt[3]	Rand and Cooper, 1966
Beef	Contact	Pilot	2,300[1]	2,350[1]	150[1]	6,350[1]	3.0	84	93	75	na	82	98	Stebor et al., 1989
Poultry	Packed bed	Laboratory	1,023	703	265	2,043	5.2	80	82	82	61	79	98	Harper, et al., 1989
Poultry	Packed bed	Laboratory	na	1,168	1,316	3,482	7.0	90	na	85	88	89	98	Yang et al., 1986
Poultry	Packed bed	Pilot	1,016	1,177	169	2,478	2.8	66	86	84	92	75	98	Valentine, et al., 1988
Beef	Packed bed	Pilot	na	1,122	1,100[1]	3,135	3.6[1]	79	na	81	32[1]	81[1]	90	Andersen and Schmid, 1985

[1]Median values
[2]BOD_5 loading rate
[3]Operated at local ambient temperatures

comparable DAF based pretreatment system. However, as the cost of skimmings dewatering and disposal increases, more consideration may be given to anaerobic pretreatment of poultry processing wastewaters as a means to reduce wastewater pretreatment operating costs.

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MINIMIZING FACTORS INFLUENCING THE STABILITY OF THE NUTRIFICATION PROCESS

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Although there are numerous physical and chemical methods available for partial or complete Ammonia removal or transformation, biological treatment has proven to be the most cost effective, reliable, environmentally sound and, therefore, most popular means of transforming Ammonia into a nontoxic form. Recognition of the variability of treatment and the factors that cause this variability needs to be incorporated into the regulatory process, specifically into the rational development of average and maximum permit limits.

Biological systems rely on a chain reaction of microbiological activity to convert Ammonia first to nitrite using nitrosomonas bacteria and then oxidation of nitrite to nitrate by nitrobacter. The system most used at present is the single sludge activated sludge process which under normal circumstances can achieve an average discharge of 1.0 mg/l or less for sustained periods of time when treating poultry wastewater with ammonia levels in the 100-150 mg/l range. A variety of factors other than mechanical failure can effect the biological process. The most common ones are shown in Table 1.

Table 1. Factors Affecting Nitrification Efficiency in Biological Treatment

Temperature
Ammonia concentration
Dissolved Oxygen
pH
Food to microorganism ratio
Presence of toxic materials

TEMPERATURE

Temperature affects the nitrification process by modifying the efficiency of the bacteria responsible for nitrification while at the same time changing the rate at which the biomass settles in the clarifier. As recently as 1986, there were a number of theories, not always compatible with one another, regarding the actual impact of temperature on the rate of ammonia oxidation. Figure 1 is a presentation taken from the work of Shammas (1986). Figure 1 shows graphically the numerous theories summarized in the introduction to that document.

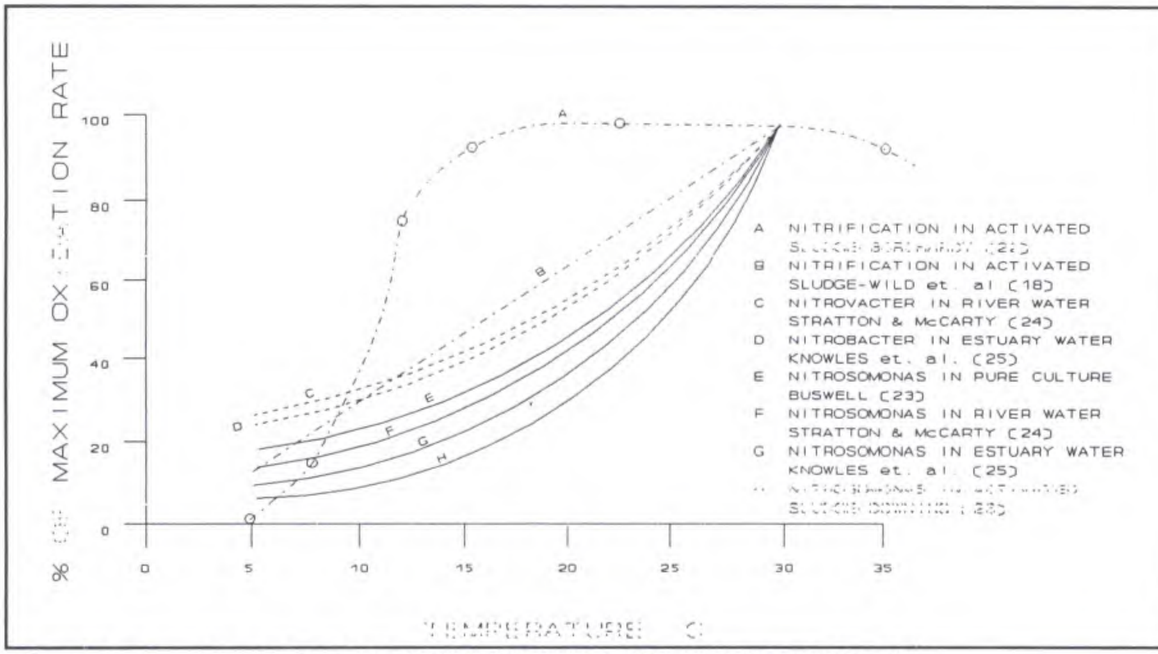

Figure 1 EFFECT OF TEMPERATURE ON NITRIFICATION

Shammas (1986) subsequently presented the results of his work in an attempt to resolve these contradictory theories. Figure 2 shows that at any given pH the maximum specific growth rate decreases with temperature and that the rate at which it decreases is significantly influenced by the mixed liquor solids concentration until that concentration is 500 mg/l or less. Thus, in the mixed liquor solids ranges that are normally used in the food processing industry, the maximum specific growth rate would be significantly affected by temperature. If either of the ammonia conversion bacteria species is lost at these low temperatures, it is reported that they cannot be reestablished at temperatures below 10°C, (Boyajian, 1987). Randall and Buth (1984) report that there is a temperature range above which the inhibition of nitrate formation is greater than the inhibition of nitrite formation. This occurs because the nitrate formers have a higher temperature coefficient than the nitrite formers. Thus, there exists a critical temperature below which the rate of nitrite formation will be greater than the rate of nitrate formation resulting in a build up of nitrite to inhibitory levels. This is presented in greater detail when toxics inhibition is discussed.

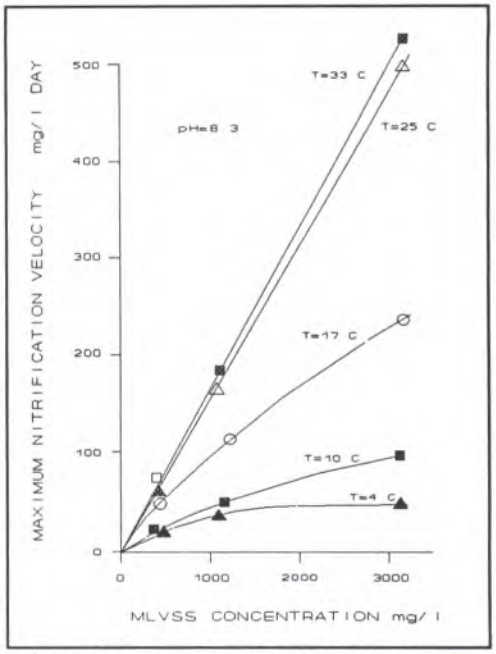

Figure 2 VARIATION OF MAXIMUM NITRIFICATION VELOCITY WITH MLVSS CONCENTRATION

The designer has several ways to deal with the temperature problem, all having to do with the management of heat. Conservation of heat can be accomplished by using enclosures, adding heat, the application of insulation and by reducing the exposed surface area. For larger systems, the most cost effective means of reducing heat loss is to maximize the wall height of the aeration cell, thereby, minimizing the surface area of the aeration cell. This is cheaper than enclosing the system and we have not found insulating the side walls to be necessary or cost effective.

By separating the oxygen transfer and mixing functions, the designer can provide not only additional operator flexibility but a means of heat addition as well. Heat can be added to the system by using a diffused air system where heat is added by the compression step, and by installing mixers for the system in the liquid in the aeration cell. Submerged jet aeration systems as described by Norcross (1984) accomplish the same thing.

From an operations standpoint, the traditional means of combatting low temperatures is by increasing the bacterial population. Having a larger mass, i.e. higher Mean Cell Residence Time (lower food to microorganism ratio), allows for more bacteria working at a lesser rate to accomplish the same amount of Ammonia conversion. Increasing the mass of bacteria also reduces the apparent influence of liquid temperature change on the settling rate. As shown in Figure 3, Reed and Murphy (1969) established that the dependency of settling on temperature decreases with increasing mixed liquor solids concentrations. Therefore, the designer has to provide adequate clarifier capacity and recycling capability to handle the enlarged biological population. Wells (1990) developed a predictive model to assist the designer in selecting a clarifier configuration to prevent thermal short circuitry.

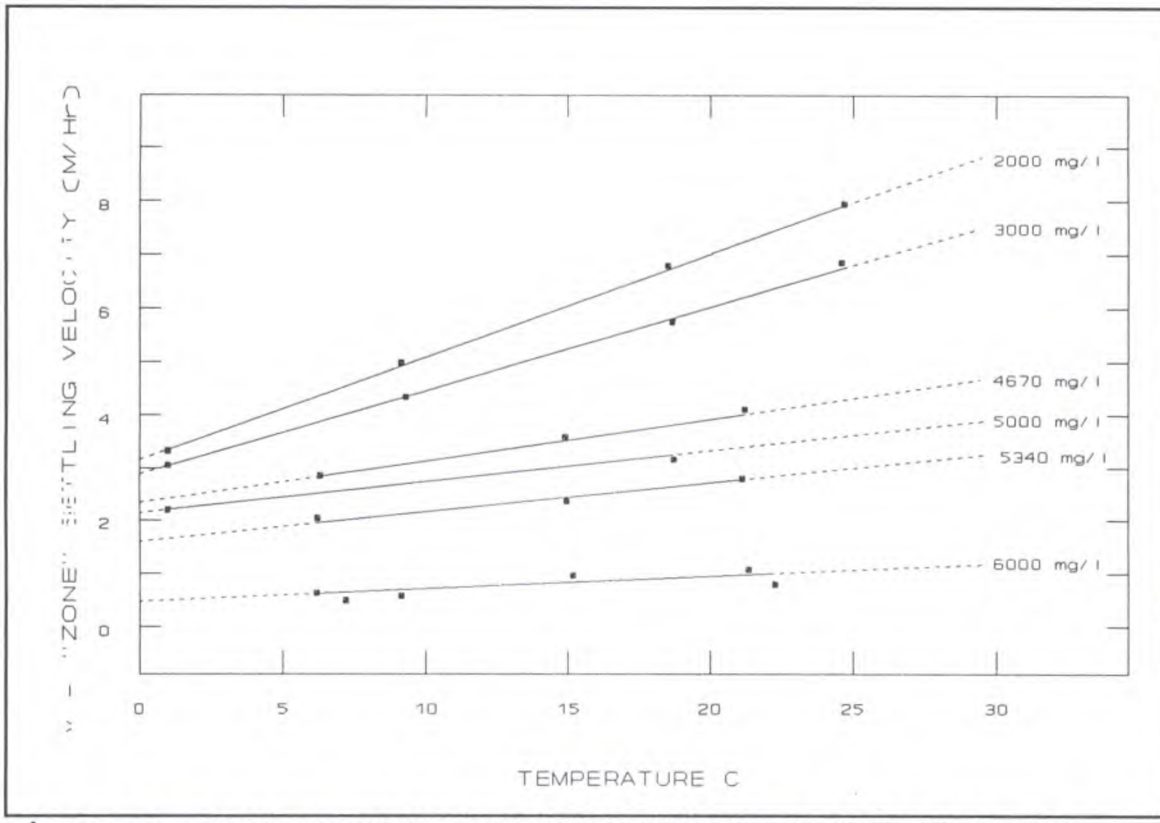

Figure 3 ZONE SETTLING VELOCITY VERSUS TEMPERATURE FOR VARIOUS MLSS CONCENTRATIONS

AMMONIA CONCENTRATION

The influent ammonia concentration in certain types of reactors and the mixed liquor ammonia concentration in any reactor can reach levels at which the substrate itself inhibits the operation of the treatment facility. Anthonisen et al., (1976) developed basic boundary conditions for this phenomena which are depicted in Figure 4. Anthonisen hypothesized and confirmed there are three zones of nitrification inhibition possible, two of which are related to the toxic properties of free ammonia. Verstraete et al., (1977) later verified the nitrification tolerance graph which is shown in Figure 4. As pH increases, the amount of unionized ammonia increases. At a free ammonia concentration of greater than 1 mg/l, free ammonia inhibits nitrobacter reducing the efficiency of the bacteria which converts nitrite to nitrate resulting in a build up of nitrite. At a free ammonia concentration greater than 150 mg/l, the inhibition extends to nitrosomonas as well.

This was depicted more recently by Rozich and Castens (1986). Referring to Figure 5, for years the Monod growth rate model has been used for explaining the nitrification process. In 1986, Gaudy first suggested that the Haldane growth rate model more closely represents the nitrification process, because there is a critical substrate beyond which the specific growth rate is reduced due to the presence of the substrate. This is basically another way of depicting the findings of Anthonisen. It can be mentioned here, however, that experimental work done by Gee <u>et al.</u>, (1990) was supportive of the Haldane equation for Nitrosomonas, but not for nitrobacter, whereas, Rozich and Castens (1986) supported the Haldane theory in it's entirety.

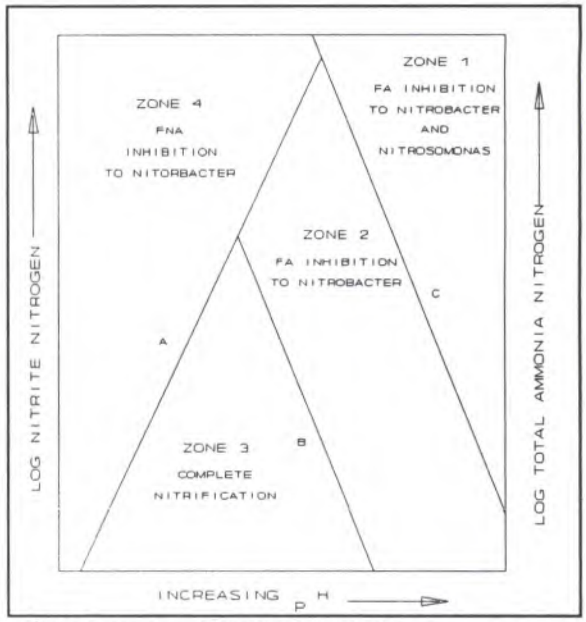

Figure 4 POSTULATED RELATIONSHIPS OF FREE AMMONIA AND FREE NITROUS ACID INHIBITION TO NITRIFYING ORGANISMS

An interesting use of the nitrification tolerance graph for an operating situation was by Verstraete <u>et al.</u>, (1977) who did bench scale start up work using the graph to identify appropriate loading methods for a system with an influent Total Nitrogen of 1000-1060 mg/l. They found that the best operating condition for start up was to select a loading rate as a function of the ammonia ion level and the pH of the mixed liquor so that an optimal adaptation of the nitrifiers was to be expected. In other words, he selected a loading function and a pH that allowed start up to occur in Zone 3.

From a design standpoint, the principle factor which must be taken into consideration is the need to install pH adjustment equipment so that the incoming wastewater can be preconditioned to allow for the most favorable pH level in the reactor.

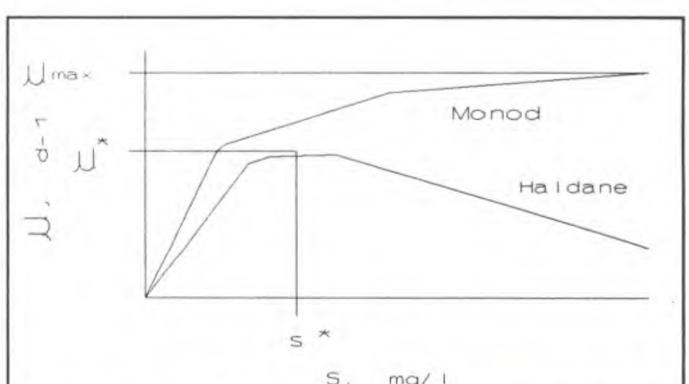

Figure 5 COMPARISON OF MONOD (NON-INHIBITORY) AND HALDANE (INHIBITORY) GROWTH RATE MODELS

DISSOLVED OXYGEN

There is a limited consensus in the environmental engineering community that nitrification can only be accomplished if the aeration cell dissolved oxygen (DO) is maintained at a concentration of 2 mg/l or greater. Further, it is generally accepted that nitrification will not occur at a DO of 0.5 mg/l or less. The stoichiometric oxygen requirement is 4.6 pounds of DO for each pound of ammonia converted to nitrate. To make sure that these conditions are maintained, the designer must provide a method of mixing and aeration which ensures that both macro and micro DO conditions are the same so the recorded DO is the same DO level to which the bacteria are exposed. The best way to accomplish this is to provide mixing which is separate from the oxygen transfer device. Fortunately, this is compatible with the system used to add heat to rectify the temperature problem.

pH

The nitrification process is particularly sensitive to pH changes. Shammas (1986) presented the same litany of theories for the effect of pH on nitrification rate as formerly existed for the influence of temperature. Referring to Figure 6, note there is some agreement that this process is optimal at a pH

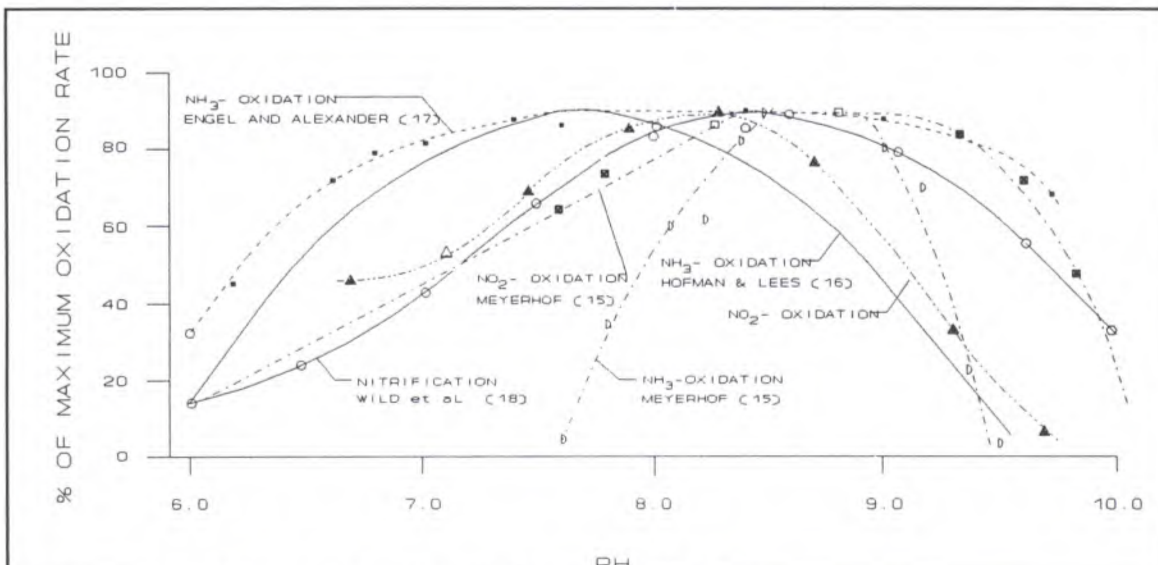

Figure 6 EFFECT OF pH ON NITRIFICATION

of approximately 8.5. Although much of the literature indicates nitrification capability is lost as the pH falls below 7.0, a number of systems have been able to achieve reasonable nitrification at a pH in the range of 5.8 to 6.0. This can be done if the nitrifying bacteria are acclimated to that pH over a long time. The point is, however, once acclimated, the pH must be maintained or nitrification loss may occur. The nitrification tolerance graph shows why varying pH's can result in varying nitrification rate efficiencies depending on the amount of free nitrous acid and free ammonia present. Shammas (1986) did some work on this as well in order to put all the theories to rest. Figure 7 clearly indicates that given a specific temperature and mixed liquor solids concentration, the specific growth rate decreases as pH decreases within the range tested, i.e. from pH of 7.0 to 8.3 Standard Units.

If there is an inadequate buffer capacity in the incoming wastewater, some alternate means of providing alkalinity must be designed into the facility because nitrification consumes alkalinity at a rate of 7.18 pounds of alkalinity for each pound of ammonia converted. Chemicals such as lime, sodium hydroxide, and sodium bicarbonate are used for this purpose. The use of chemicals for alkalinity adjustment can create pH problems if either too much or too little chemical is added.

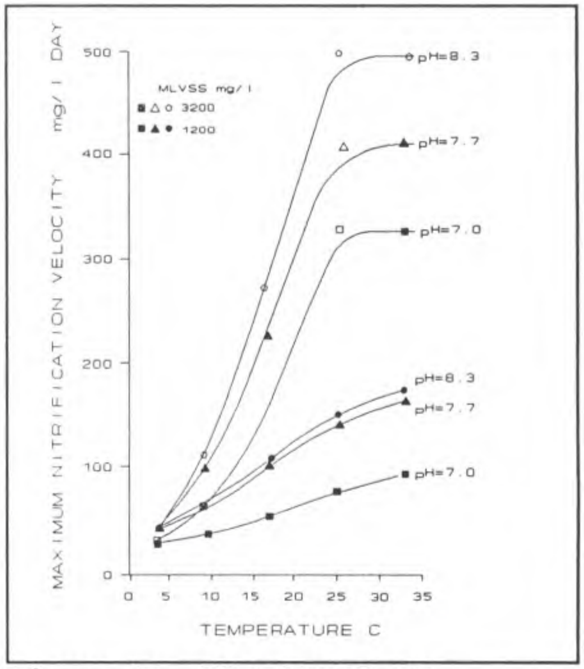

Figure 7 VARIATION OF MAXIMUM TEMPERATURE, pH AND MLVSS CONCENTRATION

FOOD TO MICRO-ORGANISM RATIO

As indicated previously, an operator generally tends to decrease wasting as winter approaches in order to increase the mean cell residence time (MCRT) of the facility. Since MCRT is the inverse of food to micro-organism ratio, changing the MCRT from 5 to 20 days reduces the F over M ratio from .2 to .05 pounds of BOD_5 to pounds of mixed liquor solids. As discussed previously, the designer must make sure that there is adequate oxygen transfer capacity to maintain the increased inventory of solids and that there is adequate clarifier capacity to provide for a reasonable solids flux and recycling capability.

TOXIC MATERIALS

The presence of inhibitory or toxic materials has been discussed as it relates to ammonia, but there are many other compounds which are in themselves inhibitory to the nitrifying bacteria, in particular, nitrosomonas. Hockenbury and Grady (1977) studied 20 organic compounds that are widely used and found that dodecyclamine, aniline, and n-methylaniline were toxic at concentrations below 1%. Nitrifying micro-organisms appear to be particularly sensitive to the presence of metals as well and as many food processing facilities have metal based piping, the products of corrosion could inhibit the wastewater efficiency. Salt can be a de-stabilizer of nitrification systems if it is not normally present and is suddenly added as a surge load which imbalances the total dissolved solids (TDS) concentration relationship between the internal contents of the bacteria and the external contents of the aeration cell. Randall and Buth (1984) stressed the importance of the toxic matter over biomass ratio since in most situations the nitrifying community represents a very small portion of the heterogenous biomass.

The obvious way to design for corrosion control is to take care in the selection of piping materials and provide water conditioning if the water is particularly aggressive. To guard against surges and dumps requires constant management attention and awareness of the impacts of this type of spill.

RECENT INNOVATIONS

Another way in which nitrite can be formed, which is not so readily addressed, was noted by Randall and Buth (1984). In one case it was noted that nitrification capability was repeatedly lost at mixed liquor solids temperatures in the range of 24°C to 26°C. The authors concluded that this was caused by nitrobacter inhibition by ammonia concentrations of 0.1 to 1.0 mg/l at a pH greater than 8.0 and by nitrosomonas inhibition at free ammonia concentrations greater than 10 mg/l at pH less than 7.5.

In another investigation, Randall and Buth (1984) found that the critical temperature range was between 14°C and 17°C and that in this temperature range the nitrite to nitrate reaction ceased and there was an attendant build up of nitrite. The nitrite continued to increase until the temperature dropped to a value that halted all nitrite production. This temperature was 10°C. They also noted that the reaction rate changed from zero order to a higher order as the temperature changed and this might explain the different reaction rates reported by others.

In 1973, Chudoba et al., (1985), while comparing various types of aeration cell configurations and degrees of mixing, concluded that a complete mix system inherently lends itself to an excessive growth of filamentous organisms. In further studies, the same authors concluded that the use of a selector would control filamentous organisms. They defined a selector as part of the aeration system along which a substantial concentration gradient of the substrate exists. Following up on Chudoba's work, Palm et al., (1980) verified that for systems operating at similar low organic loadings compartmentalized aeration basins exhibited no filamentous bulking when completely mixed. Others who have confirmed these findings are; Lee et al., (1982), Van den Eynde et al., (1984), Daigger et al., (1985), Chudoba et al., (1973), Poole et al., (1987), Linne et al., (1989), and Salameh et al, (1989). In particular, Van den Eynde et al, (1984) showed that having an anoxic selector that provided nitrification and denitrification will also prevent filamentous bulking. This is depicted in Figure 8 based on the early work of Tomlinson (1978) as reported by Salameh and Melina, Jr. (1989).

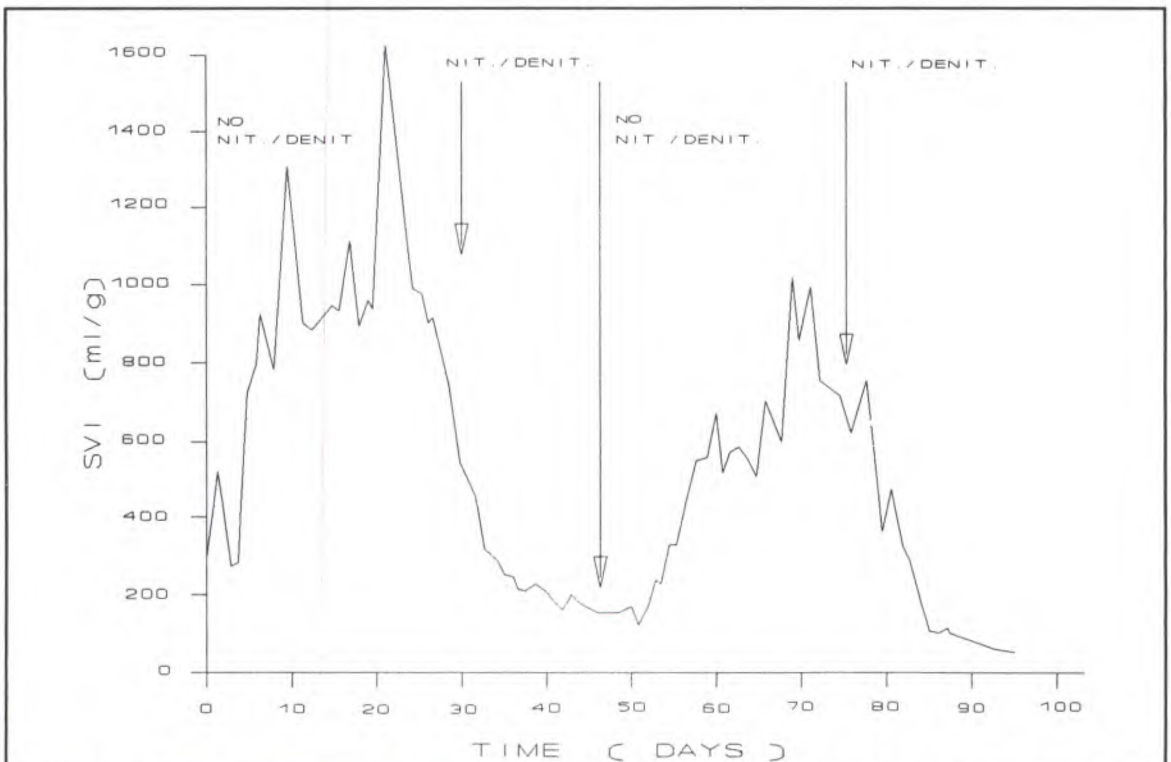

Figure 8 EFFECT OF NITRIFICATION AND DENITRIFICATION ON SVI* IN THE CONTROL UNIT

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WASTEWATER TREATMENT BY pH ADJUSTMENT AND POLYACRYLAMIDE FLOCCULATION

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Handling of dissolved air flotation (DAF) skimmings is an ongoing problem for poultry processors. The skimmings are a by-product of wastewater pretreatment where commonly iron or aluminum salts are added to the wastewater to coagulate suspended and colloidal organics. The coagulated organics are then flocculated with anionic polyacrylamide to bind the floc into larger particles to facilitate removal from the waste stream. Although effective in reducing the concentration of organics in the waste stream to that of domestic sewage, this system produces large amounts of iron or aluminum rich DAF skimmings. Ten Have (1983) reported the iron concentration in dried DAF skimmings to be 1.7 to 4.5 percent.

Renderers will not put this material into pet food grade by-product meal. Due to the high aluminum content of aluminum flocculated DAF skimmings, renderers will not include the material in any grade of rendered product. Successful flocculation of processing wastewater without using iron or aluminum salts can be beneficial to poultry processors.

Previous studies of broiler processing wastewater have shown that the contaminant load is mainly in the form of floating and suspended tissue particles. Usually less than 20 percent is in the soluble form. The soluble form is defined as those contaminants that pass through a 934 AH glass fiber filter as specified in "Standard Methods for the Examination of Water and Wastewater".

Anionic polyacrylamides have been found to be effective in flocculating particulate matter from the waste stream when the pH of the wastewater is adjusted to an appropriate flocculation point. No iron or aluminum salts are required for coagulation.

To test the premise that wastewater from a processing plant could be reduced to municipal discharge codes without the use of iron or aluminum salts, poultry processing wastewaters were adjusted to an appropriate flocculation pH and then flocculated with an anionic polyacrylamide polymer.

Experiment 1: Treatment of Evisceration Wastewater

A study of wastewater discharge volumes from a broiler processing plant showed that 70-75 percent of the plant flow was discharged by the evisceration operation. Analysis of evisceration wastewater showed that more than 95 percent of the waste load was in particulate matter form and that the soluble contaminant concentrations were at or below municipal discharge codes (Table 1).

Table 1. Composition of Evisceration Wastewater

	Whole wastewater	Soluble fraction
COD (mg/L)	7875	345
Percent of total	100	4.4

Based on this observation, evisceration wastewater from a broiler plant was acidulated by bubbling CO_2 through the wastewater until a stable pH (4.5-5.0) was reached. Eight mg/L of a commercial anionic polyacrylamide was blended into the acidulated wastewater and the flocculation process was allow to take place. After five minutes of separation, the subnatent was withdrawn from the bottom of the reaction beaker and analyzed for biochemical oxygen demand (BOD), chemical oxygen demand (COD), total suspended solids (TSS), fat, oil and grease (FOG) and pH (Table 2).

Table 2. Treatment of Evisceration Wastewater by CO_2 Acidification and Polymer Flocculation

	BOD	COD	TSS	FOG	pH
		TRIAL 1			
Whole	1594*	2900	1656	1659	
Filtrate	382	550			
Polymer treated	338	610	134	38	4.51
		TRIAL 2			
Whole	1210	3256	2481	1273	
Filtrate	235	495			
Polymer treated	231	440	89	8	4.79
		TRIAL 3			
Whole	1768	5700	4882	1953	
Filtrate	357	575			
Polymer treated	408	730	146	60	4.98
		AVERAGE			
Whole	1527	3952	3006	1628	
Filtrate	325	540			
Polymer treated	325	593	123	35	4.76

*mg/L

The data in Table 2 shows that when evisceration wastewater was acidulated to a pH of 4.5-5.0, the polymer would flocculate essentially all of the particulate material from evisceration wastewater. The wastewater would meet municipal discharge codes for TSS and FOG, 200 and 100 mg/L, respectively. BOD concentration, 325 mg/L, was found to be only slightly above municipal discharge codes, 250-300 mg/L BOD. Segregation of evisceration for this specific treatment would produce an iron or aluminum free DAF skimming yet would produce an effluent near discharge codes.

Experiment 2: Treatment of Combined Plant Effluent

Additional experiments were conducted to determine whether pH adjustment and polymer flocculation would reduce combined plant effluent to code. Combined plant effluent from a broiler processing plant was acidulated by bubbling CO_2 through the wastewater until a stable pH was obtained. Carbon dioxide alone would only reduce the pH of combined plant effluent to a pH of 5.2-5.4, therefore 1 N H_2SO_4 was used to further acidulate the wastewater. Beginning at a pH of 5.1, the wastewater was acidulated in increments of 0.1 pH units to a pH of 4.2. At each 0.1 pH unit increments, a 500 ml aliquot of the wastewater was poured into a 1 liter flask. The flask was shaken 20 times to incorporate air into the wastewater and the wastewater was poured into a beaker. Six mg/L of polymer was blended into the sample and the flocculation process was allowed to go to completion. After 10 minutes of floc separation, the subnatent was analyzed for COD (Table 3, Figure 1).

Table 3. Treatment of Combined Plant Effluent by Acidification and Polymer Flocculation

Soluble	Trial 1	Trial 2	Trial 3	Average	Estimate BOD
Whole	5950*	4500	3800	4750	2550
Soluble	1100	975	780	950	535
pH					
5.1	1440	1300	1040	1260	700
5.0	880	1200	1000	1025	575
4.9	900	1040	710	885	500
4.8	975	840	570	795	455
4.7	925	880	570	790	450
4.6	670	780	660	705	405
4.5	760	830	625	740	425
4.4	580	1050	950	860	490
4.3	870	1170	1260	1100	615
4.2	1200	1650	1140	1330	740

*mg/L COD.
Estimated BOD = COD (0.53) + 33 mg/L.

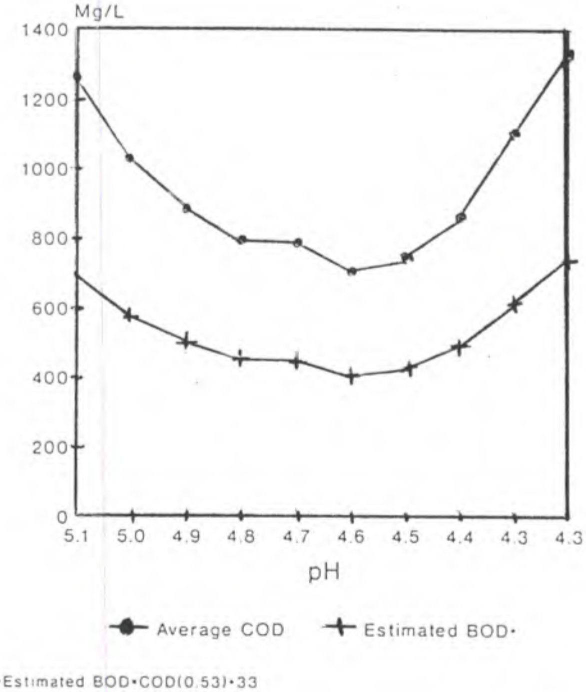

Figure 1. Treatment of Combined Plant Effluent by Acidification and Polymers

When combined plant effluent was pH adjusted to the range of 4.4-4.7, the polymer was able to reduce the estimated BOD to the range of 440 mg/L BOD. This estimated BOD exceeds municipal discharge codes by 150-200 mg/L. In-plant solubles reduction to the range of 600-700 mg/L COD may allow this mild acidification process to reduce the BOD to discharge code. Processors facing problems of handling iron or aluminum rich DAF skimmings may find it feasible to reduce solubles loading to the range of 600-700 mg/L COD. Using solubles minimization, they may be able to preclude the use of metal salts yet still meet municipal discharge codes.

Those companies that discharge into company owned biological treatment plants can reduce the effluent strength by approximately 75 percent by polymer flocculation of pH 5.0-5.1. This process would reduce the need for aeration in the biological process, however, the polymer flocculated skimmings would have to be handled. Individual plant situations would determine the feasibility of this system.

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CONSIDERATIONS FOR THE DESIGN OF POULTRY WASTEWATER SYSTEMS

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Environmental considerations have joined the list of primary criteria used to site, and ultimately design, new poultry processing facilities. This paper will set forth what those considerations are, and suggest approaches to satisfy those considerations.

Generally, when one sets out to build a new processing plant, the general geographic location is specified by grow-out capacity or inherent grain pricing advantages. Within that general geographic region, there may be several suitable sites for plant construction. The objective is to screen those sites independently initially to weed out, with the minimum amount of effort, those which will not be acceptable from an environmental standpoint. The survivor sites from this screening process can then be investigated in more detail, and, ultimately, cost estimates made, to compare the sites from an environmental perspective.

For screening purposes, the following criteria should be evaluated:

1. Water availability and cost
2. Land availability and cost
3. Previous site history

Water is the key utility in poultry processing. Even a well managed plant will utilize 4 to 4.5 gal/bird, which for a two-line, two-shift NELS plant, translates into 700,000 gpd to 800,000 gpd. The fact of the matter is that many otherwise desirable sites will not have access to potable water supplies of this magnitude.

Certainly, many communities may be willing - even anxious - to build additional water treatment plant capacity to service the needs of a new large industry. However, one must insure the timetable for construction of the water plant, or additional water plant capacity, coincides with construction of the poultry processing facility. Typically, water plant construction is financed through bonds, state-sponsored loan programs and state grants. The time element to apply for and arranged financing can be significant; often stretching to twelve months or longer before the first spade of dirt is turned. Actual construction time can also extend to twelve months or greater. If the water plant financing/construction schedule cannot meet the processing plant needs, and alternative water sources cannot be found, then obviously the site must be eliminated from further consideration.

Facility location in an area of good groundwater supply can solve many of the water supply problems. The processor then has the choice of installing his own potable water supply system. However, virtually all states now require a groundwater withdrawal permit, and are allocating groundwater use. In some areas, new large allocations are simply not available.

Land Availability

A second screening criteria is the availability, and cost, of land to site the processing facility. From an environmental perspective, plant siting should be such that the operating facility can have the minimum amount of impact on community neighbors. Consideration needs to be given to truck traffic patterns and noise, employee traffic patterns, the potential for offensive odor, and the number of immediate neighbors. These potential problems can be minimized by purchasing a sufficient land area so that the processing plant has a company-owned buffer surrounding it. As a minimum, 100 acres should be considered for purchase for a poultry processing facility, 1000 acres should be considered if there will be on-site rendering.

With such large land purchases, one can quickly determine which sites he can and cannot afford. The purchase of the built-in buffer will pay for itself many times over in terms of nuisance complaints, neighborhood lawsuits and lost management time and resources dealing with same.

Previous Site History

A final initial screening tool is a cursory review of a potential site's previous history. At this stage, a full blown environmental audit of each site is neither warranted nor justified. However, some common sense questions to local officials concerning the properties previous use, combined with a walk through of the property, can often ferret out any red flags. If the property was formerly a manufacturing facility of some sort, telephone interviews with local regulatory personnel and/or a review of regulatory files can provide further information on any environmental liability the site may have. At this point in the initial screening process, it is simple to walk away from an environmentally impaired site. With a little bit of investigative work at this point, one can avoid wasted effort and, in the worst case, inheriting someone else's problem.

Many potential sites will fail one or more of the preliminary screening criteria. Those that remain need to be compared with the short lists of sites developed by grow-out concerns, personnel concerns and sales concerns. This cross referencing, and subsequent negotiation and compromise, will generally produce two or more sites worthy of detailed evaluation.

Sites surviving the preliminary screening criteria will have available one or more of the following treatment options:

1. Discharge to POTW
2. Conventional waste treatment system
3. Land application of wastewater

To determine which of these choices may be most suitable for a given site, at least the following three factors must be considered:

1. Regulatory requirements
2. Expandability
3. Cost

POTW Discharge

Regulatory requirements for a POTW discharge are generally administered by the local sewer authority, under pretreatment programs authorized by the state, or in some cases, by the federal EPA. There are two phases of regulatory review that have to be considered. First, what specific limits will be required to meet the pretreatment program. Additionally, the adequacy of the POTW to handle the additional load and maintain compliance with its own permit need careful review.

Expandibility, or the availability of excess capacity at the POTW, to meet short to intermediate term expansion, should be investigated.

Cost for POTW treatment will be the summation of pretreatment cost plus the utility billing rate.

Conventional Waste Treatment System

Regulatory review for conventional waste treatment systems will require meeting with state regulatory officials to determine what level of discharge will be allowed into area streams. If a large river is located adjacent to the site, typically attainment of secondary treatment levels only is required. On smaller streams, water quality models will dictate more stringent limits.

Sufficient land area should be available to provide for future expansion.

Cost estimates should include both pretreatment and final treatment costs, from both a capital and operating standpoint.

Land Application Systems

Regulatory review for hand application system will require meeting with state regulatory officials to determine buffer zones, allowable loading rates, cover crop requirements, storage requirements, etc.

Expandability will require a review of the site, and adjacent sites, to insure the availability of adequate land area for future production capacity.

Cost analyses will consist of both the pretreatment cost and the actual land application system cost, including the purchase of additional land area necessary for the system.

Final Selection

When the above factors have been evaluated, a cost figure is generated concerning the expense of waste treatment for each site. This figure is combined with other construction costs and operational imputs to select the most cost-effective site location that meets the needs of the broiler complex.

RENDERING PLANT ODOR CONTROL TECHNOLOGY

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Rendering plants continue to be a potential source of odor nuisance problems in the surrounding community. The purpose of this paper is to review the rendering process technology and the control methods in current use for treating the odor emissions from inedible rendering plants. Odor sensory data is presented to quantify the odor emissions from rendering plants and also to illustrate the odor reduction performance of control equipment which has been tested. This paper also describes the design and operation of two commercial size biofilter systems which treat the high intensity odor emissions from poultry rendering plants located in Alabama and Georgia.

RENDERING PROCESS CONSIDERATIONS

The basic rendering process with batch cookers has been described in detail (Prokop, 1985) and primary sources of high intensity odors include the noncondensables from the cooker exhaust and the emissions from the screw press. The hot cooked material from the batch cooker discharges into the perc pans which are open to the plant atmosphere. This discharge releases not only odor but also fat aerosol particles which tend to become airborne and deposit upon equipment and building surfaces within the plant. Other sources of high intensity odor include driers, centrifuges and tallow processing tanks.

The raw material is another source of odor but it normally is not significant when processed without delay. However,the age of the raw material is important because older material that has deteriorated will result in substantially higher odors being generated during the cooking and processing operations.

An important trend during the 1970's and 80's involved the replacement of batch cooker systems with continuous rendering systems which are essentially enclosed and are capable of confining the odors and fat aerosol particles within the equipment. By providing proper equipment seals and locating suction pickup vents at strategic points, a major percentage of the odor generated from the continuous rendering process is capable of being confined and treated.

A variety of continuous rendering systems are available and have been described (Prokop, 1985). For example, the Duke continuous rendering system is manufactured by the Dupps Company in Germantown, OH. It consists of a large vessel known as the Equacooker for moisture removal and has a rotating shaft with paddles to receive the raw material and discharge the cooked material at a constant rate. Another similar type of cooking equipment used in the rendering industry is the Stord Rotadisc Drier which is manufactured by Stord, Inc. in Bergen, Norway and is represented by Stord in Greensboro, NC.

Poultry Rendering Process

Poultry by-product material from poultry processing plants consists of offal and feathers. Two different systems are used for processing either material. Conventional rendering systems, both batch and continuous, are used to process the poultry offal in the same manner as animal by-product material.

The poultry feathers consist mostly of keratin which is a long chain, highly cross-linked, relatively indigestible protein. The rendering process converts the keratin by chemical hydrolysis, combining with water at elevated temperatures of 140-150°C (284-302°F), into shorter chain, more digestible amino acids. This hydrolyzation is accomplished by processing the feathers in a batch cooker with an internal cooker pressure of 40-50 psig maintained for 20-45 minutes. The moisture content of the feathers after hydrolyzation is approximately 50% and is reduced to 10% by the subsequent drying operation. Various drying methods include flash drying and rotary, direct-fried units or rotary, steam-tube dryers.

High Intensity Odor Emissions from Rendering Process

Odor emissions from rendering plants are relatively complex mixtures of organic compounds. Samples of these odors from plants processing animal by-product material have been analyzed by a combination of gas chromatographic and mass spectrometric methods. A total of 30 or more odorous compounds were identified (Snow, 1972). The major compounds included organic sulfides and disulfides, C4 to C7 aldehydes, trimethylamine and various C4 amines, and C3 to C6 organic acids.

These odorous compounds emitted from the rendering process range in intensity from 10,000 to 100,000 odor dilution to threshold units (Prokop, 1991). These odor sensory results are obtained using the IITRI dynamic-dilution, forced-choice triangle olfactometer (Dravnieks and Prokop, 1975). The higher values relate to the cooker noncondensables and to the press vents. The high intensity odor emissions from poultry rendering plants likewise include the offal cooker noncondensables and press vents, the feather hydrolyzer noncondensables and to a lesser extent, the feather dryer exhaust. Table 1 provides odor emission data for various high intensity odor emissions together with their corresponding volumetric emission rates for rendering plants processing both animal and poultry by-product material.

Table 1. Odor Emissions from Rendering Plants

Plant	Material Category	Rendering Process & Type Emission	Odor Dilution to Threshold	Rate cfm
A	Beef Slaughter	Duke - Noncord.	59,400-93,800	600
		Duke - Total[a]		2,600
B	Poultry Offal	Stord - Noncond.[b] & Presses	23,000	13,000
B	Poultry	Rotary Drier[c]	3,400-4,700	27,000

[a]Includes two presses, centrifuge, drainor, meal product conveyor and storage bins.
[b]Includes feather hydrolyzer noncondensables.
[c]Exhaust from spray condenser which receives drier exhaust.

CONTROL OF ODOR EMISSIONS

The basic purpose of providing odor control in a rendering plant is to reduce the odor emissions from the plant to a level that will result in the surrounding ambient air <u>not</u> containing odors that are a source of valid nuisance complaints. In designing a new control system or revising an old one, each individual plant situation must be evaluated separately based upon a variety of factors: Proximity of neighbors to the plant, category(s) of neighbors present, surrounding topography, prevailing winds, plant building features, ability of rendering process to confine odors, type of raw material and seasonal climatic conditions.

The fundamental question often to be resolved is whether to treat the high intensity odors only or also treat a large volume of air that would be used to ventilate the operating area within the plant. A decision to treat only the high intensity odors is usually predicated on the ability of the rendering process to confine these odors within the equipment. As discussed before, continuous rendering systems usually have this capability. Boiler incineration or multistage, low volume scrubbing of the high intensity odors is particularly compatible with this type of system.

Boiler Incineration of Process Odors

The installation and operation of afterburners or incinerators solely for pollution control is relatively uncommon due to the capital investment and fuel costs required. Currently, boiler incineration of the high intensity process odors is a regular practice throughout the U.S., since all rendering plants require the generation of steam for the cooking and drying processes. The following factors should be considered for boiler incineration of high intensity odors:

1. Minimize the volume of odorous air to be handled. Ensure that odor pickup points in the rendering process are not pulling excessive quantities of air.

2. Maximum fuel economy is achieved by using the odorous stream as primary combustion air. Particular care must be taken that the air stream is essentially free of moisture and particulate which can interfere with the operation of the burner and controls. This is accomplished with a combination scrubber and entrainment separator of proper design. A water spray is provided to cool the odorous air and condense out the moisture. Likewise, the solid and fat aerosol particles should be removed.

3. The boiler size and burner capacity should be compatible with the amount of odorous air to be incinerated. This boiler should be equipped with suitable burner controls to ensure that the minimum firing rate is sufficient to incinerate the volume of odorous air passing through the fire box, regardless of the steam demand. A temperature of 1200°F or more is usually obtained in the fire box at the minimum firing rate. The residence time in the boiler fire box at maximum fuel rate is normally in excess of one second.

Previously, Table 1 summarized odor emission data for high intensity odors from Plants A and B. Table 2 illustrates the odor removal efficiency achieved by boiler incineration for these same plants.

The results clearly show that boiler incineration is a very efficient method of odor control for treating the high intensity odors from the rendering process.

Table 2. Boiler Incineration of Rendering Process Odors

Plant	Fuel Used	Fire Box Temp. °F	Odor Dilution to Threshold[a] Broiler Inlet	Stack Exhaust	Odor Removal %
A	Nat Gas	1250	28,100-59,200	202-356	99.3
B	Nat Gas	----	23,900	204	99.2

[a]Odor sensory data obtained with IIRTI dynamic olfactometer.

Wet Scrubbing of Process Odors

Multi-stage scrubber systems for treating the high intensity odors provide an alternative to boiler incineration when the latter approach may not be feasible due to the boiler plant being remotely located or for other reasons. These multi-stage systems have been successfully applied to rendering plant emissions since the early 1970's.

These scrubber systems have used various chemical solutions including bases and acids. Chemical oxidizing agents were found to be the most effective. Sodium hypochlorite or the addition of chlorine gas to a caustic soda solution has been used since the early 1970's. More recently, chlorine dioxide generated on site by the addition of chlorine gas to sodium chlorite solution is used in a number of these scrubber systems.

The chemical oxidant solutions used in wet scrubbers are normally recirculated to conserve water and minimize chemical and wastewater treatment costs. The concept of balancing the oxidant chemical addition rate with the chemical use rate is important to achieve optimum usage and minimum cost.

A two stage scrubber system consisting of a venturi and a packed tower is described (Prokop, 1974). This scrubber system treats high intensity odors including the screw press vents, blood dryer exhaust, raw feather receiving, feather noncondensables, feather cooker discharge and feather dryer exhaust. The scrubber system capacity is 32,000 cfm.

A three stage scrubber system consisting of a venturi and two packed towers in series is also described (Prokop, 1977). This scrubber system treats high intensity odors including the Equacooker noncondensables, drainor, pressor vents, centrifuge and the steaming of grease barrels. The scrubber system capacity is 7,500 cfm. In this system, the high intensity odors enter the throat of the low-energy venturi scrubber which removes the particulate matter, cools and saturates the air with water vapor. Phosphoric acid solution is recirculated through this stage to remove the amine type odors and NaOCl solution is recirculated through the 2nd stage to remove the sulfide type odors.

Table 3 summarizes the odor sensory data obtained for these two multiple stage scrubber systems. The odor removal efficiency of these two systems is approximately 99%.

Table 3. Multi-Stage Scrubbing of Rendering Process Odors

Scurbber Category	Exhaust Flow cfm	Scrubber Solutions			Odors Units/scf[a]	
		1st	2nd	3rd	Inlet	Outlet
Venturi & 1 P Tower	32,000	Water	NaOCl		5,000-20,000	50-100
Venturi & 2 P Towers	7,500	Na_3PO_4	H_3PO_4	NaOCl	14,000	185

[a]ASTM syringe method (Mills et al., 1963).

Wet Scrubbing of Plant Ventilating Air

Plant ventilating air scrubbers provide a more complete solution to an overall plant odor problem. Fugitive odors within the plant can be captured and treated in a uniform manner with this type of scrubber. It is particularly suited for rendering plants located near sensitive population areas, such as residential or commercial. For this application, it is essential to have adequate distribution and flow of air throughout the plant in order to pick up and capture the ventilating air those fat aerosols and other particles emitted from the rendering process.

In addition to accomplishing effective odor control, these scrubbers provide proper ventilation of the plant operating areas, thereby maintaining satisfactory working conditions for the employees. It is important to recognize that sufficient ventilating air must pass through the operating area during the summer months. Otherwise, doors and windows will be opened, allowing the plant odors to escape from the building instead of being treated by the scrubber system. Ideally, a slight negative pressure should be maintained within the rendering plant.

A typical plant ventilation air scrubber consists of a single packed tower through which NaOCl solution is circulated. These scrubbers have capacities normally ranging from 20,000 to 80,000 cfm. This type of scrubber is capable of achieving 95% or more odor removal based on inlet values of 2000 to 5000 and exhaust values of 100 to 200 (IITRI dynamic olfactometer).

For example, a single packed bed scrubber with a capacity of 55,000 cfm treats the plant ventilating air from the poultry offal processing area in an Alabama rendering plant. The results of four odor sensory performance tests are shown in Table 4.

Table 4. Single Stage Scrubbing of Plant Ventilating Air

Exhaust Flow cfm	Scrubber Solution	Odor Dilution to Threshold[a] Inlet	Outlet	Odor Removal &
55,000	Chlorine dioxide	2700-7160	190-300	93-96

[a]IITRI dynamic olfactometer.

BIOFILTER TECHNOLOGY: DESIGN & OPERATION

Biofilter technology developed during the past 10 years in Europe and elsewhere has been applied to the treatment of rendering odors (Prokop, 1992). Biofilters consist of large beds of porous materials such as compost, peat moss, bark and soil. These are capable of adsorbing odorous gaseous compounds and breaking these down through aerobic biological action into less odorous components. Biofilters are less expensive to operate than wet scrubbers since chemicals are not normally used and less electrical energy is required.

Biofilter Media Characteristics

Biofilter beds consist of a media having specific desired characteristics and the ability to provide a favorable environment for aerobic microbial growth. Four important factors which affect the microbial population and its growth are the following: moisture, temperature, pH and availability of nutrients. Adequate moisture is essential for microbial growth. Too much moisture also is a problem. Excess water in the bed will tend to fill the bed's pores and void spaces, preventing the adsorption of odorous compounds and their contact with the aerobic bacteria.

Temperature is another important factor. Microbial activity rate roughly doubles with each 10°C rise in temperature up to about 40°C (105°F) Ottengraf, 1986). Biofiltration relies predominantly on the activity of mesophilic and, to a lesser extent, thermophilic microorganisms.

Likewise, pH is an important parameter because adsorption and aerobic microbial action decreases significantly when the bed medium becomes acidic. Normally, a slightly alkaline condition of 7 to 8.5 pH should be maintained. If the odorous compounds are predominantly acidic, it may be necessary to mix lime into the bed periodically to maintain a slightly alkaline pH.

The biofilter bed material has a finite lifetime because of compaction, accumulation of salts and exhaustion of nutrients.

Biofilter Design Parameters

The following design parameters should be considered when planning a biofilter installation:

1. Inlet gas flow to bed: The size of the biofilter both in surface area and volume of bed medium, depends upon the inlet gas flow in m^3/hr (cfm). The size and configuration of the biofilter also is influenced by the available space.

2. Distribution of gas flow thru bed: Perforated plastic pipe or pre-cast concrete slabs with oblong slots are used to distribute the inlet gas flow upward through the bed. It is essential that a uniform flow be provided across the entire cross-sectional area of the bed to utilize fully the adsorptive and microbial capacity of the bed. Channeling can occur along the vertical retaining walls for the bed medium.

3. Surface loading rate: The flow rate through biofilters is usually expressed in volumetric flow per unit surface area. Typically, this ranges from 35 to 180 m^3h per m^2 (2-10 cfm/ft^2).

4. Desired concentration in exhaust from bed: The desired odor level in the exhaust is dependent upon the proximity of neighbors to the plant, the prevailing wind direction, surrounding topography and the typical atmospheric conditions including stability and wind speed.

5. Bed depth and volume to provide residence time: For a given flow rate, fixing the bed depth and volume establishes the residence time for a bed medium of known void space. An adequate time is necessary for the odorous molecules to be adsorbed by the bed medium. This depends to a certain degree upon the water solubility of the individual compounds being adsorbed. An acceptable range of residence time in a biofilter varies from 15 to 30 seconds.

6. Pressure drop across bed: The gas flow velocity is the most important factor affecting pressure drop through a granular bed, since it varies nearly as the square of velocity. Due to gradual compaction of the bed medium, pressure drop and electrical power consumption will increase with time.

When the pressure drop exceeds the design value, it is necessary either to turn the bed over to re-establish the desired operating parameters or replace it with fresh material. Replacement of the bed medium can vary from 2 to 5 years depending upon the type of medium and the operating conditions of the biofilter.

Shutdown of a biofilter during periods of equipment maintenance pose a potential problem regarding loss of microbial activity when nutrients are not supplied to the bed. Ottengraf and Van Den Oever (1983) investigated this issue and determined that no significant loss of microbial activity occurred during two weeks. Thus, startup of a biofilter after an extended shutdown requires essentially no additional time.

TWO COMMERCIAL BIOFILTER SYSTEMS

Two similar designed commercial biofilters treat the high intensity odor emissions from poultry rendering plants located in Alabama and Georgia. Odor sensory performance data are presented for the biofilter system in Alabama. The results of an investigative study of the biofilter bed medium and operating parameters are presented for the system in Georgia.

Both plants process poultry offal and feathers. The high intensity odor emissions from rendering the offal consist of the cooker noncondensables, the venting of the screw presses and emissions from the raw material supply pumps. The high intensity odors from the feather processing consist of the batch hydrolyzer noncondensables and the exhaust from the rotary dryers. A Heil rotary, direct-fired dryer processes the hydrolyzed feathers at the Alabama plant and when over-loaded may discharge a "blue smoke" exhaust which has a high odor intensity. At the Georgia plant, four Louisville rotary, steam-tube dryers (each of two units in series) process the feathers. Hoods are placed over the batch feather hydrolyzers and Stord Rotadisc cookers processing offal to capture any high intensity odors that escape from this equipment.

The biofilter in Alabama has been in operation for 15 months, whereas the biofilter in Georgia has been operating for nearly 24 months. Both biofilters have the same surface area of 100 ft. by 130 ft. and use pine bark as the medium for the bed obtaining it from the same source. Table 5 provides data on the differences in bed media characteristics for the fresh pine bark compared to the used pine bark.

Table 5. Characteristics of Biofilter Bed Media

	Fresh Pine Bark	Used Pine Bark[a]
Bulk density, lb/ft^3	14	41
Void space fraction[b]	0.60	0.37
Moisture content, %	26-36	75
Organic content, % d.b.[c]	99	89
pH	7-8	2-3

[a]After 15 months operation at the Georgia plant.
[b]Average void space fraction of 0.49 in biofilter bed.
[c]Organic content is determined by ignition loss.

Table 6 provides a comparison between the Alabama and Georgia biofilters regarding their design, operation and cost.

Table 6. Comparison of Alabama and Georgia Biofilters

	Alabama Unit	Georgia Unit
Inlet Gas Flow - cfm	40,000[a]	90,000[b]
Inlet Gas Temp. - F	70-130	70-110
Bed Surface Area - sq. ft.	13,000	13,000
Bed Depth - ft.	5	3
Bed Residence Time - sec.	47	13
Bed Moisture Content - %	67-76	65-75
Installed Cost[c]	$270,000	$365,000

[a]Includes 27,000 cfm dryer exhaust and other process emissions.
[b]Includes 47,000 cfm process emissions and remainder is plant ventilating air.
[c]Includes ductwork to biofilter.

Biofilter System in Alabama

A 6 ft. dia. stainless steel duct delivers the high intensity odors to a concrete plenum chamber which distributes the inlet stream to 12-inch dia. plastic ducts spaced on 30-inch centers. These ducts contain perforated holes for flow distribution and are located below the bed of pine bark. A plastic liner is located below the ducts to prevent percolation of water into the soil and to capture any leachate of water for processing in the wastewater treatment system.

The first performance test was conducted during early August and the second series of two performance tests were conducted during September of last year. During each test, two samples of the high intensity odor inlet to the biofilter and six samples of the bed exhaust were obtained at different locations to obtain an overall representative sample of the exhaust. A plastic hood with base dimensions of 1½ ft. x 2 ft. was used to capture the exhaust samples from the surface of the biofilter bed. The top of the hood was connected with Tygon tubing to a moisture trap and peristaltic pump. Each sample was evaluated using the IITRI dynamic-dilution, forced-choice triangle olfactometer. The odor sensory results are expressed as ED_{50} values which are based on an odor dilution to threshold technique.

The odor sensory results for the three performance tests conducted during August and September are shown in Table 7.

Table 7. Biofilter Odor Sensory Performance Results

Sampling Location Category	Aug.	Sept. 1st	Sept. 2nd
Biofilter Exhaust - #1	270	970	764
Biofilter Exhaust - #2	350	760	618
Biofilter Exhaust - #3	291	933	425
Biofilter Exhaust - #4	838	940	583
Biofilter Exhaust - #5	871	1,300	2,280
Biofilter Exhaust - #6	966	1,035	2,140
Biofilter Inlet - #7	1,570	3,660	12,800
Biofilter Inlet - #8	3,130	10,900	12,300

Based on an average of the six exhaust samples and average of the two inlet samples, the biofilter during the August test achieved less than 80% odor removal. This is considerably less than expected. The poor performance was due to the bed medium of pine bark having too low a moisture content. As a result, a water mist spray system was installed to wet the entire surface area of the bed. The rate of water addition was approximately ½ gal per day per ft^2 of bed area.

Table 8 shows the difference in bed moisture content with varying depth resulting from the water mist spray addition.

Table 8. Moisture Content and pH of Biofilter Bed

Depth Below Surface Ft.	Moisture[a] %	Moisture[b] %	pH[b]
1	25.7	74.8	8.2
2	33.6	72.9	8.3
3	36.8	75.8	8.2
4	26.0	67.2	8.9

[a]Bed samples collected in August before water spray addition.
[b]Bed samples collected in September after water spray addition.

The water spray addition system definitely improved overall performance of the biofilter. Table 7 indicates an odor removal efficiency of 86% for the first test and 91% for the second test in September.

During the sampling conducted during August and the first test in September, a definite "blue smoke" was observed to be emitted from the surface of the bed. The intensity of this smoke was greater from that half of the bed nearest to the inlet compared to the opposite half of the bed. This "blue smoke" emission was attributed to the Heil dryer exhaust which passes through the new spray type condenser.

Observation of the operation of the biofilter during these tests indicated that the inlet temperature of 122-130°F was higher than desired. This also was due to the Heil dryer exhaust not being treated adequately by the new spray type condenser. It was found that a flow of only 260 gpm of water was being supplied, whereas a flow of 350 gpm is required. This condition was corrected later in September.

In summary, the biofilter system at the Alabama plant is functioning satisfactorily with an estimated odor removal efficiency of approximately 90%. However, improvements probably can be made in its operation which would result in better performance. These include a reduction of the inlet temperature and an improved distribution of flow throughout the bed.

Biofilter System in Georgia

It should be noted that nearly 50% of the total odor emission is due to the plant ventilating air. Also, the use of four steam-tube dryers instead of a single direct-fired unit which processes feathers at the Alabama plant avoids the problem of emitting "blue smoke" which increases the level of odor intensity. As a result, the odor intensity in the total emission from the Georgia plant is considered to be significantly less than from the Alabama plant. Thus, the lower residence time in the biofilter bed is adequate to treat the odor emissions from the Georgia plant.

The installation of a biofilter system was completed and startup operation began during November 1990. The construction of the biofilter is similar to that of the Alabama biofilter except that pre-cast concrete slabs with slotted holes for inlet gas distribution are provided. This type of construction is very substantial allowing the use of front end loaders to move and turn over the bed material. However, it is more costly as indicated in Table 6. Based on a cost of $7/yd^3 for pine bark, replacement of the bed would cost $16,800 exclusive of labor.

The following discussion relates to the experience obtained with the biofilter system at the Georgia plant since November 1990.

1. The moisture content of the bed is checked weekly and it has ranged from 65 to 75%. A water addition system is used which is similar to that described for the biofilter at the Alabama plant.

2. The temperature of the inlet gas stream has ranged from 70°F during the winter months up to 110°F during the summer months. At the lower temperature, less water needs to be added to the bed to maintain the moisture content.

3. Prior to early August 1991, the pH of the bed remained within a range of 7-8. The bed was then turned over and within 3 weeks the pH had dropped to 2. Approximately 0.3 lb of lime per ft^2 of bed surface was added and the bed was thoroughly irrigated with water. This was sufficient to restore the pH to a range of 7-8. Subsequently a similar drop in pH occurred after 120 days of operation, requiring the desired range of pH to be restored.

4. The inlet gas stream has been analyzed for the following nutrients: NH_3, Se, Cu, K, Zn, Ca, Mg, Mn, Fe and Na. These nutrients appear to be adequate.

5. The pressure drop across the bed at startup in November 1990 was 1.0 in. of water. During a 14 month period, the pressure drop only increased to 1½ in. of water. During the next month, the pressure drop increased to 3 in. of water indicating that considerable compaction occurred due to bark decomposition and settling. The moisture content remained constant at 72%. As a result, a mixture of new bark and old bed material was used for replacement with 3 to 4 parts of new bark mixed with one part of old bed material.

Although no performance tests have been conducted by collecting samples of high intensity odor inlet air and bed exhaust for evaluation by dynamic olfactometry, observations of the odor emissions from the biofilter appear to indicate that the odor removal is satisfactory.

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MICROBIOLOGY OF DAF SKIMMINGS

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Large quantities of wastewater are produced by poultry processing facilities. These wastewaters have been shown to contain high concentrations of biochemical oxygen demand (BOD), chemical oxygen demand (COD), total organic carbon (TOC), oil and grease, and suspended solids (Chen et al., 1976; Whitehead, 1976; Woodard et al., 1977). The most common treatment for these wastewaters is chemical coagulation combined with the dissolved air flotation (DAF) process (Woodard et al., 1977). Employing the coagulants, aluminum sulfate, soda ash, and a cationic or anionic polyelectrolyte, this treatment has been found capable of BOD removals in excess of 85%, and suspended solids removals greater than 90% from poultry processing wastewaters (Woodard et al., 1977).

During the treatment of poultry processing wastewaters with combined coagulation and DAF, a sludge is produced which has a high moisture content (90%) and which presents difficulties in disposal (Carr et al., 1988). Although this sludge is often rendered to produce an animal feed supplement, its high moisture content makes it expensive to render (Carr et al., 1988). Moreover, this sludge can degrade the quality of other feed ingredients with which it is mixed. For these reasons, many rendering facilities no longer accept poultry processing sludge. Therefore, new disposal/utilization method(s) must be developed for this sludge. One such method involves land application of the DAF sludge. Sludge application to cropland adds nutrients to the soil which can be utilized by growing plants (U.S. EPA, 1978). In this connection, DAF sludges have been shown to contain significant levels of crude protein, crude fat, certain amino acids, and iron, and low levels of

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toxic heavy metals (Mulder et al., 1987). Sludge application to land also improves several soil properties (e.g., increases water content, cation exchange capacity, and organic carbon content) which are important for crop growth (U.S. EPA, 1978). Undigested DAF sludge has been applied to land as a sole source of nitrogen for corn production, resulting in good corn yields without an increase in nitrate levels in ground water (Carr et al., 1988).

With respect to land application or any other utilization of poultry processing sludge, questions remain as to the microbiological safety of this sludge. Little is currently known concerning the microbial content of poultry processing sludge. In a recent study in The Netherlands, flotation sludge from poultry processing was shown to contain high levels of aerobic bacteria, Escherichia coli, fecal streptococci, and Salmonella spp. (Mulder et al., 1987). In the present study, poultry processing DAF sludges and sludge filtrate from the rotary vacuum filter were obtained from a single broiler processing plant. These samples were then characterized with respect to heterotrophic plate count bacteria, total and fecal coliforms, fecal streptococci, Aeromonas hydrophila, and Salmonella spp. We have also determined the effect of DAF sludge treatment on these organisms. These results are useful in the assessment of the microbiological risks posed by DAF sludges during disposal and/or utilization.

MATERIALS AND METHODS

Poultry Processing Wastewater and Sludge Samples

Poultry processing DAF sludge (untreated sludge, dewatered sludge, and sludge filtrate) samples were obtained from a single U.S. broiler processing plant. A flow diagram of the treatment processes used at this plant for the DAF sludge, as well as the sampling points, are shown in Figure 1.

Physicochemical Characterization of DAF Sludges and Sludge Filtrate

The pH, conductivity, biochemical oxygen demand (BOD), chemical oxygen demand (COD), total solids (%), and volatile solids (%) of these samples were determined according to standard methods (APHA, 1985).

Bacteriological Analyses

Poultry processing sludge samples were collected in sterile containers, and bacteriological analyses were initiated within 2 hours of collection. Untreated (50 g) and dewatered (25 g) sludge samples were homogenized with 50 mL of a solution

Untreated DAF Sludge
Stored in Holding Tank Adjacent
to the DAF Unit

↓ Untreated Sludge Samples

Flocculation
Adjust pH to 9.0 with
NaOH + AddAnionic
Polyelectrolyte
(or Ferric Sulfate in
Hot Summer Months)

↓

Dewater by Rotary Vacuum Filtration

↓ ↓

Sludge Filtrate Samples → Sludge Filtrate | Dewatered DAF Sludge ← Dewatered Sludge Samples

↓ ↓

Return to Wastewater Influent Stream for DAF Treatment | Rendering

Figure 1. Flow Diagram of Poultry DAF Sludge Treatment Process Showing Sampling Points for Sludge Samples Used in this Study

containing (per 100 mL of water) NaCl (9 g), $Na_4P_2O_7$ (0.1 g), and polyoxyethylene ether W1 (0.1 g) as described by Farrah and Bitton (1984). The homogenized samples, as well as the sludge filtrate samples, were diluted with 0.1% peptone water

(APHA, 1985) prior to analysis. Enumeration of heterotrophic plate count (HPC) bacteria in these samples was accomplished by the standard pour plate method using plate count agar at 35°C for 48 hr (APHA, 1985). Standard membrane filtration and incubating conditions were used to enumerate total coliforms (TC) on m-Endo agar (35°C for 22 hr), fecal coliforms (FC) on m-FC agar (44.5°C for 24 hr), and fecal streptococci (FS) on KF streptococcus agar (35°C for 48 hr) (APHA, 1985).

Salmonella spp. (SA) were enumerated in the homogenized DAF sludge samples using a multiple-tube enrichment, most-probable-number (MPN) procedure (3-tube set of dilutions) consisting of pre-enrichment in 1% buffered peptone water (37°C for 24 hr), and transfer of pre-enrichment cultures for enrichment to tetrathionate broth with 1:100,000 brilliant green (37°C or 43°C for 24 hr) or selenite cystine broth (37°C for 24 hr) (APHA, 1985; Cox et al., 1983; Edel and Kampelmacher, 1973; Farrah and Bitton, 1984; Hussong et al., 1984; Thomason et al., 1977). A loopful of each enrichment broth was then streaked onto plates (incubated at 37°C for 24-48 hr) of brilliant green agar (BG), bismuth sulfite agar (BS), and xylose lysine brilliant green agar (XLBG) for the selective isolation of Salmonella spp. (APHA, 1985; Cox et al., 1983; Edel and Kampelmacher, 1973; Farrah and Bitton, 1984; Hussong et al., 1984; Thomason et al., 1977). Suspect salmonellae colonies were confirmed on triple-sugar-iron agar (TSI) slants, lysine-iron agar (LIA) slants, and using a sugar fermentation scheme (Cox and Williams, 1976) or API 20E strips (Analytab Products, Plainview, NY). Confirmed salmonellae isolates were serotyped by the National Veterinary Services Laboratory, Ames, IA and reported here by serovar. Positive tubes were used to determine the Salmonella spp. MPN in the samples by consulting MPN tables (APHA, 1985).

Aeromonas hydrophila (AH) enumeration in homogenized poultry DAF sludge and sludge filtrate samples was accomplished with the membrane filtration procedure of Rippey and Cabelli (1979) on mA agar (at 37°C for 20 hr) followed by in situ mannitol fermentation and oxidase tests. This procedure allows confirmation of A. hydrophila colonies directly on the filter (i.e., trehalose +, mannitol +, and oxidase + colonies).

RESULTS AND DISCUSSION

The physicochemical characteristics of the untreated and dewatered broiler processing DAF sludge samples evaluated in this study are presented in Table 1. The untreated and dewatered sludge samples displayed similar pHs. The mean chemical oxygen demand (COD) of the untreated sludges was 200 g/kg wet weight (i.e., 200,000 mg/L) while that of the dewatered sludge samples was 1,370 g/kg wet weight.

Table 1. Physicochemical Characteristics of Poultry Processing DAF Sludge Samples and Sludge Filtrate Samples from a Rotary Vacuum Filter (Mean ± standard deviation)

Sludge type	pH[a]	Conductivity[a] (μmho/cm)	BOD (g/kg)[b]	COD (g/kg)[b]	Total Solids (%)	Volatile Solids[c] (%)
Untreated (Raw)	5.6±0.07	847± 6.3	45± 2.5	200±23	6.54±4.2	98.9± 1.5
Dewatered (Vacuum Filtered)	5.5±0.05	482±17	34± 2.0	1,370±1,010	42.8±2.9	69.5± 3.6
Filtrate	8.0±0.08	241±14	60±11[d]	97±42[d]	5.64±5.0	2.11±1.6

[a]For the dewatered sludge samples, these parameters were measured following dilution (1:1) of the sample with reagent grade I water (deionized, ultrafiltered, etc.).
[b]Based on wet weight.
[c]Based on total dried solids.
[d]Units of mg/L.

The total solids content of the untreated and dewatered sludge samples were 6.54% and 42.8%, respectively. Most of the solids in these sludges were volatile. The results for the untreated (liquid) DAF sludges were similar to those of Carr et al. (1988) for the same sludge type. These investigators reported the following parameters for liquid DAF sludge from a Maryland broiler processing plant: solids-15.0%; pH-5.5; COD-287,000 mg/L.

The physicochemical characteristics of broiler processing sludge filtrate samples from the rotary vacuum filter (i.e., fluid removed from DAF sludge during drying) were also shown in Table 1. Sludge filtrate displayed a higher mean pH (i.e., 8.0) than the DAF sludges as a result of the addition of NaOH to the sludge prior to vacuum filtration (Figure 1). The sludge filtrate samples also displayed low BOD, COD, and total solids contents relative to the DAF sludges (Table 1). Most of the solids in the filtrate samples were non-volatile. The BOD and COD concentrations in the sludge filtrate samples are much lower than those reported for poultry processing DAF wastewater effluents (Chen et al., 1976). Consequently, the sludge filtrate could be discharged directly into the municipal sewer system with the DAF wastewater effluent rather than being returned to the wastewater influent stream for DAF treatment (Figures 1).

Several media were evaluated for the recovery and enumeration of Salmonella spp. in DAF sludge samples by the multiple-tube enrichment (MPN) method. Pre-enrichment in 1% buffered peptone water at 37°C for 24 hours was undertaken for all homogenized sludge samples. However, two different enrichment media and incubating temperatures were evaluated for salmonellae recovery. Comparable recoveries of Salmonella spp. from untreated and dewatered DAF sludges were obtained with enrichment in either tetrathionate broth with brilliant green (37 or 43°C) or selenite cystine broth (37 or 43°C)(data not shown). It should be noted that the 43°C enrichment incubating temperature has been used previously (Edel and Kampelmacher, 1973), and that selenite cystine broth was recommended by Cox et al (1983) for the recovery of salmonellae from broiler carcasses. In the present study, three different selective media were also evaluated for the recovery of salmonellae from enrichment cultures of untreated and dewatered DAF sludges. Greater recoveries of Salmonella spp. MPN from these sludges were found by using brilliant green agar as the final isolation medium rather than xylose lysine brilliant green agar or bismuth sulfite agar (data not shown).

Results of the enumeration of HPC, TC, FC, FS, SA, and AH in poultry processing DAF sludge and filtrate samples are summarized in Tables 2 and 3. High concentrations of all bacterial parameters were found in the untreated (raw) liquid DAF sludges, as well as in the dewatered DAF sludges.

Table 2. Summary of Indicator Bacteria, Aeromonas hydrophila, and Salmonella spp. Concentrations in Poultry Processing DAF Sludge Samples

Bacterial group	Mean Log_{10} CFU or MPN[a]/g Dry Weight		
	Untreated sludge	Dewatered sludge	Percent of untreated found in the dewatered
HPC Bacteria	11.1	10.4	19
Total Coliforms	8.95	8.11	15
Fecal Coliforms	8.08	7.08	10
Fecal Streptococci	8.71	7.72	10
A. hydrophila	5.63	4.95	21
Salmonella spp.	8.26	≥ 8.08	≥ 67

[a]MPN unit for Salmonella spp. only.

Table 3. Summary of Indicator Bacteria, Aeromonas hydrophila, and Salmonella spp. Concentrations in DAF Sludge and Sludge Filtrate

Bacterial group	Mean Log_{10} CFU or MPN[a]/g Dry Weight		
	Untreated sludge	Dewatered sludge	Percent of untreated found in the dewatered
HPC Bacteria	11.1	6.00	0.001
Total Coliforms	8.95	4.15	0.002
Fecal Coliforms	8.08	4.90	0.066
Fecal Streptococci	8.71	4.46	0.006
A. hydrophila	5.63	5.32	49
Salmonella spp.	8.26	3.71	0.003

[a]MPN unit for Salmonella spp. only.

Table 4. Salmonella Serovars Identified in Poultry Processing DAF Sludge Samples

Sludge type	Serovar(s)
Untreated	S. hadar S. heidelberg
Dewatered	S. montevideo

Worthy of note are the high concentrations of the pathogens, Salmonella spp. (log_{10} MPN/g dry wt.: 8.26 untreated sludges, $\geq$ 8.08 dewatered sludges) and Aeromonas hydrophila (log_{10} CFU/g dry wt.: 5.63 untreated sludges, 4.95 dewatered sludges). As shown in Table 4, three Salmonella serovars were identified in the DAF sludge samples in this study; namely, S. hadar and S. heidelberg in untreated sludges, and S. montevideo in dewatered sludges. Similar concentrations of total aerobic bacteria, FC, and FS, as found in the present study, were reported by Mulder et al. (1987) for poultry flotation sludge samples in the Netherlands. These investigators also detected salmonellae in 9 of 29 flotation sludge samples, but did not enumerate salmonellae in the samples. To our knowledge, there are no other studies on the enumeration and sterotyping of Salmonella spp. in poultry DAF sludges.

Table 5. Comparison of Salmonella spp. Concentrations in Poultry Processing DAF Sludges and Municipal Wastewater Sludges

Sludge type	Salmonella spp. conc. (Log_{10} MPN/g dry wt.)	Reference
DAF Untreated	8.26	This Study
DAF Dewatered	$\geq$ 8.08	This Study
Undigested Municipal	0.66 to 1.48	Farrah & Bitton (1984)
Digested Municipal	- 0.40 to 1.52	Farrah & Bitton (1984)

It is apparent, however, that the concentrations of Salmonella spp. detected in the DAF sludges in our study (Tables 2 and 3) are extremely high particularly when compared to (Table 5) undigested municipal wastewater sludges which contained salmonellae at 0.66 to 1.48 log_{10} MPN/g (Farrah and Bitton, 1984), or digested municipal sludges which contained - 0.40 to 1.52 log_{10} MPN/g (Farrah and Bitton, 1984) or 0.30 to < 1.38 Log_{10} CFU/g (Dudley et al., 1980) of these organisms.

On a solids dry weight basis, recovery of bacterial parameters in the dewatered sludges relative to the untreated liquid sludges ranged from a high of $\geq$ 67% for Salmonella spp. to a low of 10% for fecal coliforms and fecal streptococci (Table 2). These results indicate either inadequate recovery of the viable bacteria from the dewatered sludges (e.g., bacteria bound tightly to sludge solids), and/or the killing of bacteria during the dewatering process. These two possible conclusions are consistent with the high recovery ($\geq$ 67%) of Salmonella spp. found in the dewatered sludges. The pre-enrichment and enrichment procedures used to enumerate salmonellae in the sludges would allow better recovery of sludge solids-bound bacteria, and injured bacteria than the membrane filtration methods used to enumerate the other bacterial parameters.

Shown in Table 3 are the results of the enumeration of bacterial parameters in sludge filtrate samples. Bacterial concentrations in these samples were 3 to 5 logs lower than those in the untreated liquid DAF sludges. These results indicate that the low recoveries of bacteria in the dewatered sludges described in the previous paragraph cannot be attributed to the transfer of bacteria to the sludge filtrate during dewatering. Furthermore, the low concentrations of bacteria in sludge filtrate samples may be indicative of the sorption of bacteria to the sludge solids.

In conclusion, the untreated and dewatered broiler processing DAF sludges contain very high bacterial concentrations, including salmonellae, which may pose risks to the environment and to public health if disposed of or utilized in these forms. As with other sludge types, poultry processing sludges must be stabilized before land application (U.S. EPA, 1978). Stabilization reduces the pathogen content, eliminates odors, and reduces the putrefaction potential of sludges (U.S. EPA, 1978). We are currently completing a study dealing with the evaluation of methods for the stabilization of broiler processing DAF sludges, and the determination of the effects of such treatment methods on the microbial flora of these sludges.

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TREATMENT OF FURTHER PROCESS WASTEWATER

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DEFINING "FURTHER PROCESS" WASTEWATER

Water Flow Rates

Unlike slaughter plants, which have a fairly predictable flow rate during processing and cleanup, the further processing plants can vary widely in flow characteristics. A further process non-cooking plant can have wastewater flow rates during processing that vary by as much as 40% from day to day.

In slaughter plants, we talk in terms of gal/bird and we can compare water usage from plant to plant because the processes are all very similar. In a further process facility the process changes during the processing period due to marinating, cooking techniques, sauce changes, breader/batter usage, etc. These changes can cause more or less water flow for things like floor cleaning, belt washing, etc.

Flow changes are also caused by the type of operation of the facility. A two shift processing plant with cleanup on a shortened third shift will have higher peak flows during cleanup than a single shift operation with a longer cleaning time. Slug loads of water can be seen when fryers or ovens are cleaned or freezers are defrosted.

In a typical slaughter plant the maximum flow occurs during cleanup and is about 40% above the average daily flow. In a typical further processing cook type plant we can expect maximum flows during cleanup to be 100% or more above the average daily flow in gallons/minute. These flows, of course, have a drastic affect on wastewater equipment sizing.

One plant reported water usage during the daytime of 150 gal/min and flows for 4 hours during cleanup in excess of 950 gal/min. As you can see, if your system is not flow equalized it is way too large during most of the day.

Contaminates

Compared to a slaughter facility, a further processing plant can be extremely difficult to treat due to different and changing contaminant loadings. Typical slaughter plants discharge such things as bloody water, oils and fats, solids proteins and soap.

A further processing facility will discharge all of the above plus chemicals from margination, cleaners for fryers, cleaners for ovens, heavy solids loading from breaders and batters, high and low pH's during operation and cleanup, cooking oils as well as higher fat due to the cooking.

Of course, as I said before, a further processing wastewater is variable in both flow and contaminates throughout the day.

TREATMENT OF FURTHER PROCESS WASTEWATER

Pretreatment for Discharge to POTW

By federal law, most cities in the United States are required to prepare, if they haven't already done so, a pretreatment program for industry.

These pretreatment programs usually limit the following contaminates:

Item	Typical Range
pH	5 to 10
BOD	250 mg/l to 400 mg/l
TSS	300 mg/l to 400 mg/l
Oil and grease	100 mg/l
Foam	None visible

What do we have to remove from the influent?

Item	Typical Range
pH	5 to 13
BOD	4500 to 9000 (COD's up to 100,000)
TSS	1500 to 6000
Oil and grease	350 to 550

A typical pretreatment system for further processing will include a good secondary screening system, flow equalization of influent, a system to neutralize any pH swings (Alkali and/or Acid) a system to flocculate the contaminates, a float cell (Dissolved Air Flotation) or similar to remove the flocculated materials from the water stream, a chemical system to supply treatment chemicals to the float cell and in extreme cases a semibiological system to remove BOD caused from processing chemicals. One of the main problems in treating Further Process Water is the soluble BOD.

The end use of the secondary nutrients (skimmings) from the float cell will determine the type of chemical flocculation to be used in the system.

Some typical chemical systems used today are:

Ferric coagulant with polymer
Aluminum coagulant with polymer
Dual polymer
Single polymer
Acidulation with polymer

If you are operating or anticipate operating a pretreatment wastewater plant for further processing wastewater, you should monitor very closely for things that can interfere with the chemical program. Some of these things are:

Phosphates (from margination and/or flour, soaps)
pH changes (from cleaning operations)
TSS loading (from cleanup)

Another item that should be considered are odors from the flow equalization tank. These odors are generally mercaptans that are released from the sauces and marinates. These are amides with attached molecules. The odor index for mercaptans start at about one part per billion.

Full Treatment with Discharge to a Stream

Of course, if you are biologically treating for stream discharge you generally can't introduce full strength further process wastewater directly to the biological system. Some form of pretreatment must generally be used to lower the BOD.

When full treatment is used the preferred method is to use a basin in front of the system to give seven day equalized flow. If seven day equalization is not used, we create what I call a Monday-Tuesday syndrome. I liken this to our wives telling us on Friday night that she is not going to feed us again until Monday. You can imagine the result.

It generally takes a nonequalized flow system until about Wednesday to settle down and begin to properly treat water.

Other reasons to pretreat and equalize these flows are:

1. Leveling of loads going to the system.
2. Protection of the biological system from toxics such as chlorine used in cleanup.

Chlorine and other sterilizing agents do the same thing in a biological treatment system that they do in the process plant. They kill the bacteria used to eat BOD, etc. When further processing wastewater is stored, even after screening, the batters and flours used tend to ferment rather than turn rancid as oil and grease does. This fermentation causes an acid condition in the storage vessel that can eat up a steel storage tank over a period of 3-4 years.

CONCLUSIONS

Treatment of further processing wastewater is typically much more difficult than treating kill plant water. This is due to the variability of flow and contaminates.

In order to keep the treatment system size as small as possible, an equalization tank should be used to buffer flow and contaminate loadings.

Many treatment schemes are available and in use. A thorough analysis and Jar testing will help you decide which is best for your system.

INSECT AND PEST CONTROL AND ENVIRONMENTAL QUALITY

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The control and management of pests of poultry facilities are important parts of the day-to-day management of any poultry facility. This management is intended to improve environmental quality for both birds and man; however, the term environmental quality can have very different meanings depending on the circumstances under which it is used. In general, we are concerned with the environment within the house and how it impacts on the rate of lay, hatchability, weight gain and other performance factors. However, the impact of the poultry operation on the environment surrounding the house is an issue that has recently become important. Choosing a technique or control strategy for use in and around the poultry house becomes more difficult when questions other than "does it work" must be answered. The perception of using a pesticide and it's impact on the environment, for example, changes if one is using the pesticide to control a problem that is impacting production vs. the concern that the use of the pesticide may have negative impact in the environment surrounding the poultry facility.

To a poultry producer, an overabundance of flies, mites or rodents is certainly detrimental to production and to the quality of the environment of the birds and the workers. If pest problems spill out into the surrounding human habitat, (i.e., the neighbors), they may feel that these pests are detrimental to their environment and request help in dealing with the problem from the producer or integrator or seek legal advice. To manage pests associated with a production facility, economic and environmental issues should be addressed. The most effective way to do this is to utilize an Integrated Pest Management (IPM) program for poultry (Axtell and Arends, 1990). An IPM program sets goals of having no economic losses due to pests and ectoparasites and to do so in a manner that the environmental quality of the house and surrounding environment is not compromised.

The interaction between pest, poultry house and environment is complex and constantly changing. To effectively deal with the problems we must consider a number of aspects when formulating pest management plans. There are a variety of pests and ectoparasites of importance to the poultry producer. These pests and ectoparasites can attack the birds, the poultry house or surrounding area. To have effective pest control, each pest may require a specialized management plan to effectively maintain it below economically damaging levels (Arends and Robertson, 1986).

There is little question that the poultry producer perceives flies as a major pest problem. Flies that feed on the blood of the birds are important because of the irritation to the birds that is caused by the biting of the flies and the potential of the flies in vectoring disease. In addition,if flies are present in large numbers they can disperse to the surrounding area (Axtell and Arends, 1990) and create a major problem.

Biting flies (blood feeders) are viewed by both the producer and neighbors as serious pests. Birds serve as excellent hosts for blood feeding flies. Poorly managed lagoons (Axtell and Arends, 1990) can breed large numbers of mosquitoes that can disperse to the surrounding area. Control of these mosquitoes could be accomplished though area wide spraying, but using this approach would be expensive and could be harmful to nontarget species. A more correct approach would be to simply manage the lagoon correctly, keep the margin free of weeds and the lagoon free of floating mats of material (Axtell and Arends, 1990). Other species of biting flies can breed in areas around a house that drain poorly. These areas are due to improper grading around the house, and water will accumulate providing a breeding area for culcoides (punkies, no-see-ums) as well as mosquitoes. In addition, poor drainage usually allows water to seep back inside the house creating environmental problems inside the house as well as the potential for problems outside the house if manure leaks out.

Filth flies (non-blood feeding) can be present in large numbers if manure and other waste is not managed properly. The impact of filth flies varies from vectoring bacteria, specking eggs, being pests of the workers or dispersing to the surrounding area and being pests at human dwellings. If these flies disperse into the surrounding area they can cause large environmental problems in terms of fly nuisance to surrounding home owners. There is no distinction by the producer or surrounding home owners of flies that are beneficial insects and those that are pests; all flies are bad and are a nuisance and should not be tolerated is the most prevalent attitude.

People consider filth flies to be pests based upon the number of flies they see in an area. In some places, individuals are tolerant of flies and the threshold is quite high. In others, the tolerance is low and a few flies in an area will elicit an undesirable response. In most cases, where complaints are registered concerning flies, the individuals do not care how the flies are controlled, only that the fly numbers be lowered. It is important, though, to remember that many fly control practices, if done incorrectly, can create more problems than they solve. In addition, to effectively manage any fly population, an integrated approach that utilizes biological, cultural and chemical control practices (Axtell and Arends, 1990) should be used and the practices used will also impact on the environment.

The starting points for any fly management program are cultural/mechanical techniques that can be utilized to lower or eliminate fly breeding. Manure management is considered the key to any fly management program (Axtell, 1981) in a poultry facility. The key facet is the management of water, both within the house and outside the house. Run-off from the roof and surrounding the building must be handled in a way that it is channeled away from the foundation to ensure that during periods of heavy rain, water does not run under the foundation and back into the manure. It is also important that the water is channeled away in such a fashion as not to cause other environmental problems, i.e. surface water contamination of streams. Water in the buildings, from broken water lines, leaks in the system or roof must be minimized. Drinkers should be properly adjusted, especially in breeder hens. Wet spots in manure create instant hot spots for fly breeding and, if enough water is added, can allow the manure to flow from under the slats to the scratch area or outside the building. In addition, houses with wet manure are difficult to clean out. Most equipment is built to handle dry material, and wet manure is not easily contained in this equipment. Manure is spilled onto the road during transport and is not spread evenly in the fields.

The price for not observing water management in a poultry building is having to deal with wet litter/manure. Waste that falls from a truck during transport is an environmental hazard and usually brings a visit from law enforcement. Manure that is improperly spread may violate rules on waste management and void cost share monies for the landowner. If manure is spread incorrectly, it can wash into streams and lakes creating a significant environmental problem.

The use of biological control agents in poultry facilities to control flies is well documented (Axtell, 1986a; Axtell, 1986b; Axtell and Arends, 1990). There are many predators and parasites that naturally inhabit poultry manure. These include beetles, mites, fly larvae and hymenopterous parasites (Axtell and Arends, 1990) that are very active in destroying filth fly larvae and eggs, thereby reducing fly levels. In situations where manure is allowed to accumulate, breeder housing and caged layers, these biological control agents can keep fly breeding in check. However, if the environment of the manure is altered through poor management or chemical use, these predators and parasites are killed. Manure that is too wet will be a poor environment for the biological control organisms and, because it is not conducive to their survival, fly populations increase rapidly. In addition, these organisms are very sensitive to insecticides (Axtell, 1986a; Axtell and Edwards, 1983), and misuse or sloppy use will many times decimate the biological control in a building but have little or no impact on fly breeding.

Perhaps the most noted environmental quality issue is the use of pesticides. Each pesticide that is used in or around food animals must have a label indicating that this is an approved use. If the site is not on the label, i.e., chicken, chicken house, etc., then the use of the pesticide would be illegal. Any time a pesticide is used, the substrate that it is used on and its future should be taken into account. Pesticides used in a poultry facility can be used on a number of substrates, birds, manure, the structure and in the surrounding area to control unwanted pests, and because the public perception of pesticide use is often negative, care should be taken when choosing a product to use in or on poultry.

The misuse of a pesticide can cause a number of environmental concerns. Residues in meat or eggs are certainly of concern and a great risk if an unregistered product gets into the birds. These include products that are used directly on the animals as well as products that may have been used on the feed ingredients. Illegal residues in food ingredients many times translates into problems in the birds as well. Products that are used in pest control for stored food ingredients as well as those that might be used in the production of food ingredients can present problems.

An obvious first question concerning a pesticide use would be, what is the impact of the product on the animals. If the product has a label that clearly states that it can be used on poultry, this question is answered. If there are withdrawal times indicating the length of time post treatment birds should be held, they should be followed.

The use of pesticides on manure to control flies is a problem with many facets. If the manure is wet enough to be breeding large numbers of flies, the addition of more liquid insecticide will have only an impact for a short time. In addition, the use of an insecticide has detrimental effects on the biological control agents. Of further consideration is the disposal of the manure after treatment. Residues in the manure from an insecticide treatment may have an undesirable effect on the crops that are grown on the land the manure is spread on. Under appropriate circumstances, leaching from treated manure could cause problems by contaminating rain run-off, streams, etc. There is a great deal of interest in the use of manure as fertilizers, composted products and feed. Any material that is used in the manure to control any type of pest should be chosen carefully so as not to jeopardize the use of that manure for, as an example, animal feed. The use of a chemical that is not registered for use or has no established tolerances for animals would make the use of that manure for feed illegal.

The use of rodenticides on the exterior of the building and the use of herbicides to control vegetation around a structure are also areas of concern. Rodenticides should be used according to label and only registered products should be used around facilities. When a rodenticide is used, the impact on nontarget species should be taken into account. If a product is registered for the site, i.e., poultry or livestock houses, then concern is minimal. However, if an unregistered material is used, the impact on nontarget species and contamination of the birds themselves should be of concern. The use of herbicides should be of similar concern, run-off and contamination off site should be taken into account when these products are used.

The impact on the environment caused by controlling pests in poultry production can be positive if pest problems are dealt with using sound management plans. Utilizing an Integrated Pest Management plan that is specially adapted for the poultry situation should assure the producer that sound, environmentally safe decisions are being made.

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NUTRIENT MANAGEMENT PLANS WITH POULTRY WASTE

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All living things contain nutrients. Nutrients occur in bone, cells, fluids, enzymes and most other parts of organisms. A natural and biologically driven process of decomposition begins when nonliving organic matter comes into contact with the soil. Microorganisms drive the process, breaking complex molecules into simpler ones and eventually releasing nutrients to the environment. A simplified example of this process is the decomposition of complex proteins into simpler amino acids leading to the release of nitrogen in the forms of ammonia and ammonium.

Land application of excessive quantities of organic or inorganic nutrients (uncontrolled disposal) is subject to surface run-off and leaching that may contaminate ground or surface waters. The potential for contamination is very site specific. For example, sites with flat topography, coarse-textured, sandy surface soils, and permeable subsoils are more susceptible to ground water contamination than sites with sloping topography having fine-textured clays and silt that are less permeable.

Where ground water contamination is a concern, depth to ground water, location of wells, and well head protection are extremely important factors to consider in developing a land application program. In areas where surface water contamination is a concern, key factors to know include degree of slope, distance from surface waters, use and classification of surface waters, and rate of water percolation into the soil profile. While most site evaluation criteria are technical in nature, there is an additional sociological factor that is becoming more important: potential nuisance and odor complaints from neighbors.

The quantity of nutrients within organic materials varies considerably between different materials and within the same material if processed or handled differently. Because of this diversity, it is extremely important that all organic materials be analyzed for nutrient content before being land applied. In addition to a standard nutrient analysis, it is important to know the quantity of heavy metals, oil and grease, and sodium that may be present in the material and the Chemical Oxygen Demand (COD) required to decompose it. These additional characteristics are more important to know for poultry processing wastes than for poultry manures or mortality composts. While each of the waste characteristics must be considered in a land application program, this paper will focus on nutrient management.

ENVIRONMENTAL CONCERNS WITH NUTRIENTS

The nitrogen and phosphorus present in organic materials are common water pollutants. Both of these nutrients can contaminate surface water, but nitrogen is the predominant nutrient of concern in ground water. Contamination of surface waters is primarily from soil erosion. Attached nutrients, pesticides, and organic matter in eroded soil disperse throughout the aquatic system. Algae present in the water thrive on the addition of nitrogen and phosphorus and rapidly increase in numbers. When algae populations begin to die, microorganisms use the oxygen in the water to decompose the dead algae. The low water oxygen level from increased algae decomposition can result in fish kills. Management to prevent surface water contamination begins with soil conservation. Best management practices for surface water protection may include some of the following erosion reduction systems: conservation tillage, contour farming, strip cropping, grassed waterways, and field borders; in conjunction with nutrient BMPs.

Because of direct competition from plants and soil organisms, ground water is less vulnerable to nutrient contamination than surface waters. Contamination can occur, however, when concentrations applied to the soil exceed plant nutrient needs. The primary nutrient of concern with ground water contamination is nitrogen. Nitrogen is a very dynamic element. It can be present in several molecular forms and in a solid, liquid, or gaseous state. Most forms of nitrogen are of little concern to human health. The air we breathe is 78% nitrogen gas. The first inorganic forms released from organic materials applied to soil are ammonia, a gas, and ammonium. Ammonia, if not incorporated can be lost through volatilization. Ammonium (NH_4+), on the other hand, is not volatile and is a molecule with a positive charge. Clay particles and humus in soil contain negative charges. The weak magnetic forces of molecules with positive charges like ammonium, therefore, and are less likely to leach to ground water. While this "magnetism" is an excellent mechanism to retain nutrients in the soil, microorganisms use the ammonium and readily convert it into a negatively charged molecule called nitrate NO_3. Since nitrate is negative and soils have a negative charge, nitrate is quite susceptible to leaching and is the primary source of nitrogen found in ground water. Nitrate is also the one form of nitrogen that can be a concern for human or animal health.

The maximum drinking water standard for nitrate-nitrogen (NO_3-N) is 10 ppm for humans. At concentrations above this level, there is an increased health risk in infants less than six months old. The digestive system of a human infant has a higher pH and different microorganisms than that of adults. When nitrate enters their digestive system, it converts rapidly to a form called nitrite that is extremely reactive and combines with the oxygen-carrying hemoglobin in the baby's blood stream and forms a compound called methemoglobin. This compound eventually decreases the oxygen available to the baby's system, and the baby begins to suffocate from lack of oxygen. The disease is called methemoglobinemia or blue baby syndrome. Death occurs when 70 percent of the body's hemoglobin converts to methemoglobin. While the cases of blue baby syndrome are now quite rare, it is still important to prevent nitrate buildup in drinking water.

NUTRIENT MANAGEMENT PLANS

To prevent an over application of nitrate or other nutrients, it is important to develop and use a site-specific nutrient management plan. Plans should contain the best management practices (BMPs) necessary to promote nutrient uptake efficiency and prevent off-site movement. In developing a plan, it is important to know the concentration and availability of each nutrient present in organic materials, the nutrient and management requirements of the plant being grown, and the nutrient and acidity status of the soil being used.

Poultry wastes can generally be characterized through analyses performed by certified laboratories. For nutrients, the report should give the moisture content of the material and the concentration level of each plant nutrient. Most concentrations are reported on a dry-weight basis. When looking at the quantity of nutrients reported, it is important to know that the entire concentration is not readily available to plants. Some of the molecules are so tightly bound in the organic structure that they are not available during the first year of land application. In general, only about 50% of the organic nitrogen is available (mineralized) to plants during the first year, while most inorganic nitrogen is readily available, if ammonia volatilization can be minimized. Volatilization losses can be estimated, depending on the method of land application system used. North Carolina has developed nutrient availability estimates for poultry manures and other wastes that include an estimate of both mineralization and volatilization. Coefficients for poultry waste are listed in Table 1. When developing a nutrient management plan, it is important not only to know the concentration of nutrients present in the organic material but to estimate the availability of those nutrients to the plant. Once this is accomplished, an application rate can be determined based on the nutrient requirements of the cropping system.

Table 1. Nutrient Availability Coefficients for Poultry Manures

Manure Type	Injection[a]	Soil Incorporation[b]	Broadcast[c]	Irrigation[d]
	P_2O_5 and K_2O availability coefficients			
All manure types	0.8	0.8	0.7	0.7
	---- N availability coefficient ----			
All poultry litters*	--	0.6	0.5	--
Layers (no litter)	--	0.6	0.4	--
Layer anaerobic lagoon sludge	0.6	0.6	0.4	0.4
Layer anaerobic liquid slurry	0.8	0.7	0.4	0.3
Layer liquid lagoon	0.9	0.8	0.5	0.5

[a]Manure injected directly into soil and covered immediately.
[b]Surface-spread manure plowed or disked into soil within 2 days.
[c]Surface-spread manure uncovered for one month or longer
[d]Sprinkler-irrigated liquid uncovered for one month or longer.
*Includes in-house and stockpiled litters.

RATE

Application rates can be made to supply any nutrient of need, providing the rate will not over supply another nutrient that may negatively affect the cropping system or environment. If the application rate is based on a nutrient other than nitrogen, a soil test should be used to determine the site-specific needs. If the rate is based on nitrogen, the yield potential of the site should determine the rate applied. Nitrogen application guidelines, being used in North Carolina, are based on production potential and are listed in Table 2. Other management options that need to be considered and implemented when developing a land application program include the proper timing and uniformity of application.

Table 2. Nitrogen Recommendations for Various Crops

Nitrogen Commodity	Use	Plant Available Recommendations (lbs N/RYE[a])
Corn	grain	1.00-1.25 lbs/bu
Corn	silage	10-12 lbs/ton
Cotton	lint	0.1-0.15 lbs/ton lint
Wheat, rye	grain	1.7-2.4 lbs/bu
Barley, triticale	grain	1.4-1.6 lbs/bu
Oats	grain	1.0-1.3 lbs/bu
Fescue	hay[b]	40-50 lbs/ton
Hybrid bermuda	hay	40-50 lbs/ton
Orchardgrass	hay[b]	40-50 lbs/ton
Timothy	hay[b]	40-50 lbs/ton
Small grain	hay[b]	50-60 lbs/ton
Ryegrass	hay[b]	50-60 lbs/ton

[a]RYE means realistic yield expectation.
[b]Reduce N rate by 25% if grazing; rate for established fields only.

TIMING

The south's mild climate allows decomposition of organic materials throughout the year. When an organic material is land applied, decomposition begins and nutrients are released. If wastes are applied in the absence of actively growing plants, the nutrients are more subject to potential leaching or runoff. This mismatch between land application timing and active plant growth is a common problem with poultry litters. Many poultry houses in the south are cleaned out by custom operators and haulers. When the birds are removed, the custom operators come in, remove the litter and apply the litter to the fields.

Land application timing is often based on the poultry cycle, which may or may not coincide with the nutrient needed on an actively growing crop. An example of how this mismatch can potentially impact ground water can be seen in Figure 1. This was a site with 14 years of poultry litter applications. The rate applied was reasonable for the bermudagrass hay system being used. Yet, elevated concentrations of nitrates were found at a depth of 8 feet. We feel, in this site-specific case, that the poultry litter was land applied during the winter when bermudagrass was dormant. Nitrogen released was not used by the plant and began to leach. By the time the crop began active growth, much of the nitrogen was below the root system.

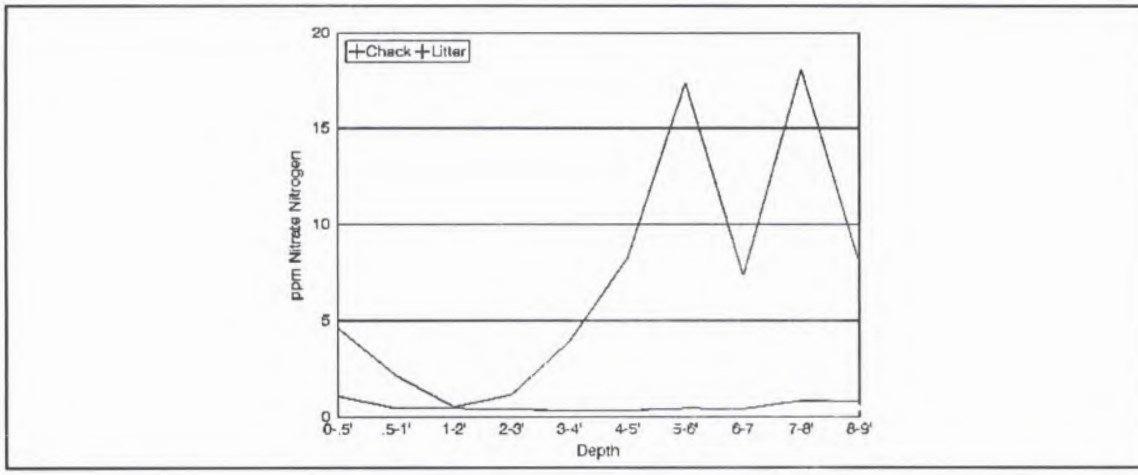

Figure 1. Nitrate Nigrogen in Soil Treated With and Without Poultry Litter.

APPLICATION PATTERNS AND EQUIPMENT

Nutrients must be soil applied so they are available to plant roots. Research with commercial fertilizers have shown changes in nutrient uptake efficiencies by adjusting placement to correspond with the roots position at the time of application. This precision placement is possible because of the uniformity of fertilizer materials and the mechanical advances in fertilization equipment.

Manure application equipment accuracy is still fairly crude compared to its commercial counterparts. Much of this is directly attributed to the lack of uniformity in the material itself. Sources such as poultry litter contain a wide range of particle sizes, shapes of particles and moisture contents. With this diversity, even the best equipment will have difficulty in obtaining a uniform distribution. Conscientious efforts must be made in equipment calibration to assure that the proper rate is being applied and that it is uniformly spread to provide adequate nutrition to all the plants across the field.

CONCLUSION

To land apply poultry waste in an environmentally responsible manner, requires a well-planned program that balances the nutrients present in the materials with a cropping system capable of using the same nutrients. A plan must include a soil and waste analysis, calculation of application rates based on plant nutrient needs, and application timing and placement to promote plant nutrient uptake.

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CURRENT LITTER PRACTICES AND FUTURE NEEDS

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The Poultry Industry has long been interested in alternative forms of litter which are better or less expensive. Some early writers mention as acceptable, forms of litter such as straw, peat moss, shavings, ground corncobs, sugar cane pulp, and peanut hulls. Probably the one litter type which has emerged in our industry as the most widely accepted would be wood shavings.

Most poultry growers would agree that over the years good wood shavings have become harder to obtain, or very expensive. It should be realized that wood shavings became the primary litter type because of its cost and availability. In early years, wood shavings were a waste product generated by the planing of lumber. Wood shavings could be had at relatively low cost because there were few competing uses for this product.

Over time, however, we have seen the cost of this product rise, primarily due to increased use of the product. New resins used in the lumber industry have allowed this lumber waste to be turned into 4X8 sheets of chip board for use in the construction of homes, buildings and even poultry houses. Within the poultry industry, we have seen more than a 300 percent increase in production since 1960, which also had an effect on the price and availability of wood shavings.

WEST VIRGINIA

West Virginia broiler producers have been spending about 2000 dollars per year to bed each house with wood shavings or peanut hulls. The standard practice within the state has been to bed chicks with less than 1 inch of litter material, and totally clean out houses between every brood. Bedding suppliers have typically blown shavings (or peanut hulls) into a series of piles down the center of the broiler house. The poultry farmer has been responsible for distributing the bedding material throughout his house. This has been about a four-man-hour job. The problem herein lies with multiple (sometimes many) houses on a farm, summer downtime of less than 1 week, and all-in/all-out production practices. Many farmers with single-story/clear-span houses load bedding material into a manure spreader, then use this common farm machinery to disperse the bedding.

The one commercial supplier of newspaper bedding in the state uses a dairy farm bale chopper to further chop and disperse 60-pound bales of chopped newspaper. This supplier can bed a house in about a half hour; the farmer can be doing other things while this individual is bedding the house. Despite the caking that takes place between weeks 2 and 3 of growout, West Virginia producers are accepting chopped newspaper as a bedding source and the entrepreneur involved in providing this bedding is enjoying success. This service costs less than bedding with more widely accepted sources, and saves the farmer a substantial amount of time.

SURVEY

In May, 1992 a survey assessing current industry litter management practices was sent to broiler company growout managers. Thirty-nine responses were received. Responding companies produce 2.4 billion broilers, in over 22 thousand houses; this represents about 40 percent of 1991 production. The Mid-Atlantic region (WV, DE, VA, MD, PA) represented 410M birds (3837 houses), the South-Atlantic (NC, SC, GA, FL) represented 412M birds (3646 houses), the South (AL, MS, LA, TN) region represented 401M birds (3783 houses), the South-Central (AR, TX, MO, OK) represented 1.1B birds (10797 houses), and the North (OH, IN, IL, WI, MI, and MI) represented 66M birds and 275 houses.

Litter Practices

The first question of the survey, dealing with litter practices, asked how often growers clean out their houses. This practice is tremendously variable between companies and between regions of the country (Table 1). Nine percent of houses reporting in this survey are cleaned out every flock, 15 percent every 2 to 3 flocks, 7 percent every 4 to 5 flocks, 50 percent every 6 to 7 flocks (once per year), 13 percent each 8 to 15 flocks, 4 percent observe an even longer time between cleanouts, and 3 percent of companies make no recommendation to growers.

Does utilization of built-up litter actually save bedding, or does it simply save the grower the time involved with cleanout? In West Virginia, our growers use less than an inch of bedding each flock. At the end of 1 year they have used litter equivalent to about 7 inches. If a grower using built-up litter starts with a 3 inch base and top-dresses with a half inch of bedding between flocks, at the end of 1 year he has also used about 7 inches of litter. The grower using built-up litter has to remove cake, condition the remaining litter, worry more about ammonia concentration, worry more about disease, and has to have a more rigorous program for the control of darkling beetles.

Table 1. Litter Practices: Percentage of Birds Raised Under a Particular Cleanout Schedule

No. flocks	Mid. Atl.	So. Atl.	South	So. Cent.	North	National
Each flock	14.3	29.4	1.1	2.7	0	8.8
2 to 3	2.3	28.8	18.6	12.4	21.8	14.5
4 to 5	0	22.2	20.2	0	0	7.0
6 to 7	0	16.4	30.5	84.8	78.2	49.8
8 to 15	45.5	0	29.6	0	0	12.8
Longer	22.2	0	0	0	0	3.8
No Recommend.	15.6	0	0	0	0	2.7

Manure Utilization

When asked about manure utilization practices (Table 2), companies estimated that 90 percent is land applied on the growers own acreage, 4 percent is fed to animals, 2 percent is sold "as is", and 1 percent is composted and sold. Companies representing 1.3 percent of the birds made no estimate as to manure utilization.

This question of what is being done with the manure is one of the major reasons for this conference. It can be expected that over the next short period of time, the mix between land application, animal feed, sales, and composting and marketing will change dramatically. Each of us attending this conference is interested in facilitating this change and allowing poultry manure to be seen not as "waste" but as "brown gold".

Table 2. Manure Utilization: Percentage of Manure

	Mid. Atl.	So. Atl.	South	So. Cent.	North	National
Land applied	82.6	94.6	89.3	92.4	86.2	90.5
Fed to animals	0	4.4	3.9	5.9	.5	4.2
Sold "as is"	3.3	.9	6.4	.8	13.3	2.3
Composted/sold	1.3	0	.5	.9	0	.7
No estimate	7.8	0	0	0	0	1.3

Responsibility

Companies were asked whether they took any responsibility for manure disposal. Only 3 out of 39 companies indicated that they take responsibility (Table 3). One company was in the Mid-Atlantic, one in the South, and one in the North. If our industry continues to grow, and if there is continued encroachment by urban populations, companies will have to get involved with the end utilization of their litter.

Table 3. Company Litter Policy by Number of Companies Responding

	Mid. Atl.	So. Atl.	South	So. Cent.	North	National
Companies	8	9	11	8	3	39
Responsibility for disposal	1	0	1	0	1	3
Supply litter	6	1	5	1	2	15
Litter allowance	7	1	5	1	2	16
Litter policy	8	5	11	8	3	35

Bedding Supply

Companies were asked whether they supplied bedding material to growers (Table 3). Fifteen out of 39 companies indicated that they do. The vast majority of these companies (11 of 15) are in the Mid-Atlantic or South. Companies were asked whether there was a bedding allowance in the grower contract. Only one company indicated that there was a monetary factor in the contract to help growers pay for bedding.

Companies may have to take a more active role in either supplying or helping growers to procure bedding materials in the future. As the industry becomes more competitive and as contracts necessarily become tighter, the company may serve the grower well to supply bedding, or supply bedding at cost. If companies run a bedding service as a service to growers, and not as a profit center, growers could benefit greatly.

Litter Policy

Thirty-five of 39 companies indicated that they have some sort of policy on the type or amount of bedding, or the number of flocks between cleanout (Table 3).

Bedding Rank

Companies were asked to rank (best to worst) the types of bedding being used by their growers (Table 4). Softwood shavings were ranked as first or second by 32 of 39 companies, sawdust by 19, hardwood shavings by 4 companies, a rice-or-oat-hull/softwood shaving mix by 3 companies, and peanut hulls were ranked as first or second by 2 companies. Other litter types receiving lower rankings were rice hulls (6 companies), chopped straw (4 companies), newspaper (2 companies), chopped cardboard (1 company), and peat moss (1 company).

In several cases, rankings and willingness to use a particular type of bedding reflects regional attitudes and availablility of a bedding source. Companies in the South and South-central regions mention rice hulls as bedding. A company in the North mentions peat moss. In both cases, these bedding types are available within the region, and this availability may be reflected in cost and willingness of growers to use the bedding material.

Future Litter Types

Five companies mentioned paper as being a bedding type which they saw on the horizon as being practical. One company thought that there would be more chopped straw, and one company thought that rice hulls would become more prevalent.

Table 4. Litter Ranking by Number of Companies Responding

Rank	Sawdust	Softwood shavings	Hardwood shavings	Peanut hulls	Shaving/ hull mix	Other
1	7	24	0	1	2	
2	12	8	4	1	1	Rice hulls (2)
3	3	0	5	0	0	Straw (2) Rice hulls (3) Peat moss
4	0	0	1	0	0	Straw (2) Paper Rice hulls Cardboard
5	2	0	0	0	0	Paper

CONCLUSION

Our industry has undergone unprecedented growth over the last 30 years. This growth has led to major changes in the birds we use, feed, equipment, and management. It has also led to pressure on the finite supply of inputs, such as shavings for bedding. As the industry continues to change, it will always be watchful for new sources of material which can be used as bedding, sources which are more available, less expensive, or simply work better.

EVALUATION OF LITTER MATERIALS OTHER THAN WOOD SHAVINGS

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Poultry litter is a combination of excreta, feathers, wasted feed, and a bedding material. Wood shavings from softwood species (primarily pine) has been the predominant material for poultry production. Periodic shortages and escalating cost has promoted the search for alternative sources. With increased emphasis on waste issues, the type of bedding used may require more in-depth consideration in the future. Perhaps the material and its management in facilities need to be viewed in terms of its overall contribution to waste production and more importantly how it enhances the litter for end-product utilization (e.g., fertilizer, compost, feedstuff, fuel, etc.). The following discussion will focus on the physical characteristics of bedding, their effect on poultry performance and carcass quality and the possible implications on waste issues. Bedding materials used and evaluated are generally by-products derived from three basic sources: wood, plant, and waste.

WOOD BY-PRODUCTS

Wood by-products are the predominant bedding source in the U.S. (Malone, 1992). Softwood species (particularly pine) tend to be more absorbent and preferred over hardwood in part due to perception (has more appealing color/odor and fewer mold problems than hardwood). Hardwood has been associated with Aspergillosis particularly in turkeys (Dyar, et al, 1984) while pine shavings have been reported to be carcinogenic to rodents (Schoental, 1973). Storage and rearing conditions which lead to dry/dusty bedding can exacerbate aspergilla problems regardless of wood species. Malone (author's data) observed higher mortality and inferior feed efficiency with broilers reared on pine sawdust that had been stockpiled for three months compared to those reared on either fresh pine, fresh or stockpiled oak sawdust. Furthermore, those fed 2 1/2% ground pine sawdust in the ration had inferior weight gain compared to broilers fed the same quantity of red or white oak sawdust. The use of any wood treated with preservatives such as chlorinated phenols, dieldrin, creosote, or arsenic compounds must be avoided (Humphreys, 1979).

Pine **shavings** has been the most widely used bedding, supports excellent poultry performance and is a standard to which many other alternatives are compared. Reed and McCartney (1970) rated pine shavings the most desirable of eight materials evaluated based on seven different physical characteristics. Under commercial growing conditions, shavings may exhibit greater moisture and caking compared to sawdust. Like most materials having a low bulk density, it can result in bedding contamination of feeders and open-type drinkers.

Sawdust is second to shavings as a major bedding source. Bulk density is approximately twice that of shavings and has greater moisture holding capacity. The high percentage of fines can lead to dusty conditions when dry and increase the incidence of litter eating particularly among young poultry. Broilers may consume 3 to 5% of their ration in the form of bedding with a preference for wood by-products and small particles like sawdust (Kubena, et al., 1974; Malone et al., 1983).

Wood chips from whole pine and hardwood trees or pine stumps having particles up to 3/4" have performed satisfactorily experimentally (Reed and McCartney, 1970; Carter, et al., 1979; and Parsons and Baker, 1985). Similar to sawdust from green trees, initial moisture is usually higher (40-55%) than kiln-dried shavings (12%). Reports on the effect of the large, sometimes sharp edge, splintery particles on incidence of breast blisters are inconsistent. Wood chips do not compress nor degrade with multiple flocks to the extent of shavings and sawdust. **Shredded wood pallets** 1/4" to 1 1/4" diameter have low initial moisture and comparable absorbency to conventional wood-base bedding (White and McLeod, 1989). Although pentachlorophenol was the most commonly found pesticide in pallets, analysis for 54 contaminants were all within safe limits for bedding. Shredded pallets (less than 1") are currently being used. Under floor-pen test, broilers but not turkeys reared on **wood fiber pellets** performed satisfactory with less caking than shavings (Nakaue, et al., 1985). **Pine straw** (chats) mats severely rendering it undesirable as a bedding (Reed and McCartney, 1970).

Experimentally, both soft and hardwood **bark** mostly with reduced particle size (<3/4") has acceptable physical characteristics and supports broiler performance and carcass quality equal and in some cases superior to shavings (Golan, et al., 1969; Pope, et al., 1969; Reed and McCartney, 1970; Thronberry and Arnold, 1970; Martin, et al., 1971; Dick, et al., 1976, and Brake, et al., 1992). Stringly textured and splintery bark is less desirable. Both bark and wood chips have limited usage commercially due to concerns of greater caking and increased incidence of breast blisters. Furthermore, So, et al. (1978) found pine and hardwood bark litter had consistently higher mold spore counts than shavings over five consecutive flocks yet had no apparent influence on health. Randall, et al. (1981) reported a case of encephalitis caused by Daclylaria Gallopava in broilers reared on bark.

PLANT BY-PRODUCTS

Numerous plant by-products have been evaluated since they are often locally available within poultry production areas. Those derived from stalks require efficient and appropriate collection, processing, storage and preparation (chopping) for acceptability. Potential pesticide residues is a concern with all plant by-products.

Perhaps the most popular and frequently used bedding from plants is **rice hulls**. It compares favorably to shavings in both physical characteristics and poultry performance (Reed and McCartney, 1970; Hester, et al., 1984; Veltmann, et al., 1984). **Peanut hulls** have low bulk density, are highly absorbent and are used commercially. They degrade rapidly (Ruszler and Carson, 1974), can be dusty and have been implicated in creating health problems due to fungi. Good quality, clean, dry chopped (< 2") **straw** (wheat, barley, rye, oat, and flax) is often an available, economical bedding that has been used successfully experimentally (Andrews and McPherson, 1963; Chaloupka, et at., 1967; and Nakaue, et al., 1978) and commercially for years. It tends to be more difficult to manage, slicks over and cakes under high bird densities and could be a potential fire hazard under certain situations. The ground pith and fiber after sugar extraction (**sugar cane bagasse**) is a highly absorbent bedding, yet tends to cake readily (Ruszler and Carson, 1974).

There are a number of products that have been used in the past or tested which have limited commercial use today. Ground **corn cobs** supports satisfactory growth yet the larger particles (> 3/8") increase the incidence of breast blisters (Smith, 1956; Chaloupka, et at., 1967). Corn cobs have very high moisture holding capacity but the particles tend to breakdown with use (Reed and McCartney, 1970; Ruszler and Carson, et al, 1974). Based on poultry performance and physical qualities, the following materials having the appropriate particle size have proven acceptable: **peat moss** (Chaloupka, et al., 1967; Enueme and Waibel, 1987; Enueme, et at., 1987): **kenaf core** (Malone, et al, 1990); **cocoa bean shells** (Chaloupka, et al, 1967; Chaloupka, unpublished); **cottonseed/cotton boll hulls and sage grass** (Gyles and Andrews, 1964); **corn stalks and spent mushroom soil** (Malone, unpublished); **citrus pulp** (Harms, et al.,1968); and **clay/sand**

(Manns, 1942; Andrews and McPherson, 1963; Reed and McCartney, 1970). Broilers grown on **wheat bran** had inferior performance associated with litter eating (Gyles and Andrews, 1964) while **soybeans stalks** (stubble) had a propensity to cake (Morgan, 1984).

RECYCLED WASTE

With increased emphasis on recycling waste streams and escalating landfill tipping fees, select products may play an increasing role as alternative bedding. To prevent possible residue contamination, a high degree of quality control will be required for these selective waste streams.

Excluding paper which represents a significant portion of municipal waste, there are several potential products. Ground **polystyrene** (<1/4") was evaluated by Chaloupka et al. (1967). With the exception of the bedding contamination of open-type drinkers and feeders, this non-absorbent material had excellent characteristics, both new and after reuse. Its low bulk density (0.5 lbs/ft^3) results in a very light-weight, fluffy material that causes the contamination. It would not create a problem with closed-type drinkers (e.g. nipples), however, compatibility with conventional handling equipment could be an issue. Furthermore, the polymers are non-biodegradable in the environment and may require a different strategy for utilization after removal from poultry facilities. Shredded **plastic** is another product having similar characteristics with the exception of higher bulk density. Most of these polymers that would be available in significant commercial qualities are non-toxic.

Composted municipal garbage bedding (residue after glass, metal and paper removed) from two pilot processes had physical characteristics equal to and broiler performance superior to birds reared on wood shavings (Malone, et al., 1983). Pesticide and heavy metal residues were within acceptable ranges. However, the commercial product that eventually evolved did not have consistently safe residue levels. The glass and plastic chips found in one of these processes were consumed by birds. It posed no ill effects but the retained particles in the gizzards create some difficulties in the processing plant. Strict physical and chemical quality control will be essential for commercial adaption of this bedding alternative.

Recycled **sheetrock** (gypsum) is absorbent, but very dusty upon installation and suppresses early growth rate of broilers (Wyatt, Oregon State University, personal communications). Sheetrock contains calcium sulphate dihydrate, limestone, paper and silica. The effect on this material on litter enrichment was not determined. Chelating agents found in gypsum and trace levels of dioxin and furans in paper warrant further evaluation with this possible product.

BULK DENSITY AND MOISTURE CONSIDERATIONS OF ALTERNATIVES

Bulk density of bedding is a function of the type of material, particle size and texture, moisture content and the extent of compaction. As shown in Table 1, the bulk density (dry-weight) of alternative beddings ranges from 0.5 (polystyrene) to 36 lbs/ft^3 (clay). In addition to previously mentioned effects on feeder/drinker contamination and possible incompatibility with handling equipment, bulk density of bedding can influence the amount (weight) of litter generated. Take, for example, a 16,000 ft^2 broiler house placing 3" of bedding every 3 flocks. At 25% moisture, with shavings (@ 6 lbs/ft^3) this would be 12 tons of bedding compared to 24 tons with sawdust (12 lbs/ft^3). At a manure production rate of 40 lbs/1000 birds/day (Malone, et at., 1992), a 21,300 capacity house growing 49-day market broilers would generate 62.6 tons of manure during 3 consecutive flocks. Total litter production would be 74.6 and 86.6 tons with shavings and sawdust bedding, respectively. The bedding component represents 16% (shavings) to 28% (sawdust) of the total litter production and composition.

The effect of bedding on litter moisture is also a factor on production and composition values. Using the same example of 74.6 tons of litter per house, this represents 18.7 tons of water at 25% moisture. On a wet-weight basis within a 20-30% moisture range, each 1% increase in litter moisture results in 1 ton additional litter due to water alone in this house. Bedding materials that contribute to higher litter moisture results in reduced (diluted) litter nutrient density, increased handling and transportation cost and a greater potential for odor problems. Furthermore, wet litter and associated fecal caking problems contribute to poultry health problems (e.g. foot pad lesions), depress growth (Martland, 1985), increase incidence of breast blisters and higher bedding replacement cost.

Water holding capacity of various bedding materials range from 0 to 8.9 units of water/unit of bedding (Table 1). Although this physical test is a useful comparison of bedding materials, it may not truly reflect the whole picture on the moisture releasing properties of a product under actual rearing situations. Polystyrene is an example of a non-absorbent material which has excellent physical characteristics as bedding.

Table 1. Bulk Density and Water Holding Capacity of Various Bedding Materials[a]

Litter Type	Bulk Density[b]	Water Holding Capacity[b]	Litter Type	Bulk Density[b]	Water Holding Capacity[b]
Shavings	6	1.3-2.0	Peanut hulls	6	2.1-2.5
Sawdust	8-13	1.9-2.5	Cottonseed hulls	2.2-2.5	-
Chips	11	1.3-3.0	Cocoa bean shells	-	2.4-2.7
Bark	12	1.2-2.5	Corn cobs	13	1.9-2.1
Chopped Pine shats	7	1.7	Peat	-	8.9
Wheat straw	5-8	2.2-2.6	Composted garbage	10-28	-
Corn stalks	4-5	2.2-2.5	Clay	36	.7
Flax stalks	2-3	2.2-2.6	Polystyrene	.5	0
Rice hulls	7	1.0			

[a]Values adapted from one or more of the following references: Enueme, et al., 1987; Midwest Plan Service, 1985; Overcash et al., 1983; Reed and McCartney, 1970; Malone et al., 1983.

[b]All values are expressed on a dry-weight basis for each litter type. Bulk density is expressed in lbs/ft^3, water holding capacity in units water absorbed/unit bedding.

NUTRIENT COMPOSITION OF ALTERNATIVES

Overall, the relative contribution of the bedding on the value and composition of the litter upon removal after multiple flocks is minimal. If bedding availability and economics permit, it may be worthy to consider selecting a bedding which optimizes and enriches the litter for its ultimate utilization (e.g., fertilizer or feedstuff). Stephenson, et al. (1990) reported litter has approximately 4 times more value as a ruminant feed than as a fertilizer. The "potential" nutrient contribution of various bedding materials is presented in Table 2. As a feed, some of the most striking differences are as follows: rice hulls and peat have high ash; crude fiber ranges from 11 (wheat bran) to 63% (peanut hulls); TDN is lowest with rice hulls (13%) and highest with wheat bran (70%); and wood by-products have low (1%) crude protein/nitrogen compared to cocoa/coffee bean shells, wheat bran and peat (16-17%). The bedding provides the primary source of crude fiber in the litter. After one or more flocks on the bedding, differences amoung types in composition are minimal (Labosky, et al., 1977; Stephenson, et al., 1990). A number of reports suggest the following relative to bedding effects on litter composition: pine bark or shavings has higher in vitro digestion than hardwood (Labosky, et al., 1977); kenaf core has greater digestibility and protein than sawdust (L. Kung, University of Delaware, personal communications) and wood products have greater crude fiber than peanut hulls (Stephenson, et al., 1990).

On a dry-weight basis, the potential contribution of the bedding to nutrients as a fertilizer (lbs/ton) ranges from 4 to 46 lbs for N, 1 to 26 lbs P and 4 to 46 lbs K (Table 2). When placing bedding on a volume basis, the higher bulk density materials provide slightly more nutrients initially. However, their effect on litter composition may actually result in less nutrients on a percent weight basis. In the previous example, after 3 flocks, shavings represents 16% of the total litter while more dense sawdust was 28%. Beddings with higher densities dilute the manure component when expressed on a weight basis. In addition, the effect of bedding on litter composition decreases dramatically with consecutive flocks. For a 21,300 capacity broiler house, 24 tons of sawdust bedding provides 96 lbs of N. Contribution of the manure per flock to N at 3% equals 1252 lbs. In this example, the bedding contributes only 7.1, 3.7, and 2.6% of the total litter N for flocks 1, 2, and 3, respectively. For this reason, after multiple flocks the nutrients derived from the bedding material appears to have minimal effect on total litter composition. The effect of the bedding on litter moisture content has equal or greater significance on nutrient content.

Table 2. Nutrient Composition of Various Bedding Materials[a]

Litter Type	Ash	Crude Fiber	TDN	Crude Fiber	N	P	K	Reference
Shavings/Sawdust	4	53	-	1	.2	.1	.2	Overcash, et al., 1983
Wheat straw	8	4.2	44	3	.5	.1	1.3	Preston, 1992
Corn stalks	7	35	59	5	.8	.2	1.1	Preston, 1992
Flax stalks	7	46	-	8	1.3	.1	1.7	Nat.Acad.Sci., 1971
Sugar cane bagasse	3	49	36	1	.2	.1	-	Preston, 1992
Soybean stalks	6	44	42	5	.8	.1	.6	Preston, 1992
Citrus pulp	7	14	-	7	1.1	.1	.7	Preston, 1992
Rice hulls	20	44	13	3	.5	.1	.4	Preston, 1992
Peanut hulls	5	63	22	7	1.1	.1	.9	Preston, 1992
Cottonseed hulls	3	48	45	4	.6	.1	1.1	Preston, 1992
Cocoa bean shells	9	18	-	16	2.6	.6	2.3	Nat. Acad.Sci., 1992
Coffee bean shells	5	36	-	17	2.8	-	-	Nat. Acad.Sci., 1992
Sunflower hulls	3	25	40	4	.6	.1	1.6	Preston, 1992
Wheat bran	7	11	70	17	2.7	1.3	1.4	Preston, 1992
Corn cobs	2	36	48	3	.5	.1	.8	Preston, 1992
Peat	22	15	-	17	2.7	.1	.3	Enueme, et al, 1987
Kenaf (hay)	10	-	53	9	1.4	-	-	Preston, 1992

[a]All values expressed as a percentage on a dry-weight basis.

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RECYCLED PAPER PRODUCTS FOR POULTRY BEDDING

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The use of recycled paper products as poultry bedding is a relatively new concept. Although there has been long standing interest in alternative poultry beddings, as evidenced by studies assessing the suitability of a wide range of materials in the 1970's (Martin et al., 1971; Cottier, 1973; Eckroade, 1974; Malone, 1976; Carter et al., 1979), serious consideration of recycled paper products appears to have occurred during only about the last 10 years. This paper will outline factors stimulating interest in recycled paper products as poultry bedding, and review the literature on the types of recycled paper based materials that have been tested for use as poultry bedding.

FACTORS STIMULATING INTEREST IN RECYCLED PAPER PRODUCTS

Pine shavings and sawdust are the primary materials used as poultry bedding in the Southeast and throughout the nation. Availability of these materials has been decreasing due to competition for their use from the rapidly developing composite board industry, for horticultural purposes, and as energy sources (Malone, 1982). In addition, the marked growth and centralization of the poultry industry has often exhausted local supplies of conventional beddings. Periodic shortages of wood by-products, due to fluctuations in the construction industry and the often seasonal nature of their availability, have also made it more difficult for poultry producers to rely on them as bedding sources. As competition for these materials has intensified and availabilty has declined, their price has increased. This has created a situation in which the use of alternative bedding materials is becoming both economically feasible and more attractive from the long term planning standpoint.

At the same time that the aforementioned changes have been occurring with respect to conventionally used wood by-products, the availability of recycled paper products has increased dramatically. Current estimates indicate that about 1 in 4 Americans receive a daily newspaper, which means that an average of over 62 million newspapers become "waste" each day (Howard and Heimlich, 1989). These figures do not account for "on demand" newsprint publications, or for the myriad of other private and commercial sources of recycled paper. The recent rapid increase in recycling programs has caused the supply of recycled paper to often exceed the demand. Therefore, it's value has markedly declined. Tipping fees at most landfills have concurrently increased. These factors have resulted in situations in which either recycled paper has been given away and delivered for free, or recyclers have paid users to take paper from their premises in order to avoid storage costs or tipping fees. Recycled paper products clearly provide a constant flow of material that if captured and used may provide a reliable source of inexpensive poultry bedding. The steady supply of this material could help balance market demand when other bedding materials are highly priced (Howard and Heimlich, 1989), and appears to be available in sufficient quantities in most poultry producing areas (Malone et al., 1982).

RECYCLED PAPER PRODUCTS TESTED FOR USE AS POULTRY LITTER

Recycled paper products have been prepared for use as poultry bedding in a variety of ways. Processing involves restructuring the sheets of paper, often through a wet process, into a completely different form and then separating the resulting product into particles or chips. Shredding and chopping involve reducing the sheets of paper into smaller pieces by cutting.

Processed Paper Products

Recycled Paper Chips: A bedding material formed by completely reprocessing waste newspaper into chips was tested in 2 successive trials at Auburn University (Lien et al., 1992). These "recycled paper chips" were made by Advanced Materials Technology, Inc. of Ashville, Alabama and are 1.5 inch long, 0.5 inch wide, and 0.125 inch thick. There were no differences in live production parameters of broilers reared on either the paper chips or pine shavings. In both trials incidences of breast blisters and leg abnormalities were numerically lower in broilers reared on paper chips, although litter moisture and caking levels were generally greater. It was concluded that the shape, size, and less abrasive nature of the paper chips may have minimized the negative effects of increased litter moisture and caking levels on carcass defects. In addition, the greater water holding capacity of the paper chips may have allowed them to maintain higher litter moisture levels without deleteriously affecting the birds. As with most paper based products (Malone and Chaloupka, 1983; Hogan et al., 1990a,b), the paper chips appeared microbilogicaly superior to the wood based materials. Unused paper chips had lower populations of aerobic bacteria and fungi than unused pine shavings, and psychrotrophic bacteria populations remained higher in pine shavings following bird removal. It appears that this material will be commercially available in the near future.

Processed Newspaper: Extensive tests were conducted at the University of Delaware on a processed newspaper bedding material made by the Reclamation Center, Inc., of Dover, Delaware (Malone, 1982; Malone et al., 1982; Malone and Chaloupka, 1983). This material was formed by a wet process in which newspaper was separated into individual cellulose fibers in a hydropulper. These fibers were then compressed to remove excess water. The resulting fiberboard material, was separated into particles ranging from 0.25 to 1 inch in diameter and dried to about 30% moisture. Overall a particle size of either 0.5 or 0.25 inch was found to yield the best performance. Improvements in growth relative to that of birds on sawdust were observed with the smaller particle sizes. Litter caking and the occurrence of breast blisters were also reduced to levels comparable to those obtained with sawdust as particle size was reduced. It was concluded that the smaller particle sizes of this material are a satisfactory substitute for sawdust and can withstand multi-flock use.

Processed Cardboard: A similar material was formed from brown cardboard by the same process and company as the processed newspaper discussed above. It was judged to be unsatisfactory as a bedding material since litter moisture and caking levels, and the incidence of breast blisters were markedly increased while broiler performance was generally poor. This was attributed to the combined effect of glues used in the cardboard and and elevated moisture levels, which appeared to increase litter caking (Malone, 1982; Malone et al., 1982).

Recycled Paper

The simplest procedures for preparing recycled paper for use as poultry bedding are shredding and chopping. Based on the literature, these two terms are often used interchangeably. In this paper, shredding will be defined as cutting the paper into narrow strips over 4 inches in length. Chopping will be defined as cutting the paper into roughly symmetrical pieces having a greatest dimension of less than 4 inches.

Shredded Newspaper: Recent field research in North Carolina (Scheidler and Hawkins, 1991) tested the use of shredded newspaper (0.5 by 12-16 inch strips) as a 1 inch deep top-dressing over a 4 inch layer of hardwood shavings in the brooding area of a broiler house in which 2/3 house brooding was being done. Live performance statistics and condemnation percentages were comparable to those obtained from birds brooded using 4 inches of shavings alone. Litter moisture was lower in the house using shredded paper, and although some litter caking occurred under nipple waterers it was not a problem after the birds were released into the entire house at 18 days of age. In addition, the house with the shredded paper was observed to be considerably less dusty.

This field research is being continued to test different shredded newspaper top dressing methods, total substitution of paper for shavings, methods for distributing the paper throughout the house, and the efficacy of the used shredded newspaper litter as fertilizer for cropland.

In research conducted in Delaware in the early 1980's (Malone, 1982; Malone et al., 1982), newspaper was shredded into 0.5 inch wide strips in a hammer mill and used as bedding for 3 successive flocks of broilers. Hardwood sawdust was used as the control. The shredded newspaper bedding was observed to be quite dusty, to have numerically greater moisture levels, and cake more severely during use than sawdust. However, even though the condition of the shredded newspaper litter appeared inferior, body weights of broilers reared on it were greater than those of broilers reared on sawdust and the incidence of breast blisters was comparable.

Chopped Newspaper: The Delaware group observed that dust problems associated with the shredded newspaper they tested were reduced by cutting the paper into 0.25 X 2 inch strips. However, results with respect to caking were similar. Interestingly, broiler body weights were again heavier for those reared on paper and the incidence of brest blisters was not increased (Malone, 1982).

Investigators at the University of Kentucky (Pescatore, 1992; Burke et al., 1992) tested unprinted newspaper which was "shredded" into 0.6 inch square particles (chopped by the above definition). This material was either combined, or layered over or under equal volumes of wood shavings and used for growing broilers. Wood shavings alone were used as the control. Production parameters such as body weight, feed conversion, mortality and the incidence of leg problems were not affected by litter treatments. However, moisture levels were greater in all treatments including paper. A two-fold increase in the occurence of breast blisters and increase in average breast blister size was attributed to increased litter moisture in the paper containing treatments. The author (Pescatore, 1992) hypothesized that substituting nipple for the bell type waterers used in this study may help alleviate breast blister problems associated with high litter moisture levels of paper litters.

It appears that chopped newspapers are receiving the greatest acceptance by the industry in West Virginia (Carpenter, 1992). Resources Unlimited of Petersburg, West Virginia is coarsely chopping and baling newspaper at a central location and then rechopping and spreading this material in broiler houses with a bale chopper. To date, over 100 houses have been bedded with these approximately 1 by 2 inch particles. A relatively high degree of caking develops around waterers and feeders during the first 3 weeks of rearing on this material. However, the increasing ventilation of the house and ability of the birds to break up the cake results in improvements in litter quality during the following weeks. Moisture levels are similar to those found in wood based litter materials and litter quality is acceptable by market age. The cost of using this material is reportedly competitive with that of conventional beddings and a substantial amount of the farmers time is saved since the paper is spread by the supplier.

In addition to assisting with the above project, researchers in West Virginia have been involved in testing other forms of chopped newspaper bedding. Newspaper chopped into 0.25 by 0.5 inch particles has been observed to perform better than that chopped into coarser particles (Carpenter, 1992). This is apparently due to the fact that the birds are able to break up caked areas at an earlier age and the increased proportion of "edge area" of the smaller particles facilitates more rapid drying. It has also been observed that since the paper is more absorbent than other bedding materials (Heimlich and Howard, 1990; Selders et al., 1991b), only about half as much (by weight) is needed to effectively bed a house (Selders et al., 1991a).

Commercial Chopped Newspaper Products: Commercially produced chopped paper beddings were introduced and tested for broiler production in Delaware during the early 1980's (Malone, 1982; Malone and Chaloupka, 1982). DICE-A-BED™ is composed of various sizes and proportions of shredded or cut newspaper while Agri-bed™ has a similar form but is made from telephone directories (both are apparently chopped by the above definition). Body weights of broilers reared on both of these products were equal or greater than those of birds reared on hardwood sawdust. This is apparently due to young broilers consuming greater amounts of sawdust containing litters than paper (Malone et al., 1983) and may also be related to higher incidences of coccidial lesions in market aged broilers reared on sawdust (Malone, 1982). Elevated litter moisture and caking levels occurred with both paper products. However, occurrences of mortality and breast blisters, and condemnation rates were not greater than those occurring in broilers reared on sawdust. Several integrators tested DICE-A-BED™ and reported improvements in body weights and feed conversion. This product was also competetively price with respect to conventional wood based beddings.

SUMMARY

It has been repeatedly suggested that with the high moisture and caking levels generally occurring in recycled paper based litters, they may be most practical when used as base or topping layers with other conventional wood-based beddings at relatively low bird densities (Malone, 1982). However, the generally more abrasive nature of wood based beddings may interact disadvantageously with the increased moisture levels occurring in paper materials and result in a greater incidence of breast blisters and condemnations as apparently occurred in the trial reported on by Burke and co-workers (1992). Based on observations with shredded, chopped, and processed paper beddings, it appears that smaller particle sizes are advantageous for several reasons. Reducing particle size should reduce abrasiveness, particularly with processed paper litters, and should increase the rate at which the material will take up and release moisture. In addition, reducing particle size should make it easier for the birds to break up areas that do become caked. While large particles of chopped or shredded paper litter materials typically become stuck together and cake over readily, processed paper litter materials with large particle sizes can be expected to cause breast irritation and ultimately blisters due to their abrasive nature. The adoption of dry cup and nipple drinkers should improve litter conditions occurring with most if not all paper based materials and when coupled with the changing economic situations associated with wood and paper based bedding sources, it appears that we may be seeing wider use of recycled paper bedding products by the poultry industry in the near future.

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EFFECT OF LITTER TREATMENTS ON THE POULTRY HOUSE ENVIRONMENT

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What I will be reporting today may not completely reflect the topic I was assigned. However, there are three areas I would like to discuss. They are in the area of alternative broiler litter and the rototilling and reuse of used broiler litter.

The Pacific Northwest turkey and broiler producers are in short supply of the traditional litter materials of wood sawdust or shaving. The short supply of these litter materials was brought about by the restricted logging of Pacific Northwest forests to protect the spotted owl habitat and the demand for these litter materials to make compacted wood products such as particle board. Because of this short supply, the costs of these litter materials have increased two to three times. We have investigated the feasibility of two potential litter materials because of this problem encountered by the turkey and broiler producers. The two materials are wood fiber pellets and chopped grass seed straw.

Wood fiber pellets are a by-product of the paper pulp industry. The wood fiber pellets are derived from slurry that was dumped in a reservoir or pond at the paper pulp plant and then released into the river. This practice was stopped because of water pollution. The plant in question investigated ways to stop water pollution and salvage slurry by drying. The residue is a gray-whitish material and is primarily wood fiber. The residual wood fiber is pelleted in 1/8 inch diameter and packaged in plastic bags.

Modhish (1987) carried out studies on wood fiber pellets with broilers and indicated that this material can be used as a broiler litter. Wood fiber pellets met eight of the ten criteria for good litter material as outlined by North and Bell (1990). After applying this material in the broiler house, the interior of the house looked clean, bright and had a paper aroma. Broilers reared on this material from day-old to seven weeks of age were not affected in their growth and foot pads (Table 1). He found that atmospheric ammonia levels and litter pH were not different between wood fiber pellets and wood shaving pens (Table 2). Pens with wood fiber pellets were dustier, and had less litter caking and litter moisture than the wood shaving pens (Table 2).

Table 1. Effect of Wood Fiber Pellets and Wood Shavings on Broiler Performance to Seven Weeks of Age

Litter Material	Mean Body Wt.	Feed Conv.	Mortality	Foot Pad Lesion
	(lbs)		(%)	(%)
WS	4.21	2.07	3.2	70
WFP	4.17	2.06	3.9	65

P>.05

Table 2. Effect of Wood Fiber Pellets and Wood Shaving Litter on Litter pH, Moisture and Caking Score and Atmospheric Ammonia and Respiratory Dust Levels

			Litter		
Litter Material	Ammonia 3-7 Wks	Moisture[1] 2-7 Wks	Caking Score[1,2] 3-7 Wks	pH 7 Wks	Dust 2-7 Wks
	ppm	(%)			$x10^8/m^3$
WS	17[a]	29[b]	2.3[a]	8.19[a]	2.65[a]
WFP	15[a]	25[a]	3.2[b]	7.99[a]	3.83[a]

[1] P<.05
[2] Litter caking score: 1 = 3/4 pen caked
4 = no caking

Savage and Nakaue (1986) reported that wood fiber pellets were not suitable litter material for turkeys because of the wet litter condition encountered. Market turkeys seem to excrete more water in their feces.

Another alternative litter source is grass seed straw. In Oregon, the Willamette Valley grass seed farmers produce approximately 1 million tons of grass seed straw annually. This large volume of straw was eliminated for many years by burning the straw in the fields. This practice caused environmental pollution and is curtailed severely now. Alternative ways needed to be investigated. From our experience with cereal straw, the grass seed straw must be chopped to less than two inches long in order to reduce the high incidence of caked litter. A preliminary study indicated that broilers reared on grass seed straw had significantly lower mean body weights but better feed conversion than broilers reared on wood shaving litter (Table 3). With higher bird densities (0.71 and 0.89 ft^2/broiler), there was more litter caking and foot pad irritation on the chopped grass seed straw than wood shaving litter (Table 4).

Table 3. Effect of Broiler Density and Chopped Grass Seed Straw on Broiler Performance to Seven Weeks of Age

Litter Types	Broiler Density	7 Wk Mean Body Wts**	Feed Conv.*
WS	1.1	5.03^{c}	2.067^{c}
CGSS	1.1	4.92^{b}	2.055^{b}
CGSS	.89	4.92^{b}	2.017^{ab}
CGSS	.71	4.77^{a}	2.015^{a}

*$P \leq .05$
**$P \leq .10$

Table 4. Effect of Broiler Density and Chopped Grass Seed Straw on Litter Score at 2, 4, 6, and 7 Weeks on Test.

Litter Types	Broiler density	Mean litter score[1,2] Wks on test			
		2	4	6	7
	(ft^2/bird)				
WS	1.1	$.9^{ab}$	$.9^{a}$	2.2^{a}	1.8^{a}
CGSS	1.1	$.8^{a}$	1.3^{ab}	2.4^{a}	2.4^{b}
CGSS	.89	1.0^{bc}	1.5^{b}	2.9^{b}	2.89^{bc}
CGSS	.71	1.2^{c}	1.9^{b}	3.2^{b}	3.0^{c}

[1] Litter score: 1 = 1/4 pen caked
4 = full pen caked

[2] $P \leq .05$

Currently, we are investigating the composting of the grass seed straw. Grass seed straw can be composted in eight weeks provided water (45 to 55% moisture in the pile) is added with equal volumes of chopped grass seed straw and used broiler litter. Stirring the compost pile daily accelerated composting. We will be further investigating the ideal levels of percent moisture and nitrogen for composting grass seed straw with used broiler litter.

The third area we would like to report is the reuse of built-up broiler litter by rototilling with a commercial rototiller attached to a tractor after each batch of broilers. Four tests were carried out on a commercial broiler farm with one house (40 ft x 304 ft) rototilled and the other (40 ft x 304 ft) not rototilled. The first test started in November 20, 1991, and the fourth test started on June 11, 1992. We encountered high atmospheric ammonia levels in the rototilled house in the second test and subsequently lower growth rate, high electrical usage because of more ventilation to rid the ammonia and high mortality caused by a high incidence of blind birds. The rototilling for the second test was done during January when weather was wet and humid. The grower did not remove the caked litter and wet spots in the house prior to rototilling. In tests three and four, the grower removed the wet spots prior to rototilling and had no difficulty. A small amount of clean sawdust was applied in the brooding areas only in the rototilled house after each batch of broilers whereas the house not rototilled, the grower skimmed the top and removed the caked and wet litter prior to blowing in about 1/4 inch deep clean sawdust. Rototilling built-up and reusing the litter has a potential of saving litter. Removing wet litter prior to rototilling is a good practice to reduce atmospheric ammonia in the house.

In summary, wood fiber pellets can be used as a broiler litter without detrimental effect on the performance of broilers. The shortcomings of this litter material is the limited supply and the dustier environment within the house created by bird activity.

Grass seed straw can be used as a litter but must be chopped less than 2 inches long. High bird density ($>.71$ ft^2/bird) can cause severe litter caking.

Reusing used broiler litter by rototilling can be another method in overcoming the shortage of litter; however, it is wise to remove wet spots in the broiler house prior to rototilling.

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MANAGING LITTER TO ENHANCE ITS CHARACTERISTICS AND MARKET POTENTIAL

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Poultry is one of the largest industries in the southeastern United States, generating more than 25% of the agricultural income of Arkansas, Alabama, Mississippi, North Carolina, Georgia, Virginia, Maryland and Delaware. This industry has a tendency to concentrate itself in local areas to increase efficiency. Although concentration reduces production costs, it can generate more waste than can be safely applied to the available land without degrading the environment.

Essentially all the broilers produced in the southeastern United States are grown on bedding which absorbs moisture. Bedding may be comprised of sawdust, peanut hulls, wood shavings or other suitable material. Raymond (1974, see Wuhrmann, 1964) reported that litter has an average moisture content of 25% (w.b.) and contains 1.7% nitrogen (N), 0.81% phosphorous (P), and 1.25% potassium (K) by weight. The use of poultry litter as a fertilizer or as a feed source is common in many states. McCaskey et al. (1990, see Koon et al., 1991) reported that 37 states have regulations which pertain to the marketing of animal wastes as fertilizers, while 45 states allow the use of broiler wastes as a feed ingredient. The potential use of poultry litter as a fertilizer or feed source is high if the form and/or condition of the litter can be improved. The major drawbacks associated with this type material is that it has; 1) a low nutrient density, 2) a low bulk density and 3) is non-uniform. Therefore, the purpose of this research is to discuss a poultry litter management system which involves the fractionation of poultry litter into materials with improved handling qualities and/or increased nutrient density.

BACKGROUND

Of the 1.25 billion broilers grown in the state of Georgia, 60% are grown in adjoining counties in the north central region of the state. Likewise, Arkansas poultry production is geographically concentrated in the northwest portion of that state (Hamilton et al., 1988). Alabama, North Carolina, Virginia, Maryland, and Delaware all have similar regional concentrations. Such concentrated production can cause more manure to be produced than can be safely utilized by spreading on the land.

Legislation exists in some poultry growing regions for the utilization of waste products. In Rockingham County, Virginia, new poultry facilities are required to have both a site plan and a nutrient management plan. The nutrient management plan requires that the grower provide for safe disposal of 100% of the animal waste produced by each poultry facility. Such a plan is required to consider the presence of any source of water, geologic formations and land topography such that no ground or surface water is susceptible to pollution. In Europe, similar concerns for excessive nutrients has caused West Germany and the Netherlands to limit the number of animal units/ha of land (Naber, 1988). Similar legislation in other parts of the southeastern United States would have a great effect on current waste utilization practices used by the poultry industry.

Collins et al. (1988) stated that "a major challenge in recent years has been to find ways of making manure and litter an attractive substitute for commercial feeds and fertilizers". Most of the problems in doing this involve economics. In many cases the transportation costs associated with the hauling of materials over great distances, such as poultry litter, may exceed the equivalent value of the product based on its nutrient density. However, if the nutrient density of poultry litter could be increased, then it would be more profitable to haul.

Fractionation of litter has been successfully conducted on a laboratory scale. Koon et al. (1984) determined that approximately 70% of a three flock litter would be retained by number 20 mesh screen (0.83 mm openings). In separate laboratory scale tests, Merka (1988) determined that 30% of poultry litter passed through a number 20 mesh sieve. He also determined that the nitrogen concentration increased as litter particle size decreased.

OBJECTIVES

The purpose of this study was to develop a simple, economical system for the efficient utilization of poultry manure and litter. Therefore, the following objectives were established.

1. Identification of a simple, efficient, and economical technique for separation of litter into coarse and fine fractions.

2. Investigation of variation that may exist in handling and separation of poultry litter from broilers reared under different management techniques.

PROCEDURE

A study was conducted to determine the variation that exists among poultry litter samples under different management techniques. Samples of litter were taken from both curtain-walled (open) and environmentally controlled (dark) houses which had from one to five flocks of birds raised on the litter before it was cleaned out.

Samples of poultry litter weighing an average of 300 kg were taken from each of the randomly selected houses located in the North Georgia area surrounding Athens, GA. The number of flocks that had been raised on the sample were noted. To ensure a representative sample of the litter material, sampling sites were located along the length of each house at approximately 12-m intervals, also along the whole cross-section of the house. On average between 6 and 12 sampling sites were located within a given house depending on the depth of the litter. For shallower litters, more sites had to be sampled so that the 300 kg sample size could be obtained. At any one of these given locations, all the litter in a 1 m by 1 m floor area was collected down to the bare floor level. Since variations could also arise out of such factors as watering facilities, any part of the house that appeared to have such unique problems was avoided. A summary of the total number of houses sampled is shown in Table 1.

Table 1. Summary of the Houses Sampled During this Study

Type of House	Number of Flocks				
	One	Two	Three	Four	Five
Curtain-Walled (Open)	14	7	6	0	3
Envir. Cont. (Closed)	6	0	1	0	1

Two different separators were used to fractionate the litter; 1) a vibrating screen separator and 2) a rotary drum separator. The vibrating screen separator was manufactured by Hance Corporation, Westerville, Ohio. A two-stage separation process separated the material into three fractions: 1) particles greater than a standard number six mesh screen (3.3

mm openings); 2) particles smaller than a standard number 20 mesh screen (0.83 mm openings); and 3) particle sizes between the above two. The equipment operating pitch was established as 12° for optimal fractionation. For the vibrating screen separator, litter from houses which had from one to five flocks of birds was tested. The rotary drum separator consisted of two parallel drums, 0.23 m in diameter. The rotary drum was constructed such that over its 1.5 m length the particles would be separated according to the same three particle sizes as that associated with the vibrating screen separator. The working pitch for the rotary drum was set at approximately 11° for optimal separation. For the rotary drum separator only one flock litter was used.

Samples of litter were collected at random from each of the three fractions and from the raw litter for laboratory analysis. Each of the samples were analyzed for (percentage by weight) nitrogen (N), phosphorous (P) and potassium (K).

RESULTS

The three fractions into which litter was fractionated were all distinct in physical appearances. The fine fraction, which was comprised of those materials less than #20 mesh screen was a brown-looking uniform powdery material that tended to clump together when squeezed. This material was believed to consist of manure, small amounts of spilt feeds, and very fine sawdust. The middle fraction which was comprised of those materials with particles sizes between the #20 and the #6 mesh screens, were mostly small wood chips, sawdust and some unidentified flaky materials. The coarse fraction, which was comprised of those materials whose particles are larger than #6 mesh screen consisted mostly of larger wood shavings, wood chips, feathers, and conglomerate clods.

Regardless of the origin of the litter materials, the content of fine fraction ranged from 22% to 40%, the middle fraction ranged between 40% and 48% while the coarse fraction ranged from 15% to 25%. For curtain-walled houses, it was determined that the number of flocks raised on the litter had a significant effect on the percentage of fine material retrieved from the litter. It was determined that, as the number of flocks raised on the litter increased, the fine material content in the litter increased. In going from one to three flock litter an increase of approximately 70% occurred in the percentage of fines retrieved.

It was initially believed that the amount of fine material in the litter was also related to the breakdown over time of the wood shavings caused by bird activity. However, the results appeared to indicate that litter material from dark houses normally will have a larger proportion of fines than litter from open houses. This idea conflicts with this point of view in that chickens are supposed to be more active in lighted environments than in poorly lit conditions.

Standard laboratory tests were conducted to determine if the number of flocks raised on the litter and the type of house affected the concentrations of N-P-K in the litter. A significant variation was observed in the percent N and the percent K in the whole litter while no significant variation was observed for the percent P among the litter that had been used to raise one, two and three flocks of chickens. The average nitrogen content for one, two and three flock litter was determined to be in the range of 3.2 to 4.3%, phosphorus content between 1.0 and 1.2%, while potassium content was in the range 1.8 to 2.4%. The analysis of percent N-P-K content by type of house indicated that litter drawn from either the open houses or the dark houses were not significantly different.

Studies were also conducted to determine the N, P, and K distribution within a given litter material, i.e. percent N, P, and K content of each one of the four fractions of litter. Within any given litter material, irrespective of its origin the distribution of N-P-K was found to be similar. The distribution of P and K appeared to be uniform within any given litter with no significant variation observed in the P and K content for the four fractions. For one, two and three flock litter the phosphorous varied from 0.9% to 1.4%, while the potassium varied from 1.7% to 2.6% for all fractions. However, the distribution of N within the litter was determined to be significantly higher in the fine material than in the rest of the fractions. For the raw litter the nitrogen content varied from 3.1% to 4.3% by weight for one, two and three flock litter while in the fine fraction the nitrogen content varied from 3.9% to 5.2% for the litter. These results agree with similar results conducted at the laboratory level by Merka (1988) who determined that as litter particle size decreased, nitrogen concentration increased.

Two separators were evaluated for their respective performances in fractionation of poultry litter. The performance of each was based on the efficiency of retrieval of the fine fraction. Only samples from one flock houses were compared. Based on this study, the two separators showed no significant difference in their ability to retrieve the fine material from the raw litter.

Additional tests were performed with litter from multiple flock houses using a rotary drum screen separator, 0.76 m in diameter and 2.4 m long, constructed using sections of #20 mesh and #6 mesh screen. During these tests both caked and non-caked litter was sampled. Based on a sample size of 9 houses the average litter was comprised of approximately 40% coarse, 40% middle fraction and 20% fines.

SUMMARY

The potential waste management system for poultry litter was studied which involved the fractionation of litter into three different fractions. The three fractions into which litter was fractionated were all distinct in physical appearance. The fine fraction was powdery and tended to clump together when squeezed. The middle fraction was composed of a uniform mixture of small wood chips and sawdust. The coarse fraction was composed of larger wood shavings, large wood chips and feathers and was the most heterogeneous. In chemically analyzing the whole litter and each fraction, it was determined that the concentration of P and K was uniformly distributed throughout the litter. From these same tests, it was determined that the percent concentration of N was found to increase as the number of flocks of birds raised on the litter increased with the N nonuniformly distributed throughout the litter with the concentration of N greatest in the fine fraction.

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BROILER LITTER AS A FERTILIZER: BENEFITS AND ENVIRONMENTAL CONCERNS

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Increased consumer demand for low-cholesterol protein sources has led to an enormous expansion in broiler chicken production. Broiler production in the U.S. currently exceeds six billion birds per year, most of which ($\approx$ 60%) is concentrated in the southern states of Alabama, Arkansas, Georgia, and North Carolina (USDA, 1989). Associated with this production is a massive quantity of waste, commonly referred to as broiler litter (manure and cellulose bedding material). For example, Alabama and Arkansas alone disposed of more than five million tons of broiler litter in 1990.

The massive quantity of litter generated annually in intense broiler production areas represents a paradox. On one hand, litter is a valuable source of plant nutrients, while on the other, it is a potential vector of serious environmental contamination. The purpose of this paper is to point out benefits and problems associated with use of broiler litter as a source of plant nutrients.

BENEFITS OF LAND-APPLIED BROILER LITTER

Broiler litter is generally considered the most valuable of animal wastes for use as a fertilizer owing to its relatively high nutrient and low moisture content (Wilkinson, 1979). Stephenson et al. (1990) determined that the average fertilizer grade ($N-P_2O_5-K_2O$) of litter from 106 broiler houses, on an "as spread" basis, was approximately 3-3-2. Their survey also showed that broiler litter contains substantial amounts of secondary plant nutrients [sulfur (S), calcium (Ca), and magnesium (Mg)] and micronutrients [copper (Cu), iron (Fe), manganese (Mn), zinc (Zn), and boron(B)].

The value of broiler litter in crop production has generally been attributed to its macronutrient content, especially nitrogen (N). Nitrogen is the most limiting nutrient for crop production, and inorganic-N fertilizers represent the single largest energy input into crop production systems (Wilkinson, 1979). Therefore, when broiler litter is used as a fertilizer, it is usually managed for its N content. However, current thought, discussed later in this paper, suggests that broiler litter should be managed for its phosphorus (P) rather than its N content.

Many field studies have demonstrated the value of broiler litter as a N source for crop production. Broiler litter applications have been shown to reduce or eliminate the need for costly N fertilizers in corn production systems (Carrecker et al., 1973; Ketcheson and Beauchamp, 1978; Sims, 1987; Oyer et al., 1987; Wood et al., 1991). During 1990 and 1991, at Crossville, AL, we compared fresh broiler litter with composted broiler litter and ammonium-nitrate fertilizer (on an equivalent N basis) with respect to their effect on corn yield and N uptake (Flynn and Wood, 1992). No differences in corn grain yield (Figure 1) or N uptake among N sources was observed in either year of the study, suggesting that broiler litter or composted broiler litter could substitute for commercial N. Benefits of broiler litter to small grain production have also been observed. At Crossville, AL during 1989 and 1990, we found that broiler litter, applied during the fall at a rate of 4 tons/acre to winter wheat, eliminated the need for fall-applied commercial N and reduced the need for spring-applied commercial N to 20 Lb/acre (Flynn et al., 1992). Perennial hay/forage crops have benefited from broiler litter applications as well. In a recent study near Snead, AL, we found that coastal bermudagrass fertilized with broiler litter had yields and quality equivalent or superior to that fertilized with ammonium nitrate (Wood et al., 1992). These studies indicate that broiler litter can substitute for commercial fertilizer N in a variety of cropping systems.

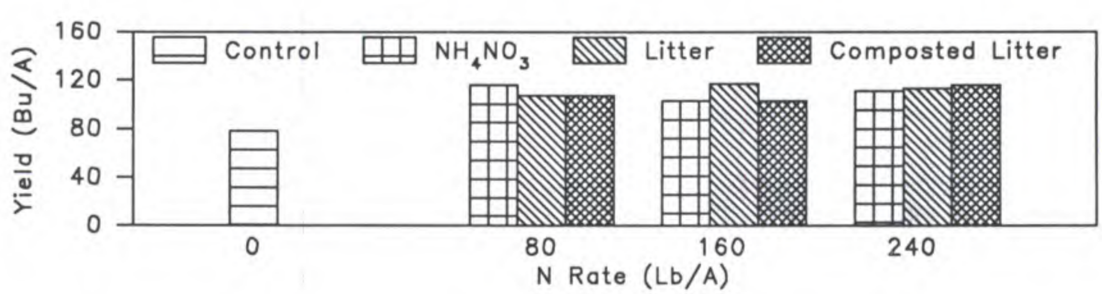

Fig. 1. Two-year average (1990 and 1991) corn yield as affected by N source and rate at Crossville, Alabama.

Since most of the N in broiler litter is in organic forms [>90% (Wood and Hall, 1991)], much of the N is not immediately available to plants. Thus, for maximum crop production, N applications based on total N may need to be greater for broiler litter than for inorganic N sources. The fraction of N recovered by crops from broiler litter during a single growing season is generally less than that from inorganic fertilizers (Sims, 1987; Cooper et al., 1984). Lower N recovery from broiler litter in comparison to inorganic fertilizers has been attributed to ammonia volatilization (Bitzer and Sims, 1988; Wolf et al., 1987; Giddens and Rao, 1975), nitrate leaching (Wengel and Kolega, 1972), and immobilization in the soil organic-N fraction (Wilkinson, 1992). Nitrogen from broiler litter that is immobilized can be released in subsequent growing seasons. Wilkinson (1992) studied the rate of N release from broiler litter applied to bermudagrass at Watkinsville, GA over several years. He found that after litter application had ceased, N released to plant available forms was 18% for the first year, 9 for the second, 5 for the third, 4 for the fourth, and 3 for the fifth. Wilkinson's (1992) findings illustrate the residual effects of broiler litter, and suggest that broiler litter rates, when based on total N content, should be reduced in years following initial application.

Benefits of broiler litter to crop production, in addition to its N-supplying capability, include its capacity to furnish other nutrients and improve soil physical properties. Increased availability of soil P, potassium (K) (Robertson and Wolford, 1970, 1975; Robertson et al., 1975), Zn (Singh et al., 1979), Ca and Mg (Kingery et al., 1992) have been documented for soils receiving applications of broiler litter. Soil organic matter contents have also been increased with land application of broiler litter (Kingery et al., 1992). Benefits to soil physical properties resulting from applications of broiler litter include increased soil water holding capacity, water infiltration, amount of water stable aggregates, and lowered bulk density (Weil, 1977; Stewart, 1992).

ENVIRONMENTAL CONCERNS

Although salutary effects of broiler litter on crop production have been demonstrated, land application of this material can cause environmental degradation. The potential for environmental contamination from broiler litter is especially high in regions of intense broiler production, where litter represents a waste disposal problem rather than a resource. Historically, in the South, broiler production has been concentrated in upland areas, such as the Sand Mountain region of Alabama (the number two broiler producing state) and the Ozark Mountains of Arkansas (the number one poultry producing state). Concentrated broiler production in these regions is related to economic (labor costs) and land-use constraints (unsuitability for row crop production), rather than any climatic benefits. High density poultry production in such regions often exceeds the available land area for disposal of broiler litter at recommended rates, resulting in excessive application rates. The problem of a limited land area for disposal could be solved, in large part, by transporting broiler litter out of intense broiler producing areas to areas of intense crop production, such as the Tennessee Valley region of Alabama and the Mississippi Alluvial Plain region of Arkansas. However, broiler litter is a low density material, and transportation costs exceed its nutrient value within short distances. Potential environmental degradation, which the above logistical factors contribute to, is further compounded by the fact that soils available for disposal in regions of intense broiler production are generally sloping, shallow to bedrock, and permeable to dissolved substances such as nitrate. Other factors that contribute to the potential for environmental contamination from land applied broiler litter include: (1) poor timing of disposal (litter is removed from broiler houses throughout the year, which may not coincide with periods of maximum nutrient uptake by plants); (2) low efficiency of nutrient recovery; and (3) lack of knowledge concerning nutrient, heavy metal and soluble salt release from broiler litter subsequent to soil application. It appears then, that the major poultry producing areas in the U.S. constitute systems with a high potential for environmental degradation.

Although a large potential for environmental contamination in intense broiler producing regions exists, data confirming this supposition are scarce. Because of the scarcity of data, we conducted a study in the Sand Mountain region of Alabama in 1991 that compared nutrient/heavy metal concentrations of soils under fescue pastures that had received long-term (15-28 years) litter applications or no litter. Details of the study design can be found elsewhere (Kingery et al., 1992). Briefly, soils under 12 litter/no litter pasture pairs, matched according to landscape position and soil type, were sampled in the four major broiler producing counties (Blount, Cullman, Dekalb, and Marshall) in the Sand Mountain region. The pastures we sampled were representative of litter management practices occurring throughout the region. Soil samples were collected to a depth of 10 ft or bedrock, whichever came first.

The depth distribution (averaged over the 12 litter/no litter pastures) of nitrate-N (NO_3-N) is shown in Figure 2. Much higher NO_3-N concentrations were found in littered than non-littered pastures below 50 inches, suggesting excessive litter-N applications. These data also indicate that significant amounts of NO_3-N are leaching towards groundwater under littered pastures on Sand Mountain. These findings are disturbing, because elevated NO_3-N concentrations in groundwater used for human and/or livestock consumption constitutes a potential health hazard. Methemoglobinemia (blue baby syndrome), cancer and respiratory illness are among the major human health problems associated with ingestion of high NO_3-N containing waters (Stevenson, 1986). In addition, elevated NO_3-N in water can cause fetal abortions in livestock (Stevenson, 1986).

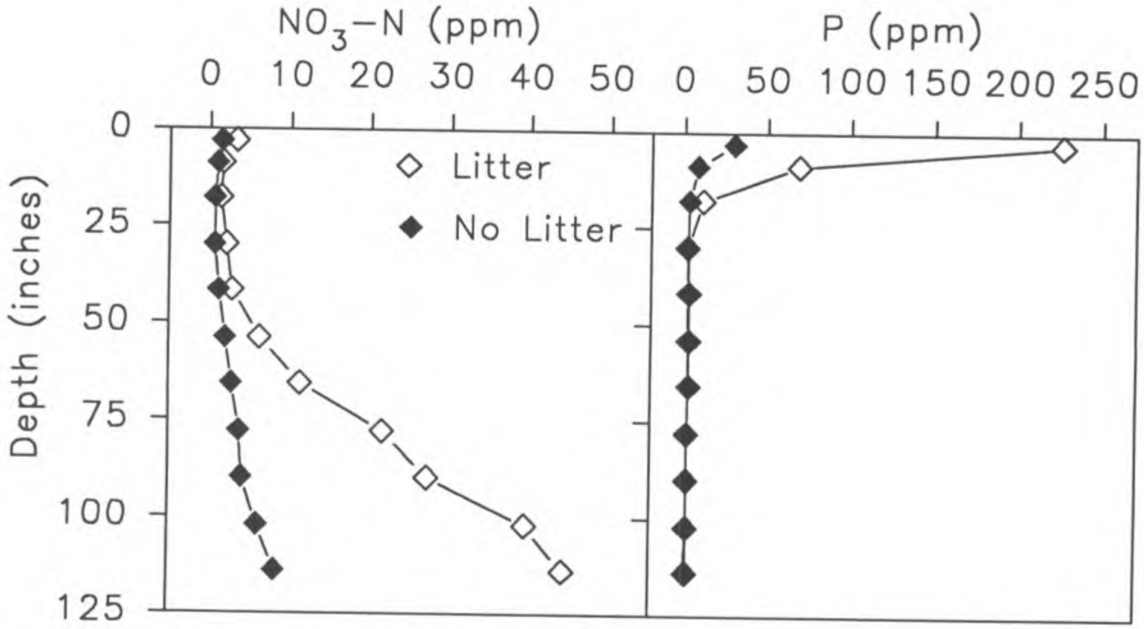

Fig. 2. Average soil NO_3-N and extractable P concentrations for 12 pasture pairs in the Sand Mountain region of Alabama that have received long-term applications of broiler litter or no litter.

Extractable P concentrations averaged 530% greater in the upper 2 ft of soil under littered than non-littered pastures (Figure 2). Extractable P concentrations under these littered pastures are considered "extremely high" (Cope et al., 1981), and indicate that P loading from litter has far-exceeded fescue nutritional requirements. Excessive soil-P increases the potential for P movement into surface waters via runoff, which can result in eutrophication (nutrient enrichment followed by noxious aquatic weed growth that lowers water quality) (Stevenson, 1986). Indeed, declining water quality owing to eutrophication in Lake Guntersville, which is a large impoundment on the Tennessee River located in the Sand Mountain region, has occurred in recent years (Anonymous, 1986, 1987). Based on our findings with respect to soil test P levels, many pastures that have accommodated broiler litter at disposal rates over the long-term should not receive further applications.

The findings of the above study suggest that long-term land application of broiler litter under present management practices has created adverse environmental impacts in the Sand Mountain region of Alabama. Similar studies indicate parallel situations in other intense broiler producing regions (A.N. Sharpley, personal communication, 1992). As previously mentioned, one avenue of ameliorating negative environmental effects of an expanding, viable broiler industry would be to move litter out of intense broiler producing regions to areas of intense row crop production. Another effective method would be to base litter applications on soil test P results rather than crop N requirements (Daniel et al., 1992). Such an approach would, in general, limit broiler litter-N applications owing to lower land application rates. For example, using the average fertilizer grade for broiler litter (3-3-2) given by Stephenson et al. (1990), the rate of broiler litter required to supply adequate P to fescue on a soil with a P rating of "medium" in Alabama (Cope et al., 1981) would be 1 ton/acre. This rate would supply 60 lb total N/acre, which, if the N was all in available forms (which it is not), is half the recommended N rate for fescue in Alabama (Cope et al., 1981). Additional N required for normal fescue growth could be applied as commercial fertilizer N. Such an approach would likely mitigate excessive buildup of P in the soil, and at the same time lower the risk for NO_3-N leaching to groundwater. A soil test P based strategy would, however, eliminate much of the land area with extensive broiler litter disposal histories; many years are required to lower soil P reserves once they reach excessive levels (Daniel et al., 1992). Therefore, lower broiler litter rates, and elimination of part of the land base available for disposal, will further exacerbate the problem of local land limitations for broiler litter disposal in regions of intense broiler production.

Because the broiler industry continues to grow in areas of intense production, and because land area suitable for environmentally safe broiler litter disposal continues to decline, massive quantities of litter will, by necessity, be moved outside intense broiler producing regions. As previously mentioned, the Tennessee Valley region of Alabama, which is adjacent to the broiler producing Sand Mountain region, could accommodate much of the litter generated on Sand Mountain. To that end, studies are being conducted at several sites in the Tennessee Valley region that are aimed at determining appropriate application rates and cultural practices for broiler litter as a nutrient source for field crops (cotton, corn, and wheat) and coastal bermudagrass. Similar studies are being conducted in the Mississippi Alluvial Plain region of Arkansas (D.M. Miller, personal communication, 1992). The goal of these studies is to utilize broiler litter in a manner that will provide for maximum economic biomass yields without environmental degradation. Final conclusions remain to be drawn in these ongoing studies. However, results to date suggest that if managed properly, broiler litter as a fertilizer can result in sustained biomass production and environmental compatibility.

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ECONOMIC EVALUATION OF LITTER MATERIALS AND PRACTICES

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Poultry bedding material alternatives are numerous and the characteristics of the ensuing litter materials diverge widely. The desirability of a bedding and subsequent litter material from an economic perspective is dependent on its performance impact, procurement, handling and disposal related costs. It is proposed that the economic evaluation index of a bedding-litter material be its amortized annual cost per 1000 ft^2 of production housing space. The most desirable bedding-litter material for a specific firm setting would then be the one having the lowest amortized annual cost index. The following discussion will focus on identifying the factors that need to be considered and appropriate costing procedures for determining an amortized annual cost index.

PERFORMANCE IMPACTS

A material must support established poultry performance thresholds before it can even be considered as an acceptable bedding-litter material alternative. Reed and McCartney (1970) considered growth, feed conversion, mortality and breast blister incidence in deeming litter material as acceptable from a performance standpoint. Brake, et al. (1992) extended the performance criteria to also include manure burns in making their inferences that hardwood bark didn't influence broiler performance or carcass quality and there are certainly additional performance or carcass quality parameters that could be associated with economic consequences. Ideally, relations on the physical trade-offs between these parameters could be established through research, valued at representative price levels and then incorporated into an amortized annual cost index. Practically, these trade-offs are difficult to quantify with suitable precision at an acceptable research cost and are usually omitted from consideration as long as a bedding-litter material satisfies the minimal acceptable or "no influence" classification. As information systems proliferate and advance in sophistication, pertinent trade-off values may become available and will then need to be integrated into bedding-litter cost calculations.

PROCUREMENT

The primary concern for bedding-litter material alternatives from a procurement perspective is the consistent availability of a uniform quality product in the volumes that are going to be required. Most of the materials that are potential substitutes are derived as by-products from other production activities or result from attempts to salvage materials initially designed for other end-product purposes and, accordingly, may not meet the consistent availability and uniform quality in sufficient quantities. If they do, our attention can then focus on procurement cost considerations. The main factors to be considered are: 1) the price or cost per unit, 2) the volume needed to adequately cover a 1000 ft^2 of production space over an annual period given the litter material being considered, the litter management strategy being practiced and usage intensity from both placement density and flock turn considerations, and 3) the bulk density of the material which directly effects transport costs. The procurement subtotal of the amortized annual cost estimate per 1000 ft^2 can then be defined as the product of the price and the volume required plus the associated transportation costs --- the product of the price or cost per ton mile, the material volume, the material bulk density and the mileage involved --- that would be incurred for spatially relocating that volume of material.

HANDLING

Handling will be construed to include bedding-litter material storage, distribution, additional processing, spreading and quality maintenance activities. Physical material attributes such as bulk density, particle size distribution, moisture holding capacity, drying rate, compressibility, penetrability, thermal conductivity and hygroscopicity (Reed and McCartney, 1970) will largely determine the handling practices, equipment and storage facility requirements. From a costing perspective, the equipment and storage facilities are durable assets with useful lives of over a year. Since the services that these assets provide will not be "consumed" during an annual period, these costs must be amortized. Using time value of money principles combined with situation specific income tax considerations, an annual equivalent after-tax cost estimate can be derived for each durable asset. Combining the annual equivalents with any bedding-litter associated annual operating costs --e.g. lime, super phosphate, disinfectant, fuel, repairs, labor-- and dividing the result with the number of thousands of ft^2 of production housing space would yield the amortized annual cost for handling activities subtotal.

DISPOSAL

When removed from the production housing space, poultry litter is primarily an aggregation of excreta, feathers, spilled feed and water and the original bedding material. Malone, et al. (1992) has measured and quantified, for broilers, excreta production rates, but the concluding litter composition still remains highly dependent on specific handling practices. Salvage or recycling use imputed as well as actual market exchange values for poultry litter vary widely but are basically related to the materials nutrient profile -- including moisture content, its particle size and bulk density and its environmental friendliness characteristics. Both Forsht, et al. (1974) and Stephenson, et al. (1990) have indicated that several litter materials have several times more value in ruminant feeds than they do as fertilizers. Thus, depending on usage alternatives, net disposal costs may be either positive or negative and, accordingly, either add to or subtract from the sum of the procurement and handling cost subtotals previously discussed. The amortized annual cost per 1000 ft^2 of production housing space disposal subtotal would be defined as the net annual disposal related costs -- which, as indicated above, may be a positive or negative number-- divided by the number of thousands of ft^2 of production housing space.

AMORTIZED ANNUAL COST INDEX

The amortized annual cost per 1000 ft^2 of production housing space can now be defined as the sum of the performance impacts --if quantified, procurement, handling and disposal subtotals previously defined and discussed. The most desirable bedding-litter material for a specific firm setting would be the material having the lowest amortized annual cost index. Because of the wide range in firm production and market settings, however, additional conditioning factors would need to be specified before valid and meaningful between-firm comparisons and evaluations using this choice-making criterion and rule could be directly made.

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POSTER

PRESENTATIONS

USE OF COMPOST IN COMMERCIAL NURSERIES

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A study was conducted to test the addition of a turkey and broiler litter compost to potting media used at a commercial nursery. The standard nursery medium of pine bark and peat moss (5:1 by volume) was compared to the standard medium with 10% (by volume) addition of compost. Three additional potting mixes of pine bark plus additions of 10, 20 and 40% (by volume) compost were included in the study. Pine bark was amended with 0.5, 6.3 and 4.2 kg/m^3 Scots Step, ProKote (20.0 N-1.3 P-8.3 K) and dolomitic limestone, respectively before blending with other components. Rhododendron cultivars 'Nova Zembla', 'PJM' and 'Chinoides' and Kalmia latifolia 'Nipmuck' were potted May 31, 1990 in 11.4 liter containers in one of 5 media and placed in 5 randomized complete blocks under 20% shade cloth.

RESULTS AND DISCUSSION

Addition of 10% compost to the standard 5:1 pine bark: peat medium decreased total pore space approximately 3% and air space 4% but slightly increased water held in the potting mix, although the available water for plant use was decreased (Table 1). Addition of increments of 10, 20 and 40% compost to pine bark produced media with approximately 4.0, 3.0 and 13.0% (respectively) less pore space, 5.0, 6.0, and 7.0% less air space and 7.0, 5.0 and 7.0% (respectively) more available water than the standard meduim. Leachate extractions had pH levels which fluctuated from 5.7 to 6.2 initially and 6.2 to 6.7 through the growing season, with but were not particularly higher in compost containing media or by rate of compost addition (data not shown).

Electrical conductivity (EC) (soluble salts) in leachates ranged from 1.5 to 3.0 deciSeimens/meter (ds/M) initially and were higher in compost containing media (Table 2). Although EC readings of 3.0 ds/M are considered extremely high, no plant damage was evident. Incremental additions of compost in pine bark increased EC, N, P, K, Ca, and Mg (K, Ca and Mg

Table 1. Physical properties of five container pine bark substrates amended with peat moss and composted turkey and broiler litter.[z]

Media	Total Porosity[y]	Air Space[x]	Container Capacity[w] (% vol.)	Avail. Water[v]	Unavail. Water[u]	Bulk Density (g/cc)
PB:P (5:1)	85.6	16.6	69.0	26.4	42.7	0.27
PB:P:C (75:15:10)	83.0	12.2	70.8	24.8	46.0	0.29
PB:C (90:10)	81.4	11.4	70.0	33.1	37.0	0.32
PB:C (80:20)	82.6	10.4	72.2	31.6	40.7	0.32
PB:C (60:40)	73.0	9.4	73.0	33.5	39.6	0.34

[z]All analyses performed using standard aluminum soil sampling cylinders (7.6 cm ID, 7.6 cm h). Total porosity, unavailable water content and bulk density are uneffected by sampling core height.

[y]Percent volume at 0 kPa.

[x]Calculated as the difference between total porosity and container capacity.

[w]Predicted as percent volume at drainage.

[v]Calculated as the difference between container capacity and unavailable water.

[v]Percent volume at 1.5 MPa.

data not shown) solution levels by rate after 12 weeks but were lower for the 40% compost medium on the first sampling date (Tables 2 and 3). Adding compost to the standard potting medium had the same effects of increasing leachate nutrient levels, but most noteworthy was the effect of compost increasing phosphate levels above 50 ppm (Table 3) throughout the study while the standard medium was deficient with less than 10 ppm on sampling dates after 9 and 15 weeks.

Consequently the increased solution phosphate levels in compost containing media increased foliar P content as sampled from Kalmia at the end of the study in November (Table 4). Visual ratings of all four test plants indicated that plants preformed as well or better in media containing 10% compost as the nursery standard (data not shown). Kalmia latifolia `Nipmuck' grown in media containing 10% compost had top dry weights that were similar to the nursery medium. The 20 and 40% additions of compost reduced growth (data not shown).

Table 2. Effect of 5 container substrates on electrical conductivity (EC) of leachates collected from containers of <u>Kalimia</u> <u>latifolia</u> `Nipmuck' 3, 8, 12, 16 and 18 weeks after potting.

Media	Leachate EC Levels (dS/m)[z] Weeks after potting				
	3	8	12	16	18
		ns	ns		ns
PB:P (5:1)	1.5[b]	0.7	0.6	0.4[c]	0.2
PB:P:C (75:15:10)	2.2[ab]	0.7	0.7	0.9[ab]	0.2
PB:C (90:10)	2.8[ab]	0.9	0.8	0.7[bc]	0.3
PB:C (80:20)	2.7[a]	1.2	1.0	1.2[a]	0.4
PB:C (60:40)	1.9[b]	1.2	1.1	1.2[a]	0.4

[z]Mean separation within columns by Duncan's multiple Range test, 5% level. Each value represents the mean of 3 replications.

Table 3. Effect of 5 container substrates on nitrogen and phosphate leachate levels container of <u>Kalmia</u> <u>latifolia</u> `Nipmuck' collected 3, 12, and 18 weeks after potting.

Media	Leachate Levels (mg/liter)[z] Weeks after potting					
	Nitrogen			Phosphate		
	3	12	18	3	12	18
		ns	ns			
PB:P (5:1)	162.7[ab]	58.2	28.7	23.9[d]	10.5[c]	5.7[c]
PB:P:C (75:15:10)	226.3[a]	59.0	30.6	147.0[c]	28.3[bc]	16.2[b]
PB:C (90:10)	231.0[a]	70.7	28.0	253.7[b]	39.7[b]	18.6[b]
PB:C (80:20)	205.6[a]	80.3	44.3	315.7[a]	49.7[ab]	27.2[a]
PB:C (60:40)	117.0[b]	89.5	34.5	255.7[b]	74.0[a]	30.3[a]

[z]Mean separation within columns by Duncan's multiple Range test, 5% level. Each value represents the mean of 3 replications.

Table 4. Effect of 5 container substrates on foliar tissue levels of Kalmia latifolia `Nipmuck' 25 weeks after potting.

Media	Foliar Tissue Levels (%)[z]				
	N	P	K	Ca	Mg
PB:P (5:1)	1.4[a]	0.14[c]	0.91[b]	0.50[a]	0.25[bc]
PB:P:C (75:15:10)	1.3[ab]	0.17[c]	0.98[b]	0.51[a]	0.25[bc]
PB:C (90:10)	1.29[ab]	0.17[c]	1.02[b]	0.51[a]	0.24[c]
PB:C (80:20)	1.22[b]	0.21[b]	0.94[b]	0.54[a]	0.27[b]
PB:C (60:40)	1.04[c]	0.30[a]	1.22[a]	0.52[a]	0.30[a]

[z]Mean separation within columns by Duncan's multiple Range test, 5% level. Each value represents the mean of 5 replications.

SIGNIFICANCE TO THE INDUSTRY

The most significant result of incorporating turkey and broiler litter compost into pine bark or into the nursery standard pine bark:peat moss (5:1) medium was the increase in phosphate solution levels and the resultant foliar P increase above deficient levels. Although all measured parameters were acceptable with 10% addition of compost, further studies to optimize nutrient capacity factors are in progress.

ALABAMA IS COMPOSTING POULTRY CARCASSES

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Alabama ranks second among the states in broiler production and produced approximately 855 million broilers in 1991 valued at nearly 1.0 billion dollars. For the same year, it was estimated that 46 cents of every agricultural income dollar is attributable to poultry production. Expansion of the poultry industry is anticipated through the next century.

Every broiler grower is faced with the reality of dead poultry disposal. Broiler mortality as a result of normal death amounts to less than 5% of the total flock size during a typical 7-week growout cycle. Considering that nearly 18 million broilers are processed weekly in Alabama, approximately 800 tons of carcasses must be disposed of in an environmentally sound manner. Carcass disposal has been identified by the poultry industry in Alabama as a serious environmental problem, that if not solved, may result in regulatory constraints which may limit future industry expansion.

CURRENT METHODS OF DISPOSAL

Open-bottom burial pits are the most commonly used method for the disposal of poultry carcasses. Increased production capacity per farm, high mortality rates, and increasing market weights may attribute to slow decomposition rates and ultimate failure of this type of system. The possible decline in ground water quality where pits are located in certain soil types having high groundwater tables is also a concern. Residue remaining in pits after years of use is recognized as another concern.

Incineration is recognized as one of the biologically safest methods of disposal. However, it tends to be slow, expensive, and generates the greatest number of nuisance complaints even when highly efficient incinerators are used. Particulate air pollution is also generated by incinerators.

Due to increasing burial or incineration costs and newly imposed local, state, and federal water and air quality standards, alternative methods of disposal are of interest to the poultry producer.

COMPOSTING AS AN ALTERNATIVE METHOD

Preliminary studies of composting as a method for the disposal of poultry carcasses were conducted at the University of Maryland's Poultry Research and Education Facility (Murphy and Handwerker, 1988). For the composting of poultry carcasses, a prescribed amount of dead poultry, poultry litter, straw, and water at a weight:weight ratio of 1:2:0.1:0.25, respectively, provide the necessary mixture for transformation into compost (Murphy, 1988). Caked or used poultry litter, comprised of pine shavings, sawdust, peanut hulls, or rice hulls, and manure is used as the primary compost medium and supplies ammonia nitrogen for microbial growth. Since a mixture of carcasses and litter have a disproportionately large supply of nitrogen, straw is added to the mixture to supply additional carbon and adjust the carbon:nitrogen (C:N) ratio. Acceptable C:N ratios are between 15:1 and 35:1, while moisture content ranges are between 40 and 60% (Donald et al., 1990).

The alternatives for the disposal of poultry carcasses are limited and composting presents itself as a very desirable environmental and economic alternative. Composting has gained widespread acceptance by the Alabama poultry industry.

COMPOSTING POULTRY CARCASSES IN ALABAMA

Testing and adoption of composting as a method for the disposal of poultry carcasses began over two years ago. In 1989, six key poultry leaders and researchers from Auburn University toured composting facilities in Maryland to determine if such techniques were applicable to the poultry industry in Alabama. Following this trip, it was decided by University researchers and industry representatives that a composter should be constructed for demonstration purposes to learn first-hand those techniques involved for on-farm composting of poultry carcasses.

The first composter was constructed in Alabama in July 1989. Subsequently, methods for composting poultry carcasses have been approved by the State Veterinarian's Office and cost share money has become available for composter construction through Soil Conservation Service (SCS) and Agricultural Stabilization and Conservation Service (ASCS) programs. The first composter demonstration has attracted hundreds of visitors and has provided an excellent means for providing educational information to the poultry grower. As a result of this initial demonstration, over 200 dead poultry composters have been constructed and are operating in Alabama with great success.

Composters constructed in Alabama must satisfy design specifications issued by the Agricultural Engineering Department at Auburn University and/or Soil Conservation Service (Donald and Blake, 1990). Common characteristics include:

An impervious weight-bearing foundation (concrete) secures the composter against insects, rodents, dogs, etc., and prevents contamination of the surrounding area.

Pressure treated lumber or other rot-resistant materials are necessary to withstand the biological activity of composting.

A roof that ensures year-round operation and controls rain water and percolation. Gutters may be needed to divert water away from composting bins.

An all-weather water line is necessary for addition of moisture to the compost and will be useful for equipment clean-up.

Some general observations concerned with composting of poultry carcasses indicate that an all-weather facility is required to protect the composting material from the elements. Straw, peanut hulls, and chopped hay are suitable for adjusting the C:N ratio and act as bulking agents (Blake et al., 1991). Recent results from controlled and field research indicate that litter (bedding + manure) alone provides a suitable compost medium when used at a level two to three times greater than the carcass weight. As a result the need for straw has been eliminated and carcasses, litter and water at a weight:weight ratio of 1:3:0.25 is the common compost formula used by poultry growers in Alabama. Composted material has also been successfully used as the primary medium through a second composting cycle. When carcasses are layered into the primary composting bin, they should be placed 6 to 8 inches from the bin sidewalls to eliminate the opportunity for insects, primarily flies, to utilize the material for breeding purposes.

MICROBIOLOGICAL SAFETY OF COMPOSTING

For composting to be a truly viable method for the disposal of poultry carcasses, it is paramount that the composting process results in inactivation of pathogenic (avian and human) microorganisms prior to land application. It has been documented that bacterial pathogens (e.g. Listeria monocytogenes) can be transmitted from farm animals to humans via land application of contaminated compost and manure used as fertilizer (Schlech et al., 1983). Therefore, in evaluating composting or any other method of dead carcass disposal, avoidance of both human and avian disease transmission must be a major consideration. Field and controlled studies have been conducted to evaluate the microbiological safety of two-stage mortality composting (Conner et al., 1991a,b).

In field studies, high coliform populations were rapidly inactivated; however, inactivation often did not occur until composting materials were transferred to the secondary bin. This indicates that transfer is needed to aerate the materials to enable a secondary heating cycle to occur. It is the interaction of time and heat that inactivates pathogenic bacteria. Since coliform bacteria are indicative or characteristic of enteric pathogenic bacteria (e.g. Salmonella), it was concluded that two-stage composting would likely heat inactivate many poultry-associated bacterial pathogens. Further investigations substantiate that coliform populations are good biological indicators for determining compost efficacy, and verify that avian and human pathogens are inactivated during two-stage composting (Conner and Blake, 1990; Conner et al., 1991a).

When properly managed, composting is a safe (biosecure), relatively inexpensive and environmentally sound means for disposing of poultry carcasses. A well managed composter will generate temperatures in excess of 130 F during three consecutive days which is capable of destroying many avian and human pathogenic bacteria that may be associated with mortalities. According to various studies (Conner et al., 1991b), two-stage composting involving aeration (transfer to a secondary bin) to produce a secondary heat cycle is necessary for effective pathogen destruction.

EDUCATIONAL PROGRAMMING

Auburn University's Poultry Science and Agricultural Engineering Departments working with appropriate state and federal agencies and poultry company representatives in the state developed an educational program to make growers and industry aware of the ever increasing environmental concerns that may affect the stature of the poultry industry in

Alabama. Through these efforts, all parties involved are aware of the proper methodology of handling farm generated poultry by-products to clearly demonstrate that the poultry industry is acting as a good steward of the environment.

In developing an extension program for poultry waste management, the most economical and practical methods for the dissemination of information is through printed publications and audio-visual materials. The "Poultry By-Product Management Handbook" embodies the most current and best information concerning the disposal of poultry farm-generated wastes in an environmentally sound manner (Blake and Donald, 1991). Approximately 28 extension publications have been placed under one cover. The handbook addresses five areas which include 1) policy and resource information regarding the roles of Federal and State agencies and their interface with the poultry industry; 2) manure management and utilization; 3) disposal of farm mortalities; 4) farm planning and enhancement; and 5) vector control.

The information contained in this handbook has been developed in cooperation with extension specialists in the Departments of Poultry Science, Agricultural Engineering, Agronomy and Soils, Horticulture, Animal and Dairy Sciences, Entomology, and Wildlife at Auburn University. In addition, various state agencies and allied industry representatives have contributed valuable input for establishing guidelines and provisions for the disposal of poultry farm wastes.

In addition to the printed materials, a 21 minute video entitled "Composting Poultry Carcasses" was developed to provide detailed instructions for the construction and management of two-stage poultry carcass composting units.

After development of the "Poultry By-Product Management Handbook", in-service training meetings were held with county agents and selected state agency and poultry industry representatives. This training meeting was the "kick-off" effort to coordinate industry and governmental agencies working together in Alabama towards voluntary compliance for environmentally safe disposal of poultry wastes.

Educational meetings were held at the county level targeted at the poultry grower. The key areas of program content were centered around guidelines for the utilization of broiler litter as a fertilizer for crops and pasture land, the feeding of broiler litter to cattle, and alternatives for the disposal of poultry carcasses. County agents are taking an active role in developing poultry by-product educational programs to assist the poultry producer in matters other than routine production covered by integrator policies.

A number of positive efforts are underway in Alabama to address educational needs of the poultry industry relative to environmental concerns to insure voluntary compliance with environmental guidelines, the poultry industry needs to be aware of management procedures which will have a direct effect on maintaining the quality of surface and ground waters, soils, as well as human and animal health.

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ON-FARM FERMENTATION OF BROILER CARCASSES

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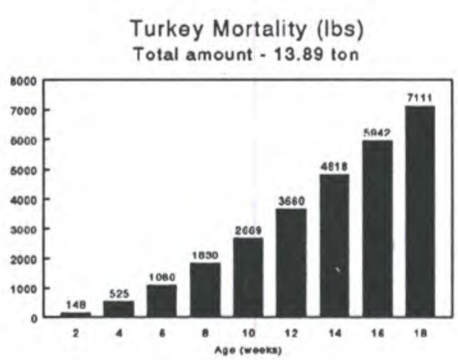
Every turkey and broiler production facility is faced with the reality of poultry farm mortalities. For a flock of 30,000 turkeys averaging 0.5% mortality weekly (9% total mortality), approximately 13.9 tons of carcasses will have to be disposed of during an 18 week growing period (Figure 1). For a flock 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 (Figure 1) (Blake et al., 1990).



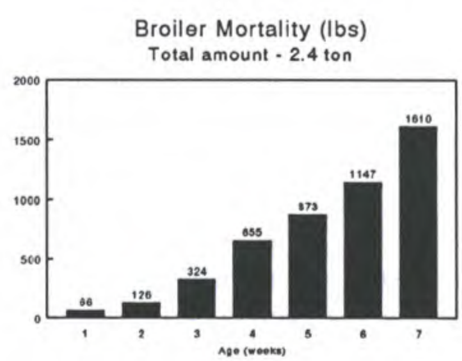


Figure 1. Weight of poultry carcasses obtained biweekly for a flock of 30,000 turkeys averaging 0.5% mortality weekly (9.0% total mortality) or weekly for a flock of 50,000 broilers averaging 0.1% mortality daily (4.9% total mortality).

Disposal of poultry farm mortality has been identified as one of the major problems facing the poultry industry in Alabama. Alabama ranks second among the states in broiler production and produced over 850 million broilers in 1991 valued at over $1.0 billion. Approximately 46 cents of every agricultural income dollar was generated by poultry industry revenues.

Unfortunately, Alabama also ranks second in the production of broiler wastes. The expansion and prosperity of the poultry industry in Alabama has brought many good things along with two potential areas of concern. These areas of concern include the environmentally safe disposal of approximately 1.7 million tons of poultry litter that is generated each year in the state and the disposal of 800 tons per week of farm mortalities that are a result of normal grow-out. Disposal of poultry wastes has been identified by the poultry industry as a priority. If poultry wastes, litter and carcasses, are not disposed of by environmentally acceptable methods, future industry expansion may be limited or regulatory constraints may be imposed.

CONCERNS WITH RENDERING

Rendering is one of the best means for the conversion of poultry carcasses into a valued, biologically safe protein by-product meal. However, spread of pathogenic microorganisms during routine pickup and transportation of poultry carcasses to a rendering facility presents a substantial threat. Until a biosecure method of carcass handling and transportation is proposed, the State Veterinarian's office in Alabama will not approve the transportation of poultry carcasses to a rendering facility.

FERMENTATION OF CARCASSES PRIOR TO RENDERING

Lactic acid fermentation of poultry carcasses prior to transport may be a method of preventing the spread of disease during transport to a rendering facility (Dobbins, 1988). Fermentation, a controlled natural process has been successfully used as a preservation method for foods and feeds for millennia, and has become well documented as a scientifically sound method for the preservation of organic materials (Ayres et al., 1980).

Information on fermentation of poultry carcasses is greatly limited. In small-scale experiments, successful fermentation was brought about by combining appropriate amounts of farm mortalities with bacterial culture and a readily fermentable carbohydrate source (e.g. sucrose, molasses) (Dobbins, 1988). Similar research has been conducted at University of Maryland by Murphy and Silbert (1990) and at Auburn University by Conner et al. (1991).

In the same small-scale studies, it was demonstrated that pathogenic microorganisms were effectively inactivated (Dobbins, 1988; Shotts et al., 1984; Conner et al., 1991). Fermented material can be stored and will remain in a stable state for several months (Conner et al., 1991). Therefore, it is probable that this type of fermentation process can be developed so that it can be initiated and continue on-farm as a biosecure method of storing mortalities until they can be transported to a rendering facility.

PROGRESS OF CURRENT RESEARCH

At Auburn University there is an interest in adapting the fermentation of poultry carcasses for on-farm use. Laboratory studies were initiated in January 1990 and an on-farm installation was constructed and has been operating since February 1992.

Laboratory Studies

Initial investigations have been conducted in small-scale vessels to evaluate the appropriate combination of ground poultry carcasses, fermentable carbohydrate, and/or other additives required to assure rapid fermentation and biosecure stabilization that would result in long-term storage on the farm. Six laboratory studies have been completed to evaluate six fermentable carbohydrate sources (glucose, whey, whey permeate, molasses, ground yellow corn, and distillers solids) for their efficacy in promoting acid production and stabilization of poultry mortality (Conner et al., 1991; 1992).

In the laboratory, ground broiler carcasses (150 g) were mixed with an appropriate amount of fermentable carbohydrate ranging from 4 to 18% (weight:weight basis) and then placed into fermentation vessels. This was repeated for 5 consecutive days to give 750 g (1.6 lb) per container. Over 30 days of storage (room temperature) pH, and populations of lactic acid bacteria, coliform bacteria, and fungi were periodically determined.

Results from laboratory studies indicate that:

1. The addition of at least 6% glucose or whey permeate to ground carcasses promoted fermentation as evidenced by a decline in pH from 5.6 to a range of 4.2 to 4.5 within 1 week after the first carcass layer was added to the fermentation vessel.

2. Molasses or whey at a level of 8% promoted an acceptable fermentation of the ground carcasses.

3. Distillers solubles at the 6% level resulted in proteolytic deterioration indicating that higher levels are required for promoting fermentation.

4. Ground corn at a level of 15% or greater was necessary to support adequate fermentation as indicated by a decline in pH to less than 4.5.

5. It was assumed that pH reduction over a shorter period of time may increase the quality of the fermented product and provide quicker stabilizing. However, the addition of an acidulant (1.3% sodium bisulfate) failed to lower pH at an accelerated rate.

6. Addition of protease enzyme had no effect on rate of pH change. Further research is desirable to determine the effectiveness of an enzyme on feather degradation.

7. Two commercial bacterial cultures comprised of lactobacillus spp., pediococcus spp. and streptococcus spp. failed to improve the fermentative process.

8. The addition of propionic acid-based antifungal agents (mold inhibitors) failed to control mold growth that typically occurs on the surface of the fermented material.

9. In a preliminary study, populations of indigenous coliform bacteria and added Salmonella typhimurium were reduced from moderately high levels to undetectable levels.

Scale-Up of Laboratory Studies

Two experiments were completed to address the scaling-up of an endogenous fermentation system of carcass stabilization from laboratory to on-farm use (Conner et al., 1992; Kotrola et al., 1992). Approximately 10 kg (22 lbs) of ground carcasses were mixed with an appropriate fermentable carbohydrate and placed in a closed container with subsequent additions occurring on four consecutive days, resultant batch size of 50 kg (110 lbs).

In Experiment 1, the carbohydrates tested were sucrose (10%), whey (10%) and 50:50 corn:whey (15%). Replicate batches were stored for 30 days at either 2 C (35 F) or 25 C (77 F). The whey:corn ferment putrified and was discarded. The pH declined from 5.8 to 4.1 (25 C) and from 5.8 to 4.8 (2 C) in mixtures with sucrose and whey. The batches of fermented material prepared with sucrose and whey were processed in cooperation with Georgia Proteins, Cumming, GA and Alabama Feed Products, Hanceville, AL (Table 1).

Table 1. Nutrient Composition of Fermented and Rendered Poultry Carcasses.

	Fermentation Substrate	
	Sucrose (10%)	Whey (10%)
Proximate Analysis		
Moisture (%)	7.8	7.0
Protein (%)	47.4	49.8
Fat (%)	23.2	18.2
Ash (%)	4.5	9.4
Calcium (%)	1.1	2.6
Phosphorus (%)	.7	1.3
Fat Analysis		
Free fatty acids (%)	17.7	15.7
Peroxide value (meq/kg)	1.7	2.6
Active oxygen method (meq/kg)	6.3	11.8
Fatty Acid Profile (%)		
Caprylic acid (C8)	.9	1.5
Capric acid (C10)	24.7	28.7
Lauric acid (C12)	72.5	68.6
Myristic acid (C14)	1.3	1.0
Palmitic acid (C16)	.3	--
Palmitoleic acid (C16:1)	.1	.1
Stearic acid (C18)	--	.2
Oleic acid (C18:1)	.1	--
Linoleic acid (C18:3)	.1	--

In Experiment 2, the carbohydrate sources included whey (10%), whey permeate (10%) (83-86% lactose), ground corn (20%) and ground wheat (20%). The layering protocol was similar to the previous experiment. The mixtures were stored at 25 C for 12 weeks. The pH decreased from 5.8 to 4.6, 4.5, and 5.1 within 7 days in carcasses with whey, whey permeate and corn, respectively. The mixture with wheat putrified and was discarded. The lowest pH for whey (4.0), whey permeate (4.3) and corn (4.8) occurred at 18 days and remained relatively constant. Initial coliform levels were greater than 10^6 cfu/g and declined to undetectable levels by the 18th day of fermentation. Results indicated that large batch fermentation was achieved with sucrose, whey, whey permeate and corn at the levels tested.

On-Farm System

A disposal facility was constructed on a 90,000 capacity broiler farm to demonstrate the feasibility of on-farm endogenous fermentation of poultry carcasses (Blake and Donald, 1992). A prototype grinding unit was specifically designed to allow for the simultaneous addition of the carbohydrate source during grinding (Autiomatic Model 601, Dixie Grinders, Inc., Guntersville, AL; K-tron Model 200, K-tron Corporation, Glassboro, NJ).

On a daily basis broiler mortality is ground and either whey (10% of mortality weight) or ground corn (20%) was utilized as the carbohydrate source. The mixture (mortality and carbohydrate) is directly fed into a 1.27 m x 1.04 m x .99 m (50 in. x 41 in. x 39 in.) fiberglass tank (TBF-38, Plastech, Inc., Warminster, PA). Tank capacity is approximately 1800 lbs.

Weekly pH measurements are obtained from the fermentation tank(s) at three locations approximately 12 inches below the surface. All pH values of the fermented product decrease below 4.5 within a 10-day period. Resulting ferment obtained at the end of a typical 7-week cycle was transported to Alabama Feed Products, Hanceville, AL for processing.

Results from these studies indicate that fermentation can be adapted for the stabilized, pathogen-free storage of broiler carcasses during a typical 7-week growout. Unlike routine pickup of "fresh" mortalities, fermentation and subsequent storage of poultry farm mortalities reduces transportation costs by 90% and eliminates the potential for transmission of pathogenic microorganisms through poultry via rendered products.

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ON-FARM COMPOSTING OF POULTRY MANURE

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Under today's environmental constraints, good manure management practices are essential. Otherwise the poultry industry may not be allowed to grow and thrive. More than 1.6 million tons of poultry manure are produced annually in Georgia. We cannot rely on old methods of disposal for manure and poultry mortalities. The challenge facing the industry is to adopt new methods that are effective, affordable, and environmentally safe.

Composting provides an alternative method of utilizing poultry manure in an environmentally safe, efficient and non-polluting manner through biological treatment to reduce pollution and protect the environment by producing a humus-rich material that can be recycled as a soil amendment and fertilizer substitute, or otherwise utilized in compliance with all laws, rules and regulations.

ON-FARM MANURE COMPOSTING

Of major importance to farmers is that composting be simple and inexpensive. The materials needed are readily available on the farm (manure, carbon sources and water), or nearby (shredded brush, bark, leaves, shredded paper, etc.).

The windrow process is the easiest and most energy efficient form of on-farm composting. Windrows should be three to five feet tall and should have a base width of 10-15 feet. The location for the windrow should be based on a soil type, slope and the ability to control surface runoff. The area needs to drain well and not to trap water in the windrows. The windrows may be as long as the materials and site allow.

Carbon Source. A dependable source of carbonaceous material must be available. The material should have a high carbon content and a high carbon to nitrogen ratio (C:N). The rate of decomposition is determined by the C:N ratio. Woodchips, leaves, shredded brush, sawdust, peanut hulls, straw, corn cobs, bark, peat moss, and well bedded horse manure are good sources of carbon.

Moisture Control. Large amounts of water are evaporated during the composting process due to operating temperatures that drive off water. A source of water must be available for compost pile moisture control from start-up through completion. Proper moisture facilitates the composting process, especially in the beginning. Dry material will not compost until it gets wet. Water content is ideal if the material feels like a well wrung-out sponge; if it balls-up or yields liquid when squeezed hard, it is too wet.

Oxygen. Adequate oxygen penetration into windrows to maintain aerobic biological conditions is needed for decomposition of organic materials. Frequent turning will help to reoxygenate the innermost region of the windrow and hasten the composting process. Attempts to accelerate the composting process without increasing the oxygen supply may create odors.

Equipment Needs. Appropriate equipment must be available for initial mixing, turning, and hauling compost ingredients and finished compost. Appropriate long stem thermometers are required for monitoring windrow temperatures in order for the operator to be able to document pathogen and weed seed kill.

Time Requirements. The time needed for the completion of the process varies with the material, process, and weather. It must continue until the material reaches a stability level at which it is safe to store without creating undesirable odors and poor handling features. Acceptable stability occurs when microbial activity diminishes to a low level. Stability may be obtained in about 45-90 days, but can require up to six months to produce the desired quality. Factors affecting composting rates are those that influence biological activities:

Moisture content
Aeration
Carbon:Nitrogen ratio
P_2O and K_2O levels

POULTRY MANURE COMPOSTING RECIPES

The recipes that follow are based on the volume rather than the weight of manure. Proper moisture is critical for good composting.

Typical Recipes for Farmer Composters

For each cubic yard of fresh broiler litter just as it comes out of the poultry house, blend in any of the following carbonaceous materials at the indicated rates. Since broiler litter is generally too dry for composting, water must be added to it before or during mixing with dry carbonaceous material. If any of the ingredients are wet, water should be added only after mixing. The final mix should feel like a well wrung-out sponge.

Table 1. Rich Broiler Litter Recipe (Carbon Requirements)

Carbon source	C:N ratio	Bulk density lb/cu.ft.	Weight/ cubic yard	Weight (lbs) required in mix	Cubic yards required in mix
Bark	256	22	594	489	0.82
Hay-Fescue	46	18	486	800	1.65
Leaves-Old	74	48	1296	845	0.65

Note: For all recipes, bring in carbonaceous materials in dump trucks or in dump trailers and drop the materials in long windrows. Keep the windrows straight and uniform in cross-section. Provide good access to the windrows from both sides, so that you can load poultry litter into the windrow from the side. Before loading the windrow, open a trench down the top of the windrow with your bucket loader, then fill the trench on top of the windrow with poultry litter or other nitrogenous material. Then cover the nitrogenous material with additional carbonaceous material, or immediately turn the windrow with a compost turning machine.

Pullet Litter Recipe

For each cubic yard of fresh pullet litter just as it comes out of the poultry house, blend in the following amounts of carbonaceous material.

Table 2. Pullet Litter Recipe (Carbon Requirements)

Carbon source	Weight (lbs) required in mix	Cubic yards required in mix
Bark	837	1.41
Hay-Fescue	1348	2.77
Leaves-Old	1442	1.11

Note: If you want to mix and match carbonaceous material to get say half of your carbon from hay and half from bark, you would do the following:

> Multiply by 0.5, the respective cubic yard requirement for both hay and bark as follows:
>
> (0.5) x (2.77) = 1.39 cubic yards of hay, and
> (0.5) x (1.41) = 0.70 cubic yards of bark.

Combine the cubic yard of pullet litter with the 1.39 cubic yards of hay and the 0.70 cubic yards of bark, add water, or let it rain. Soon you will have compost. Of course you must turn and aerate the windrow to help the composting process along.

If you are doing say 100 cubic yards of pullet litter, multiply the hay and bark figures by 100.

In spite of the directions above, you must add the litter to the carbonaceous material in order to keep the litter out of the mud.

Commercial Layer Manure

For each cubic yard of fresh, wet, hen manure just as it comes out of the henhouse, blend in the following amounts of dry carbonaceous materials (select your carbon source, or sources, and start windrowing the material):

Table 3. Commercial Layer Manure (Carbon Requirements)

Carbon source	Weight (lbs) required in mix	Cubic yards required in mix
Bark	700	1.18
Hay-Fescue	1200	2.47
Leaves-Old	1200	0.93

Note: Assume that wet hen manure weights 2,000 lb per cubic yard.

Mix materials as indicated in previous recipes. Lay down your carbon source first. Drop it in a windrow; trench the top of the windrow of carbonaceous material, and drop the hen manure into the trench. Cover the additional dry carbonaceous material, or mix immediately with a compost turning machine, such as a Wildcat or Scat.

If the hen manure is very wet or if the carbonaceous materials are not very dry, then add more carbon materials to get a mix that is dry enough for good composting.

For maximum speed in composting, follow the turning schedule shown below:

1. First Week: Turn compost daily. Add water or more carbonaceous material to adjust the moisture.

2. Second Week: Turn compost every other day.

3. Third Week: Turn compost every third day.

4. Fourth Week: Turn compost every fourth day.

5. Fifth through Eighth Weeks: Leave compost alone.

6. Ninth Week: Push compost into the barn to keep it dry prior to spreading or selling it.

For highest product quality, screen the compost before selling or spreading. Screen it down to less than one inch, or whatever small size it takes to let it flow easily through your fertilizer spreader.

MONITORING AND COMPLETING THE COMPOSTING PROCESS

The compost process is characterized by increases in temperature, moisture loss, oxygen deprivation and odor release. It is therefore recommended that a monitoring program be initiated for each composting process. The following guidelines apply.

Temperature in the composting bins must be monitored daily. Use a 24-48 inch probe-type thermometer[1]. Temperatures within the compost mass should begin to rise within 24 hours after building a pile, and should be hot in two to four days. In the bin system, temperatures typically peak at five to seven days, reaching heights of 140°F-160°F. In the windrow program, temperatures may be sustained for longer periods (up to 21 days).

The heat generated in the compost deodorizes and decontaminates carcasses. However, heat drives out moisture which carries with it the smell of the material. Therefore, adequate ventilation of a facility is recommended.

Moisture if compost materials fail to heat up, it is usually because the piles (bins) are too wet or too dry. This can be remedied by appropriate means, e.g. turning, or adding dry carbonaceous materials if it is too wet; or additions of water or rain if it is too dry.

Oxygen (O_2) Content active composting draws oxygen from surrounding pore spaces within the pile and from airspace around to support microbial respiration. The drop in oxygen levels parallels the increase in temperature. If the pile is the proper size and moisture content and turned occasionally, O_2 should not drop below 5% for lengthy periods. If it does drop to this level and stay low, it may result in unpleasant

[1]Available from VWR Scientific, Boston, Mass or Reotemp Corp.

odors and poor stabilization of the product. For these reasons, monitoring the process with a simple oxygen probe[2] is highly recommended.

The principle of oxygen monitoring is to draw a small sub-sample of air from within the pile into a small tube in which an oxygen sensitive probe is housed. A properly constructed system requires only about 1 minute to take a reading. The meter typically reads from abient (20.9% O_2) down to zero.

During rapid, high temperature composting, the lowest oxygen levels will be recorded. This is typical. If heating is sustained while oxygen is low, it is a sign that sufficient air is being supplied.

Table 4. Trouble Shooting Guidelines

	Symptom	Problem	Cure
Odor	Putrid, sour, sulphur	Too wet	Turn & add dry carbonaceous materials
	Ammonia, fishy	Surplus nitrogen	Add low nitrogen materials, e.g. leaves, bark, sawdust, etc.
Moisture	Dust, white mold	Too dry	Add water.
	Sodden & not heating	Too wet	Add dry carbonaceous materials.

Storing the Compost

Although the compost could be directly land applied after composting, it is recommended that the material be stored under cover for four to six months. This allows it to dry and cure for ease of application. Again you may recycle some of this compost into the active primary bin as a manure substitute or starter for the whole composting process.

Using Compost on the Land

Compost should be applied to the land at recommended agronomic rates. Since 70-95% of the total nitrogen in the compost is in an insoluble organic form, the compost will act as a slow release fertilizer. This characteristic of compost allows better utilization of the nitrogen by plants and reduces the

[2]Available from VWR Scientific, Boston, and complete with a sampling tube from Woods End Research Lab, Mt. Vernon, Maine.

potential for movement in surface and ground water, when compared with fresh manure.

Because of the high concentration of organic matter in the compost, land application of this material should help retain moisture in the soil profile.

When composting is properly carried out, the pathogenic bacteria and viruses associated with the carcasses and manure are essentially destroyed, making compost a safer fertilizer than fresh manure or mortalities.

VOLUMETRIC AND COMPOSITIONAL CHANGES DURING TWO-STAGE COMPOSTING OF POULTRY MORTALITIES

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Composting has been demonstrated to be an environmentally sound, inexpensive method of processing poultry mortalities for disposal on land (Murphy and Handwerker, 1988). Although composting does not dispose of mortalities, the process biologically transforms the mortalities into material that is amenable to land spreading for final disposal. To facilitate composting, the mortalities are combined with poultry litter, a carbon source such as wood chips, straw or peanut hulls, and water to achieve 50 to 60% moisture in the total combined materials. The addition of a carbon source, usually in a ratio of 20 to 30 parts carbon to 1 part nitrogen, is essential to promote microbial activity which is responsible for the composting process. The recommended procedure for composting poultry mortalities is to layer the materials in the compost bin in the following approximate ratio: 20 to 30 parts poultry litter: 10 parts poultry carcasses: 1 part wheat straw: 5 parts water (Payne and Donald, 1990).

The purpose of this study was to determine volume, mass and compositional changes which occur during two-stage composting of poultry mortalities.

PROCEDURES

Poultry litter, poultry mortalities, peanut hulls and water (in that order) were weighed in the recommended proportions and layered into a USDA/SCS approved compost bin measuring 1.75 x 2.88 m at the base. As the bin was filled at a rate of two layers per day for 4 days, thermocouple wires, for monitoring temperature, were placed in each of the materials composing each of the seven layers in the compost bin. Each layer comprised of the four materials added 0.15 m height to the compost pile. Two times the quantity of poultry litter used per layer during filling the composter was used as the base and cap on the compost pile. After the composter was filled, the quantities of all the ingredients were tallied to determine the following weight ratio of ingredients loaded into the composter (kg): 8.2 litter: 2.9 mortalities: 1.0 peanut hulls: 1.2 water. Temperature of the composting material was monitored for 29 days. The maximum temperature attained in the primary composter was 53.4 C, which was achieved 15 days into the compost period. Fourteen days after the maximum temperature was reached, the compost was loaded onto a truck and weighed to determine weight loss during the primary compost process. Samples of the compost were collected, pooled and mixed to yield representative samples for proximate and mineral analyses. The compost from the primary bin was mixed and aerated during clean out and weighing, and then placed back into the same bin for the secondary compost process. Thermocouple wires were placed into the secondary compost material 0.18 m above the concrete floor and every 0.15 m thereafter. At each height interval in the compost pile, two thermocouples were used to monitor temperature. Four days after composting, the secondary compost reached a maximum temperature of 62°C. After the material was composted for 48 days, the compost was weighed and samples collected for analyses as described previously. Proximate analysis was conducted by AOAC procedures (1984). Mineral analysis was performed by the Soils Testing Laboratory, Auburn University, using inductively coupled argon plasma spectroscopy, according to procedures outlined by Hue and Evans (1986). Total Kjeldahl nitrogen was conducted on wet samples and calculated on a dry matter basis. All other analyses were conducted on oven-dried samples.

RESULTS

Primary Composting Process

The total volume of material loaded into the primary composter was 6.16 m^3, and after 29 days of composting the volume decreased to 5.20 m^3, a 15.6% decrease (Table 1).

Table 1. Change in volume and mass of components during primary composting.

Item	Raw Material	Primary Compost	Difference	%
Volume, m^3	6.16	5.20	0.96	15.6
Mass, kg	4331	3734	597	13.8
	- - - - - - - -	kg - - - - - - - -		%
Water	1725	1494	231	13.4
Dry matter	2606	2240	364	14.0
Ash	665	668	+3	+0.4
Nitrogen	121	96	25	20.7
Bound nitrogen	19	19	0	0.0
Crude fiber	412	383	29	7.1
Ether extract	157	96	61	38.6

Mass was reduced 13.8%, from 4331 kg to 3734 kg. Proximate analysis indicated that 13.4% of the moisture and 14% of the dry matter were lost during primary composting. Major losses of dry matter components were nitrogen, 20.7% and ether extract, 38.6%, which was primarily fat in the poultry mortalities. Ash content increased slightly during composting, from 665 kg to 668 kg, which was insignificant. On a weight basis, ash would not be expected to change since minerals are not volatile at the temperatures achieved during composting. However, the percentage of ash increased from 25.5% prior to composting to 29.8% after composting. This increase was attributable to the overall loss of dry matter, 364 kg, while the quantity of ash remained relatively constant.

Secondary Composting Process

During the 48-day secondary composting process, the compost volume decreased 0.77 m^3, or 13.3% (Table 2). Mass loss was 9.6%, down 358 kg to 3376 kg after secondary composting. The decrease in mass was due primarily to the loss of water, 275 kg, rather than to loss of dry matter, 83 kg. Approximately 89 kg of ether extract (fat) was lost during the secondary composting process. This represents a decrease in concentration from 4.3% in the primary compost to 0.3% in the secondary compost, or a 92.3% loss. The quantity of nitrogen expressed on a weight basis did not change during secondary composting. However, the percentage of nitrogen in the compost increased from 4.3% to 4.5%, due to dry matter loss during composting.

Table 2. Change in volume and mass of components during secondary composting.

Item	Primary Compost	Secondary Compost	Difference	%
Volume, m^3	5.77	5.00	0.77	13.3
Mass, kg	3734	3376	358	9.6
	- - - - - - - -	kg - - - - - - - -		%
Water	1494	1219	275	18.4
Dry matter	2240	2157	83	3.7
Ash	668	659	9	1.4
Nitrogen	96	96	0	0.0
Bound nitrogen	19	17	2	12.7
Crude fiber	383	376	7	1.7
Ether extract	96	7	89	92.3

Overall Primary and Secondary Composting Process

The total change in volume and mass of the composted material from the initial placement of materials into the primary composter to the completion of the two-stage composting process is shown in Table 3. Volume of the materials was reduced 18.8% and mass was reduced 22.0%. Most of the volume reduction occurred during the primary composting process, which amounted to 83% of the total volume loss.

Table 3. Loss of volume and mass during primary and secondary composting.

Item	Raw Material	Secondary Compost	Difference	%
Volume, m^3	6.16	5.00	1.16	18.8
Mass, kg	4331	3376	955	22.0
	- - - - - - - - kg	- - - - - - - -		%
Water	1725	1219	506	29.4
Dry matter	2606	2157	449	17.2
Ash	665	659	6	1.0
Nitrogen	121	96	25	20.6
Bound nitrogen	19	17	2	12.7
Crude fiber	412	376	36	8.6
Ether extract	157	7	150	95.5

Mass reduction for both composting processes was 22%, and 63% of this occurred during primary composting. Moisture loss accounted for 53% of mass reduction and dry matter accounted for 47%. About 54% of the total water was lost during the secondary composting process, whereas 81% of the dry matter was lost during the primary process. Of the dry matter components, nitrogen decreased 20.6% and ether extract (fat) decreased 95.5%. Ash content decreased slightly, but since ash is not volatile at composting temperatures, it was assumed that the slight decrease was due to experimental error.

The effect of two-stage composting on selected minerals is shown in Table 4. The concentration of phosphorus increased from 2.14% prior to composting to 2.42% after two-stage composting. The increase was due to a reduction in total mass of the composted material. Similar increases were noted for percentages of potassium, calcium and magnesium. However, based on total quantity, the amount of each mineral in the final compost decreased by 3 to 7%. Because the minerals are not volatile, the decrease was attributed to sampling variation, since the decrease in ash was only 1%.

Table 4. Change in concentration and quantity of selected minerals during two-stage composting.

Mineral		Raw Material	Secondary Compost	Difference kg	Difference %
P	%	2.14	2.42		
	kg	55.88	52.11	3.77	6.7
K	%	2.97	3.47		
	kg	77.44	74.81	2.63	3.4
Ca	%	2.98	3.43		
	kg	77.70	73.90	3.80	4.9
Mg	%	0.58	0.67		
	kg	15.20	14.37	0.83	5.5

In summary, composting of poultry mortalities with broiler poultry litter, peanut hulls and water in the weight ratio of 2.9:8.2:1:1.2 through a primary and secondary stage process resulted in an overall 19% reduction in volume and 22% reduction in mass. Water content of the material decreased 29.4% and dry matter decreased 17.2%. Ash content, expressed on a dry matter basis, was not appreciably affected by composting. However, nitrogen content decreased 20.6%, crude fiber, 8.6% and ether extract (fat), 95.5%. The percentages of N-P-K in the final compost on a wet basis, which may be applied to land, were 2.9, 1.5, and 2.2%. Based on a wet metric ton, the compost contained the following kg quantities of N, P_2O_5, and K_2O: 29, 34, and 53, respectively. Expressed on a pounds/ton basis, the quantities were 58, 69, and 106, respectively.

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FIELD TRIALS AND DEMONSTRATIONS ON COMPOSTING SYSTEMS FOR POULTRY MORTALITY

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A field trial and demonstration project was initiated in early 1991 to evaluate the process of composting poultry mortality under North Carolina field situations. Original work at the University of Maryland demonstrated that broiler mortality could be composted in a biosecure manner resulting in a product that was suitable to be field applied as a nutrient source. Since North Carolina has a diverse poultry industry; information was needed to determine if this technology could be adapted to field situations in North Carolina including the need to compost bigger birds such as broiler breeders and turkeys.

OBJECTIVES

The first objective was to develop information to determine if the composting process was a biosecure, aesthetically sound system under North Carolina field conditions particularly for larger poultry such as turkeys and broiler breeders. The second objective was to determine if materials common to North Carolina producers such as peanut hulls and turkey brooder litter could be substituted for built up litter and/or straw. The third objective was to develop design criteria for composting larger and older poultry such as turkeys. The fourth objective was to establish well managed composters in all areas of the state that could be used to demonstrate and instruct correct composter design, and management.

METHODS

Seven cooperators were recruited to assist in the collection of information for the project. Two cooperators were turkey producers, four broiler producers and one a broiler breeder producer. These cooperators were under production contract with seven different integrators and were geographically distributed in all the major poultry producing areas of the state. Cooperators kept records of the quantity of ingredients, daily temperature of compost, dates of turning events, and other information relating to the compost processing.

Ingredient and compost samples were taken from cooperators mortality composters in May, July, and November 1991. Duplicate samples of raw litter, and at each stage of composting (first heat, second heat and third heat) were taken. Separate samples were taken aseptically for bacteria and virus analysis. The method used to aseptically sample the ingredients and compost was initiated by using a disinfected post hole digger to dig a hole at least 12 inches into the composter contents. Then using sterile gloves, a grab sample was taken, placed into a sterile plastic bag and sealed. Samples were placed in a cooler and taken to the laboratory for analysis within 24 hours.

Plate count analysis was conducted for total coliform, total bacteria, anaerobic and mold-type microorganisms. In addition, an enrichment media procedure was utilized to determine if salmonella bacteria were present in the samples. Virus isolation was conducted by the NCSU College of Veterinary Medicine.

RESULTS

Microbial Analysis

The results of the total bacteria plate count from all samples are shown in Table 1. Samples included samples of raw litter before use it was used in the compost recipe, compost during the first heat cycle, compost during the second heat cycle, and the compost during the third heat cycle. Total bacteria plate counts of raw litter averaged over 15 million organisms per gram of litter and ranged from no growth to 108 million organisms per gram. The average bacteria found in first, second, and third heat compost samples averaged 7,201,099, 3,042,00, and 2,247,818 organism per gram of compost respectively. In general, bacterial numbers tended to decrease with each successive heat. There was also a trend for the range of the number of total bacteria to narrow as the compost process progressed through the three heats.

Total coliform numbers from the composters decreased dramatically as the compost went through the series of three heats. Numbers of coliform organisms averaged 316,981 organisms per gram of material for the raw, non-composted litter, 22,438 organisms for first heat compost, 4,109 organisms for second heat compost and 345 for third heat compost (Table 2). The raw litter used in the composting

Table 1. Total Bacteria Plate Count of Samples from Multi-Stage Mortality Composters

Type of Sample	Range (/g)	Average (/g)
Litter	N.G.[1]-108,000,000	15,623,000
1st Heat	180-44,000,000	7,201,099
2nd Heat	36,000-10,800,000	2,042,000
3rd Heat	216,000-9,800,000	2,247,818

[1]N.G. = No growth.

process by the cooperators which had zero total bacteria and zero coliform bacteria counts came from deep stacked litter which was going through or had been through a heat cycle.

Table 2. Total Coliform Plate Count of Samples from Multi-Stage Composters

Type of Sample	Range (/g)	Average (/g)
Litter	0-4,520,000	316,981
1st Heat	0-256,000	22,438
2nd Heat	0-136,500	4,109
3rd Heat	0-3900	354

No Salmonella or adenovirus could be cultured from any of the samples taken from two stage composters. Plate counts of anaerobic and mold microorganisms did not show any noteworthy trends.

Time of year in which the microbial analyses were done had no impact on microbial counts of the samples from the multi-stage composters.

Recipe and Temperature Profiles

The recipe of two parts litter, one part poultry mortality, and 1/10 part straw by weight functioned well in all the multi-stage composters. Water did not have to be added if the litter portion of the recipe was 25-30% moisture. Soaking the straw before layering the recipe assisted in obtaining adequate moisture in borderline cases. In situations where litter moisture was below 20% a quantity of water was added to the birds and straw which brought the mixture of dead poultry, litter and straw to 40% moisture which promoted adequate composting. In the few instances where too much moisture was added, fly breeding and anaerobic conditions ensued.

Evidence of peak temperatures could be seen in the temperature records kept by cooperators with multi-stage composters. Temperature profiles routinely peaked at above 150 degrees F., with some peaks in excess of 160 degrees F. Figure 1 is an example of temperature profiles of a turkey mortality composter using caked turkey litter.

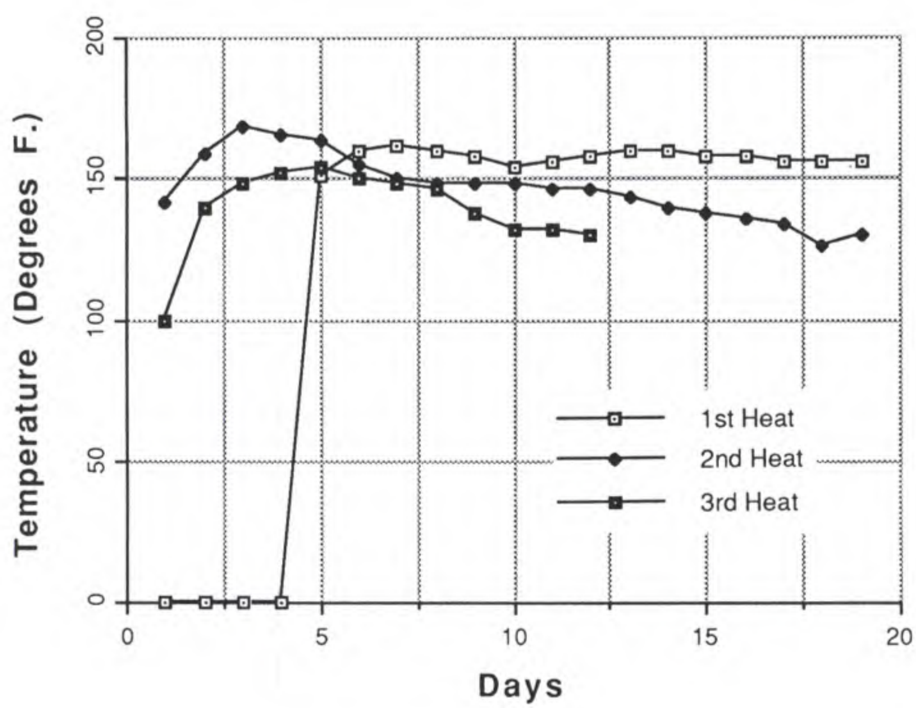

Figure 1. Temperature Profile
Multi-Stage Mortality Composter
Initiated May 31, 1991
1252 lbs. Tom Turkeys, Straw, Grower Litter as Ingredients

Alternate Ingredients

Peanut hulls and turkey brooder litter were used as alternatives to straw in the recipe for composting turkey mortality. The temperature profile for the compost utilizing peanut hulls along with caked turkey grow out litter (built up litter) is shown in Figure 2. Brooder litter (litter cleaned out after each brooding of a turkey flock) was used as the only ingredient in other trials with success (Figure 3). Optimal peak temperatures were reached utilizing both the peanut hulls and brooder litter. Moisture of brooder litter was less than caked litter resulting in a slower composting process. Additional field trials utilizing brooder litter, and moisture variations are currently being conducted to optimize the composting process with this ingredient.

Composter Capacity Determination

Data from a turkey mortality composter with records of 16 different complete series of composting, going through at

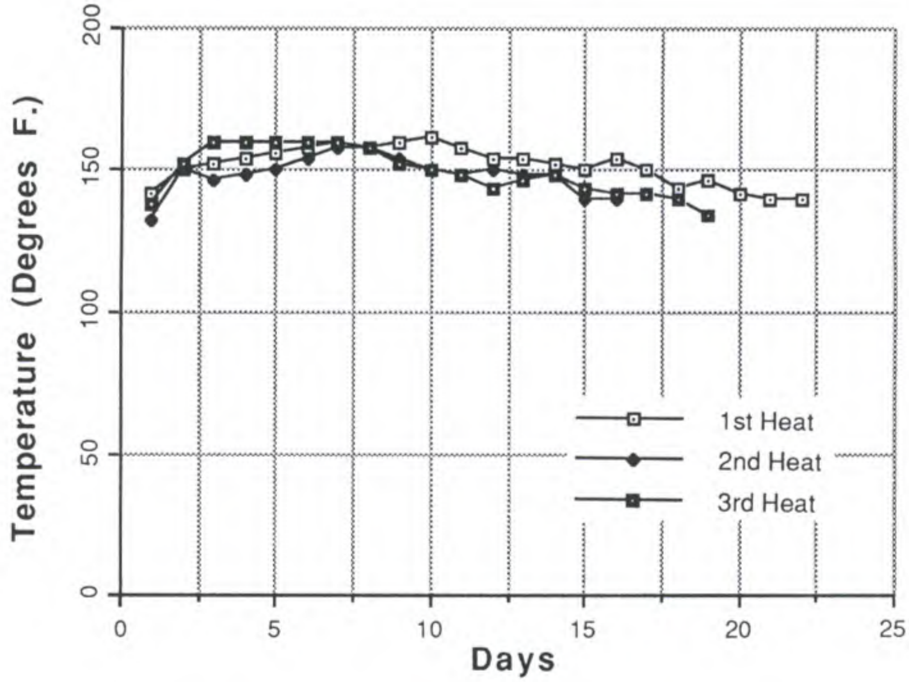

Figure 2. Temperature Profile Multi-Stage Mortality Composter Initiated September 15, 1991 1,994 lbs. Tom Turkeys, Peanut Hulls, Grower House Litter as Ingredients

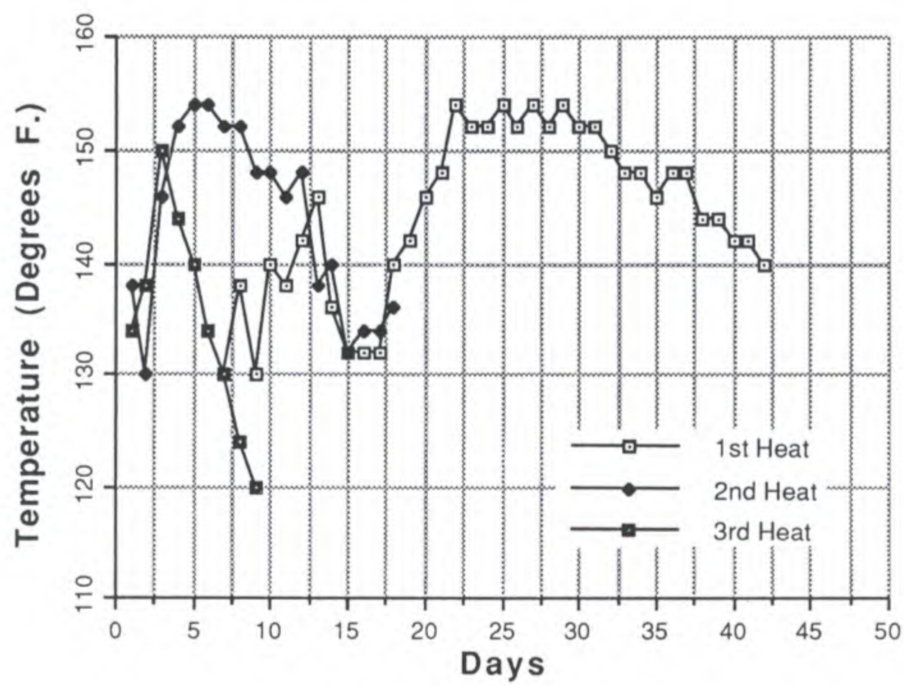

Figure 3. Temperature Profile Multi-Stage Mortality Composter Initiated August 29, 1991 1,663# Tom Turkeys, Brooder Litter as Ingredients

least three heat cycles, averaged 8.67 pounds of mortality per cu. ft. of original layered bin.

SUMMARY

Information from the field trials and demonstration projects on poultry composters indicate that the process of mortality composting is a biosecure and feasible system for disposing of poultry mortality including larger carcasses such as turkeys. Evaluation for bacteria at different stages of composting indicated that there is a dramatic reduction in the number of total coliform organisms as the compost is turned and goes through heat cycles. After the compost material tested went through three heats, the total coliform counts were negligible. Heat cycles routinely reached peak temperatures in excess of 150 degrees F and remained near that peak temperature for several days. Peanut hulls and brooder litter were used successfully as alternates to wheat straw as the primary carbon source.

POULTRY LITTER AS AN N SOURCE FOR WINTER WHEAT: A FIELD EVALUATION OF THE N AVAILABILITY COEFFICIENTS

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As early as 300 BC an early Roman writer noted that the addition of animal wastes could increase crop productivity. Throughout history, manures have remained a valuable source of plant nutrients. In fact, not until the last part of this century did man come to rely on inorganic fertilizer sources. Poultry litter, the combination of manure and a bulking agent such as wood shavings, wheat straw or peanut hulls, has been shown to be a valuable crop nutrient source. On a wet weight basis, total N content can be as high as 73 lbs N per ton of litter. In North Carolina alone this translates to 197,000 tons of N worth approximately $98 million based on a yearly production of 5.4 million tons.

Not all the N in litter is plant-available. Several reports have determined the amount and rate of N availability. Sims reported that 65-70% of N in litter is organic and must undergo mineralization. The remaining 30-35% is inorganic N, primarily ammonium (1986). Mineralization is the oxidation of organic N to available inorganic forms of nitrate (NO_3-N) and ammonium (NH_4-N). A study by Bitzer <u>et al</u>. (1988) measured N mineralization from 20 litters. After periods of aerobic incubation, available N (NO_3-N + NH_4-N) was extracted as a measure of mineralization. Results showed that mineralization was highly variable between sources. The study also indicated that two mineralizable fractions of N were present in poultry litters. The first fraction mineralized from 0-14 days and the second from 14-140 days. Available N decreased from day 80-140 suggesting simultaneous microbial immobilization of available N during the mineralization process.

Westerman et al. (1988) showed that 50% of total N was available in the first eight weeks after application. Availability declined to 10% of total N for weeks 15-19 and then increased to 65% for weeks 23-35. Their coefficient of 50% total N availability was modified to accommodate NH_3 volatilization and is being used by the North Carolina Department of Agriculture (NCDA) Waste Analysis Lab. Unpublished data (Zublena, 1991) has shown that the NCDA availability coefficients appear to be accurate when field evaluated for corn, a summer annual. This research was initiated to field evaluate the N availability coefficients for a fall planted crop such as winter wheat (Tricticum aestivum).

Two sites were selected for the test. The first site was in Raleigh, North Carolina at the North Carolina Sate University Research Farm Unit 2 using an Appling Sandy Loam, a Piedmont soil. The second site was in Plymouth, North Carolina at the Tidewater Research Station using a Portsmouth Sandy Loam, a Coastal Plain soil. Before initiation of the experiment, soil cores were taken to a depth of 90 cm to determine residual inorganic N from the previous season's corn crop. Seven ammonium nitrate (NH_4NO_3) rates were applied to develop a regression line for commercial N treatment response. Litter treatment responses were then compared to the NH_4NO_3 curves to determine the comparable N rate. The NH_4NO_3 treatments were 0, 45, 90, 135, 180, 225, and 270 kg $N \cdot ha^{-1}$. Poultry litter was applied at 135 kg predicted available N (PAN)/ha.

Crop responses evaluated for the wheat were tissue N concentration at three growth stages, dry matter production, grain head count, and grain yield. The three growth stages that were evaluated were at topdressing in early spring, flag leaf in mid spring, and soft dough stage in late spring.

There was no difference in whole plant tissue N concentration at topdressing. This was expected since N treatments were not yet applied. By flag leaf stage, trends in the data suggest tissue N concentrations increased as N rate increased. The litter rates at the two sites had tissue N concentration below that of the comparable 135 kg ha^{-1} NH_4NO_3 treatment.

Figure 1 shows whole plant tissue N concentration as a response to N rates at the soft dough stage averaged across sites. Soft dough stage is the growth stage at which there is maximum nutrient accumulation in the biomass. Trends suggest that N concentration increased as N rate increased. The litter treatments at the two sites had tissue N concentrations below the comparable NH_4NO_3 treatment suggesting mineralization of residual was not occurring as rapidly as predicted. As previously mentioned unpublished data by Zublena has shown the PAN coefficients are accurate for summer crops when soil temperatures are warm and mineralization can occur at the predicted rate. In fall planted crops, the soil temperature may not be warm enough for mineralization to occur as predicted. Differences in the litter treatment response inorganic N at the Raleigh site. Residual soil N could have added to the N nutrition of the wheat beyond that provided by the litter. There was 91 and 34 kg·ha^{-1} of residual inorganic N in the top 90 cm at the Raleigh and Plymouth sites, respectively.

Figure 1. Whole plant tissue N concentration at soft dough stage.

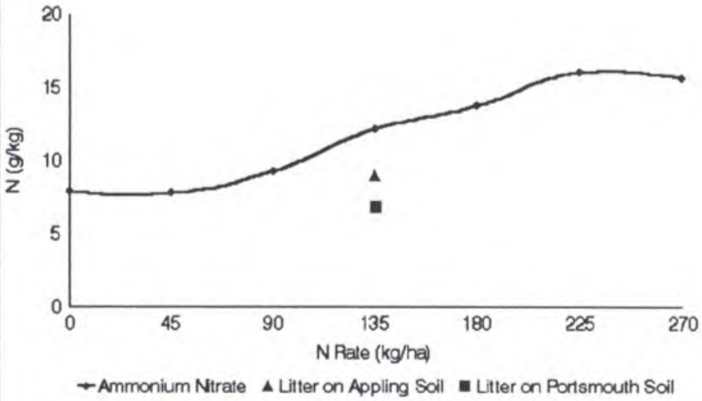
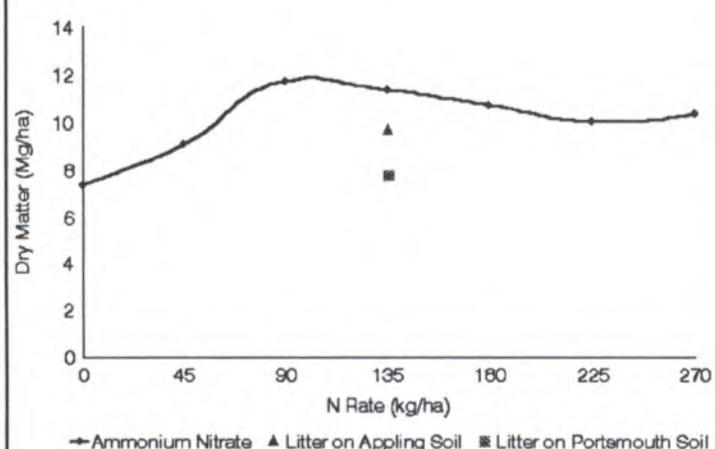


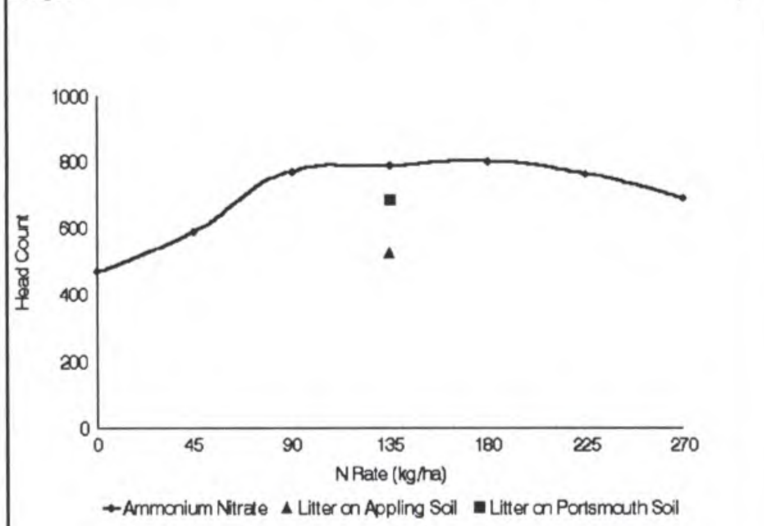
Figure 2 shows the dry matter production at soft dough stage as a response to N rate averaged across sites. Yield responses may vary depending on the parameter measured. It is possible for vegetative growth to be greater as N rate increases but grain yield may not differ. As the graph shows dry matter

Figure 2. Dry matter yield at soft dough stage.



production increases with increased N rate until maximum production is reached at the 90 kg·ha^{-1} NH_4NO_3 rate. The response to the litter treatment was below that of the comparable NH_4NO_3 rate, again, suggesting that mineralization was not occurring as rapidly as predicted. Dry matter production for the litter treatment on the Appling soil was greater than on the Portsmouth soil. This is believed to be a result of the greater residual soil inorganic N concentrations at the Raleigh site.

Figure 3. Grain head count/m^2 at soft dough stage.



Grain yield for wheat is a function of the number of grain heads, kernel weight and number of kernels per grain head. While kernel count per head was not taken, dry kernel weight decreased as N rate increased. Kernel weights for the litter treatment at both sites were below the comparable NH_4NO_3 rate. Because kernel weight is less than the comparable NH_4NO_3 rate, grain yield would be less for the farmer even if there was no difference in kernel count per grain head or number of grain heads/m^2.

Figure 3 shows grain head count/m^2 as a response to N rate. Head count increased to a maximum at 90 kg·ha^{-1} NH_4NO_3 as N rate increased. The litter treatment for both soils had lower grain head counts than the comparable NH_4NO_3 rate. Head count was greater for the litter treatments on the Portsmouth soil than the Appling soil due to a greater plant density at that site.

The results presented are the summary of the first year's data of a two-year project. At the time of paper submittal, statistical analysis was not yet completed. Trends show the predicted available N coefficient for poultry litter may not be accurate for fall planted crops. Further studies may be required to adjust the PAN coefficients for the season of application. Collection of the second year's data is not yet completed; but, visual observations of the research plots at both sites support the conclusion of the first year's results.

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A SURVEY OF THE FERTILIZER VALUE OF CO-COMPOSTED POULTRY MORTALITIES AND POULTRY LITTER

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Alabama's enormous poultry industry is the 2nd largest broiler producer in the U.S. (Payne and Donald, 1990). More than 917 million chickens were produced in Alabama broiler production systems in 1991 (Agricultural Statistics Board, 1992). Associated with this production is an average mortality rate of 5% (M.K. Eckman, Auburn University Extension Specialist, personal communication), which results in approximately 882 tons of carcasses per week. Techniques for proper disposal of mortalities are among the more critical needs for the poultry industry.

Past carcass disposal practices have generally been considered unacceptable from the standpoint of environmental and/or producer cost considerations. Methods that pose threats to the environment and are disallowed include dumping in open pits, waterways or abandoned wells and feeding carcasses to livestock. Improper disposal promotes groundwater contamination as well as the spread of infectious diseases. Approved methods of disposal include burial pits (open-bottom), incineration, rendering and composting (Payne and Donald, 1990). The use of open-bottom burial pits is the most common method employed by producers, but is becoming less desirable owing to the fact that pits fill quickly and carcasses are slow to decompose. Incinerators are widely used by producers, but are also coming into disfavor due to power costs and labor requirements. Both pits and incinerators generate offensive odors and pose the threat of water contamination through seepage, and particulate air pollution/deposition, respectively (Donald and Blake, 1990). Rendering plants produce a safe and useable by-product, but transporting carcasses off-farm to plants is costly (Poss, 1990), and can lead to the spread of pathogenic microorganisms.

Recently, some Alabama farmers have initiated composting as an alternative method of mortality disposal. This method has been approved by the Alabama State Veterinarian's Office, State and local health departments, and the Alabama Department of Environmental Management. One specific method of composting, referred to as co-composting, involves the use of a two-stage composter comprised of primary bins, for initial loading, and secondary bins, for receipt of turned primary compost. Co-composting involves combining mortalities with poultry litter, a carbon source (hay, straw, peanut hulls or pine shavings), water and oxygen to form a mixture which is conducive to aerobic microbial growth (Murphy, 1988). Heat produced by microbial activity (composting heat) degrades the carcasses, killing pathogens such as New Castle's Disease Virus, Infectious Bursal Disease Virus (Murphy, 1990), Salmonella and coliform bacteria (Conner et al., 1991). Labor requirements for managing composters involves approximately 20 minutes per day (Donald et al., 1990). Construction costs for dead-bird composters range from $3,000 to $5,000 (Donald and Blake, 1990). Except for possible purchases of a carbon source, composters require no additional expenditures. Mature co-compost visually resembles poultry litter (Murphy, 1988) and may be applied to crop land as a source of plant nutrients. It is estimated that approximately 200 dead-bird composters are now in use in Alabama, with more under construction.

Co-composted dead birds may be utilized in an environmentally sound manner if applied to crop land at rates appropriate for crop uptake and utilization. Fertilizer value of co-compost in Alabama has, in the past, been based on research conducted at the University of Delaware (Donald et al., 1990). A pressing need exists for a survey of Alabama's co-compost to ascertain fertilizer value, which will aid in determining environmentally safe land application rates. The objective of this study was to determine the fertilizer value of Alabama's co-composted poultry mortalities.

MATERIALS AND METHODS

Samples were obtained from 30 dead-bird composters in six Alabama counties (Blount, Clay, Coffee, Cullman, Franklin, and Marshall), representing north, central and south Alabama. Compost samples were dried at 105 C for 72 hours in a laboratory oven for moisture determination. Dried triplicate samples were ground in a high-speed mill and analyzed for total nitrogen (N), nitrate (NO_3-N), ammonium (NH_4-N), total carbon (C), electrical conductivity (EC), sulfur (S), ash, phosphorous (P), potassium (K), calcium (Ca), magnesium (Mg), copper (Cu), iron (Fe), manganese (Mn), zinc (Zn), molybdenum (Mo), barium (Ba), cobalt (Co), chromium (Cr), lead (Pb), and boron (B) via standard analytical procedures at Auburn University's Soil Fertility Laboratory.

An on-farm survey was conducted to gather information pertaining to composting practices and procedures. Farmers were questioned on the type and quantity of materials layered in the primary bins, maximum compost temperatures in primary and secondary bins, the length of time compost was kept in each bin, number of aerations, and the capacity of their operation (number of birds). Questions were asked pertaining to producer thoughts on co-composting and previous mortality disposal methods. The survey also contained a section on composter construction, which was completed after observation of the facilities.

RESULTS

Chemical analyses of co-compost collected in this study are shown in Table 1. Moisture content of Alabama co-compost was comparable to moisture values reported by Donald et al (1990) and Murphy and Carr (1991) for co-compost, but was slightly higher than that observed for Alabama broiler litter (Stephenson et al., 1990). Total N values were similar to those reported for Alabama broiler litter (Stephenson et al., 1990) and co-compost (Donald et al., 1990; Barton and Benz, 1990; Murphy and Carr, 1991). Ammonium-N content was low when compared to co-compost from University of Maryland and University of Delaware. The readily available N (NH_4-N + NO_3-N) content of Alabama co-compost represented only 2.35% of the total N in the co-compost. However, despite low NH_4-N and NO_3-N concentrations, much of the organic N will likely become available via microbial decomposition in the soil. The mean C:N ratio was 9.8, which is ideal with respect to use as an organic fertilizer (Tisdale et al., 1985). Initial composting C:N ratios were targeted for 23:1 by Auburn University's recommendations (Donald et al., 1990), and narrowing of C:N ratios to 9.8 indicated microbial activity during composting. Ash content varied widely, probably due to variation in broiler litter used in composters. Ash content was higher in co-compost (over broiler litter) (Stephenson et al., 1990), and may have been due to the contribution of bones and feathers from birds used in composting. Nutrients other than N in Alabama co-compost were similar to but higher than those measured in broiler litter (Stephenson et al., 1990), except for K which was slightly lower. Electrical conductivity (soluble salts) was within the range considered acceptable for salt tolerant plants (Verdonck et al., 1986).

Table 1. Chemical Properties of Co-Compost in Alabama[a]

Component	Minimum	Maximum	Range	Mean	(SE)
Moisture (%)	22	50	28	36	(1.1)
EC (S m^{-1})	0.6	1.1	0.5	0.8	(.02)
Total N (%)	2.1	5.6	3.5	3.9	(0.1)
Total C (%)	26	42	16	36	(0.7)
C:N Ratio	7.2	14.3	7.1	9.8	(0.03)
NH_4-N (ppm)	176	1870	1694	675	(8)
NO_3-N (ppm)	0	896	896	218	(5)
S (%)	0.4	0.9	0.5	0.6	(0.03)
Ash (%)	19	48	30	31	(1.2)
P (%)	1.1	2.7	1.6	1.8	(0.1)
K (%)	1.3	3.2	1.8	2.1	(0.1)
Ca (%)	1.7	5.3	3.6	3.2	(0.2)
Mg (%)	0.4	1.1	0.7	0.6	(0.03)
Cu (ppm)	75	1169	1094	615	(50)
Fe (ppm)	1265	14937	13672	4705	(589)
Mn (ppm)	322	941	619	556	(28)
Zn (ppm)	356	845	589	499	(26)
Mo (ppm)	3	18	15	9	(1)
Ba (ppm)	25	78	53	38	(2)
Co (ppm)	1	11	10	4	(0.4)
Cr (ppm)	22	132	110	57	(6)
Pb (ppm)	5	62	57	30	(2)
B (ppm)	15	74	59	38	(3)

[a]All analyses reported on a dry weight basis. Values are means of 30 triplicate analyses.

On an 'as spread' basis, one ton of Alabama co-compost contains an average of 48 lbs N, 23 lbs P and 27 lbs K. Using these values, and a N, P_2O_5, and K_2O cost of $0.28, $0.13, and $0.18 per pound, respectively, the average fertilizer replacement value of one ton of Alabama's co-compost is $26.15. The average fertilizer grade ($N:P_2O_5:K_2O$ ratio) is calculated as 2.4:2.6:1.6. In contrast, one ton of Alabama's broiler litter has a $N:P_2O_5:K_2O$ ratio of 3:2:2 and is valued at $29.20 (Stephenson et al., 1990).

The results of the on-farm survey showed that the mixture recommended by Auburn University for co-composting poultry mortalities (1 part chickens, 2-3 parts broiler litter, 0.1 part C source, 0-0.5 parts water) was altered by 90% of the farmers. Most farmers (63%) used no water and 77% either omitted the C source or replaced it with more broiler litter. With respect to compost temperatures, farmers tended to experience higher average temperatures in primary bins (145 F) than in secondary bins (134 F). These lower average temperatures in secondary bins are likely owing to a diminishing C source during the composting process. Average number of days co-compost remained in primary and secondary bins is shown in Table 2. Of the poultry farms sampled, farm capacity (number of birds) averaged 139,000, ranging from 64,000 to 352,000. Percent mortality reported by farmers was usually 5%, but ranged from 3 to 10%. When farmers were questioned on how they liked co-composting their responses were: 24 (80%) were well satisfied, 2 (7%) did not like it, 1 (3%) too new to know, 2 (7%) no opinion and 1 (3%) no answer. Farmer's previous mortality disposal methods were: 74% used pits, 13% used incinerators and 17% started their poultry business using composters. All farmers said they would choose dead-bird composters again, given all choices of mortality disposal methods. All composters and compost storage facilities were covered from weather, constructed of pressure treated wood and all primary bin floors were concrete.

Table 2. The Amount of Time Alabama Farmers Allow Co-Compost to Remain in Primary and Secondary Composting Bins

Days Co-compost Remains in Bins	Primary	Secondary
	Number of Farmers	
0-7	2	2
8-14	5	6
15-21	10	6
22-42	9	4
43+	3	8

In conclusion, Alabama co-compost is similar to Alabama broiler litter in total N content, higher in ash and most nutrients measured, but lower in K content. Farmers' co-composting practices vary widely with respect to Auburn University's recommendations. Not all farmers surveyed (2 out of 30) liked co-composting, but all farmers would use this method of mortality disposal given a choice of all disposal methods. More research is needed on co-composting poultry mortalities to characterize co-compost physical and chemical properties and to determine maturity, nutrient release rates and appropriate land application rates.

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POULTRY MANURE MANAGEMENT ON GUAM

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ABSTRACT

The only commercial layer farm on Guam has been operating for the past 30 years. It is a typical layer farm where the layers are caged in groups of three's. Manure dropped in the pit is collected occasionally by crop farmers for fertilizer or flows into a man-made lagoon. This layer farm has 18,000 birds. At present, recent developments and housing projects near the site of the farm brought numerous complaints of odor and nuisance, flies and possible seepage of poultry slurry to the shoreline. Guam Environmental Protection Agency ordered the farm to correct these complaints. A manure drying facility was installed. All the slurry was pump into concrete pits, 15' wide x 100' long x 2' deep. A roof cover made up of polyethylene plastic material was used as cover. The slurry completely dries up in 3-5 days in the drying pits and these are sold by truck/pick-up loads or in 50 lb bags.

INTRODUCTION

Guam, being a U.S. Territory, has to follow regulations from the U.S. Environmental Protection Agency with regards to pollution control from livestock and poultry farms. Existing farms on Guam were built 30 years ago where manure pollution and nuisance were never conceived to be an environmental concern. Thus, the building designs have no provisions for manure management except to be flushed into a lagoon or shoveled for field application. Farms were located in isolated places on the island. Recent developments related to our booming tourism industry and housing developments have started displacing these farms as complaints started to rise because of odor, flies and as an environmental threat, especially to our very limited groundwater sources. Environmental Protection Agency and Public Health Services are the policy making bodies with regards to pollution control and sanitation of premises.

The layer farm was given warnings of closures and heavy fines if they can not solve the problem of their poultry manure. Residents of near-by homes were becoming intolerant of the odor. Some even had their homes air-conditioned but they claim the odor still remains. The farm has to invest $250,000.00 to build a manure drying facility to accommodate the wastes of their 18,000 birds. These birds were housed in three buildings. Manure dropped in the pit was collected into a holding tank and was then pumped into the drying facility.

OPERATION OF THE DRYING FACILITY

The drying facility is made up of three pits, 15' wide x 100' long x 2' deep. The floor and the 2 feet high walls are concrete. Each pit is almost entirely covered by polyethylene plastic on its lengthwise sides, supported by aluminum poles arched on the top. The floor is safe from water run-off during heavy rains. The poultry slurry from the buildings is pumped into one of the pits at a time. The pit is filled up with slurry up to 3 inches deep. Manure completely dries in 3-5 days, shorter during sunny days. The temperature inside the pits can reach 105 F. When slurry is dried, it is bagged and sold to home gardeners and farmers. Crop farmers normally purchase the dried manure by pick-up loads. The farm has a small-sized payloader for loading. The demand has been so high that the farm usually runs out.

The problem of pollution lessened to a certain extent until the facility was destroyed by a typhoon. The 80-100 miles per hour wind blew away the plastic roof and supporting poles. These materials are very expensive since they are manufactured and shipped from Japan. Farm management should have anticipated the effects of typhoons on the facility since Guam is visited by at least 2-3 typhoons a year. Roofing materials and poles should be installed so they can be easily dismantled and reinstalled when typhoons are forecast.

LAYERS-ON-LITTER

After the short-lived drying facility, the company decided not to rebuild the facility due to the high cost of materials and labor. Instead, the operation shifted to layer production on litter from wire cages. The shift also came about when the farm was relocated due to lease termination.

At the new farm site, buildings were renovated for a litter type operation. Brooding, growing and laying were all on litter. The base floor is concrete with coarse coral on top. Litter materials composed of dried grasses and sand are placed on top of the coral. Waterers are all placed outside of the pens to prevent water leaks on the litter. Dry litter minimizes the odor problem. The production and performance of the farm has not suffered from its change from cages to litter except layer density per building decreased. The layer house can be dusty when bird activity increases, but the birds seem not to be affected in terms of respiratory disease incidence. Spent litter is sold to farmers for soil application.

USE OF SEPTIC TANKS

The Agricultural Experiment Station layer farm uses a septic tank system for waste disposal. The birds are caged and manure drops into pits. The pits are flushed regularly and waste water manure goes into the tank. A commercial sanitation company pumps out the tank when full at a cost.

CONCLUSION

Manure drying facilities require further investigation as a waste management alternative, especially in the tropics. New facilities considering the use of drying should design building layouts so that slurry can flow by gravity to the drying pits. Water is evaporated and recycled by this method. Slurry is completely dried up and ready as a soil conditioner. Methods to shorten the drying period require study for use to reduce construction costs for larger farms. Waste management costs have become another factor to reckon with in poultry operations. Manure disposal facilities have contributed a great cost to their operation. It has reached the point where manure disposal becomes a priority to meet environmental standards.

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TEMPERATURE VERSUS CHEMICAL MEASUREMENT FOR CO-COMPOSTED BROILER LITTER MATURITY

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Large amounts of broiler litter and paper mill wastes in the Southeastern U.S. offer opportunities for development of composts to be used in the greenhouse and nursery industries. However, prior to widespread use of such composts, compost maturity indices must be identified that insure an acceptable media.

The composting process occurs naturally when non-sterile organic substrates are combined with water and oxygen at ambient temperatures (Emerton et al., 1988). Microbial decomposition and stabilization of organic matter occurs via aerobic composting, and the physical and chemical characteristics of the original materials are altered. Carbon (C) is released as CO_2 during aerobic microbial respiration which narrows the C:N ratio and concentrates nitrogen (N), and inert material. The composting process results in a biologically stable material, which is desirable for potting media and soil amendments. Optimum composting conditions (C:N ratio, moisture content, aeration, pH, and temperature) have been previously defined (Verdonck, 1988; Hong et al., 1983; Jeris and Regan, 1973; Emerton et al., 1988).

Compost maturity has been measured by a variety of methods including decline in compost temperature; self heating capacity; content of decomposable and resistant organic matter; O_2 consumption (Golueke, 1977); bioassays (Zucconi et al., 1981); and C:N ratios (Chanyasak and Kubota, 1981).

The objective of this study was to identify physical and chemical factors that reflect maturity for co-composted broiler litter and paper industry waste products. Factors examined included compost temperature, C:N ratio, nitrate-N (NO_3-N), ammonium-N (NH_4-N), and total C and N.

MATERIALS AND METHODS

Two broiler litter sources, one that utilized peanut hulls and one that used hardwood shavings as a bedding material, were utilized as the primary N source for the composting process. Paper mill sludge and pine bark supplied C needed for composting. Bulk density, total C, total N, and ash content were determined for each of the substrates (Table 1). Verdonck (1988) recommended an initial C:N ratio of 25:1 to prevent N loss and provide microbial populations with sufficient C for metabolism. Substrates were measured by weight and mixed with a cement mixer to achieve uniform initial conditions (Table 2). Water was added at the time of mixing to bring substrate moisture contents to between 400 and 540 g H_2O kg^{-1}, which followed optimum conditions described by Verdonck (1988).

Table 1. Physical and Chemical Characteristics of Compost Materials Before Mixing

	HSBL[a]	PHBL	PB	PMS
Density (kg m^{-3})	660	550	190	454
Carbon (g kg^{-1})	320	260	486	254
Nitrogen (g kg^{-1})	35.0	26.0	3.2	7.3
C:N	9:1	10:1	152:1	35:1
Ash (g kg^{-1})	308	560	12	623

[a]HSBL = broiler litter with hardwood shavings as bedding material, PHBL = broiler litter with peanut hulls as bedding material, PB = pine bark, PMS = paper mill sludge.

Table 2. Initial Characteristics of Mixed Materials for Composting

Compost mixture	Weight ratio	Volume ratio	Ash	Initial water content	Initial dry weight
	C source:litter		---- g kg^{-1}	----	- kg -
PB + HSBL[b]	2:1	5:1	180	540	203
PB + PHBL	1:1	3:1	260	490	251
PMS + HSBL	10:1	12:1	640	400	374
PMS + PHBL	7:1	8:1	650	460	344

[b]HSBL = broiler litter with hardwood shavings as bedding material, PHBL = broiler litter with peanut hulls as bedding material, PB = pine bark, PMS = paper mill sludge.

Eight composting bins with styrofoam siding were obtained from Ringer Corporation (Minneapolis, MN) which allowed for two replications of each treatment. Each bin held approximately 0.33 m^3. The mixtures were aerated by manually mixing the material 3, 7, 14, and 21 days after initial mixing. Aeration was stopped when compost piles exhibited no self heating.

Samples were collected for moisture, NO_3-N, NH_4-N, total N, and total C determinations every seven days for 12 weeks after initial mixing. Samples were kept at $5^{M}C$ until analyzed. Temperature measurements were made every hour for 12 weeks with an ADC-1 (Remote Measurement Systems, Seattle, WA) connected to a Zenith 8086 computer. Nitrate-N and NH_4-N were extracted from compost samples with 2M KCl, followed by measurement via standard colorimetric procedures (Keeney and Nelson, 1982) on a Lachat autoanalyzer (Lachat QuickChem Systems, Mequon, WI). Total C and N concentrations were determined with a LECO CHN-600 analyzer (LECO Corp., St. Joseph, MI). Compost moisture was determined gravimetrically. All physical and chemical characteristics for the compost mixtures are reported as an average of two replications.

RESULTS

Pine bark plus broiler litter temperatures peaked at 66 and 70°C in 2.5 and 3.5 days for wood shaving and peanut hull litter, respectively (Figure 1). Aerations stimulated an increase in temperature to original levels for the first 10 days. Aerations after 18 days did not increase compost temperature. Bin temperatures remained above 30°C for 18 days. Initial C:N ratios for pine bark plus broiler litter were higher than those for paper mill sludge plus broiler litter (Figure 2), and this may help explain its longer period of heating (Figure 1). All reported chemical characteristics stabilized 6 weeks after the piles exhibited no self heating (Figure 2).

Paper mill sludge plus broiler litter temperature peaked at 51 and 48°C in 2.5 and 5.5 days for wood shaving and peanut hull litter, respectively (Figure 1). Pile temperature dropped below 30°C after 13 days. All aerations decreased pile temperature.

Paper mill sludge typically contains high percentages of cellulose and lignin which requires enzymes produced by a limited number of microbes (Schuler, 1980). Little temporal change in the C:N ratio indicated insufficient substrate for microbial activity (Figure 2). A high ash content (Table 1) indicated a high proportion of non-volatile material was present in the paper mill sludge. However, enough activity was present to increase the NO_3-N level, and decrease NH_4-N.

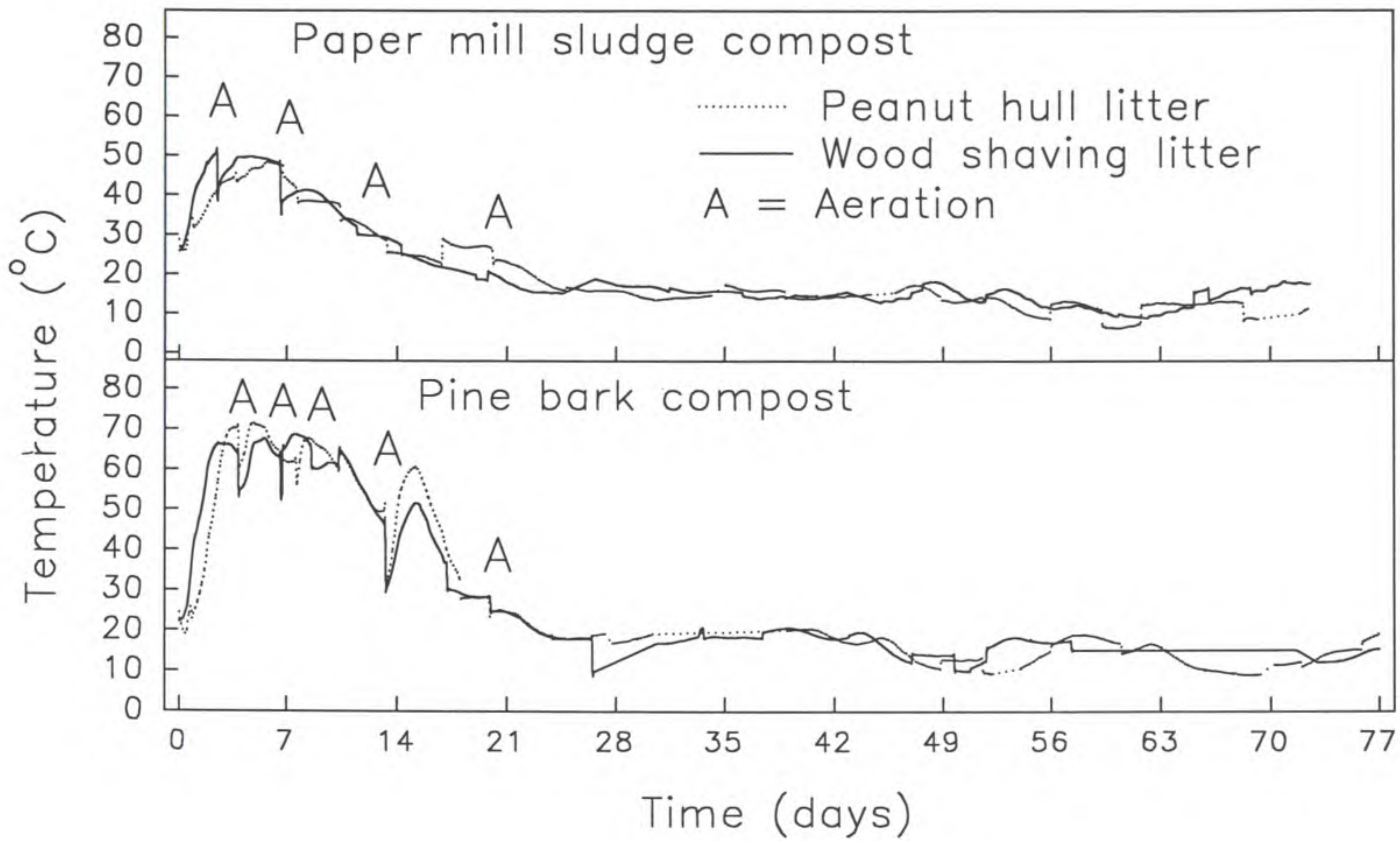

Fig. 1. Temperature increase and decline over the period of composting for pine bark and paper mill sludge with either peanut hull litter or wood shaving litter.

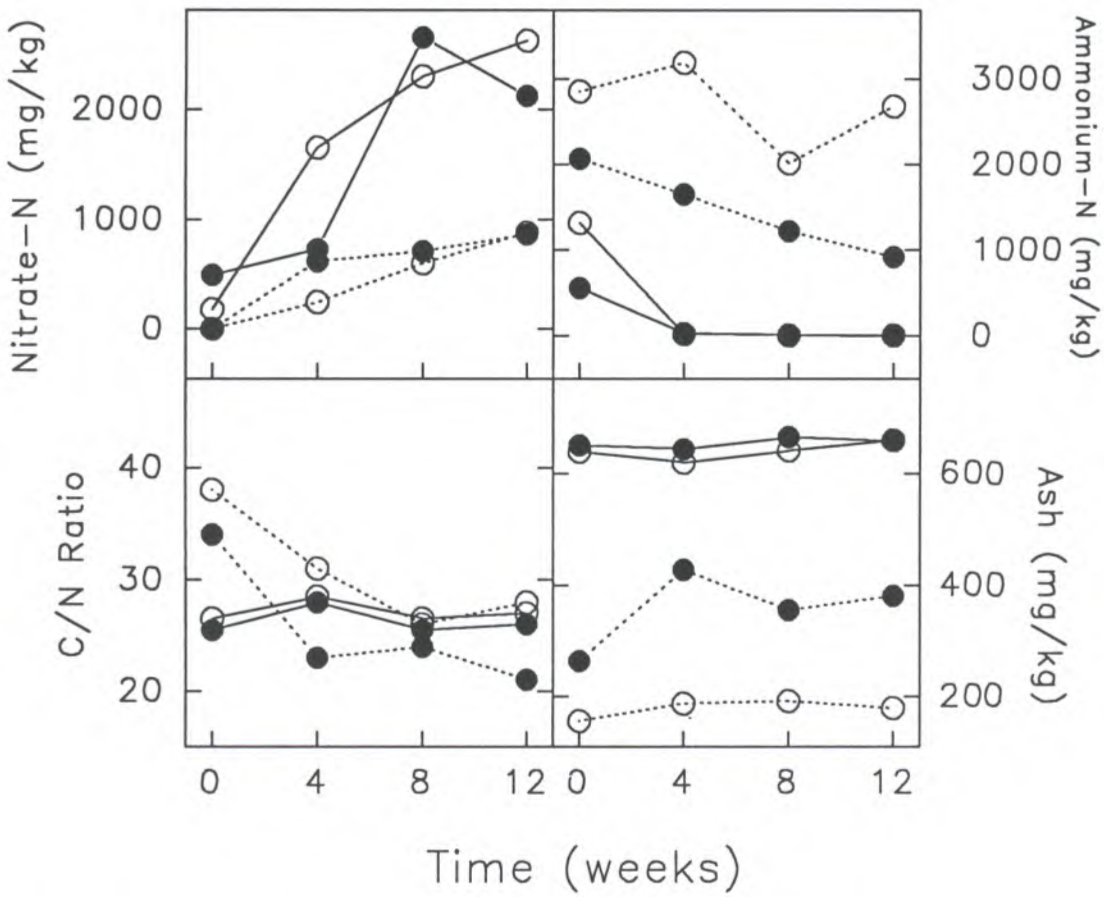

Fig. 2. Chemical characteristics over the period of the compost process for pine bark plus peanut hull litter (----●), pine bark plus wood shaving litter (----○), paper mill sludge plus peanut hull litter (——●) and paper mill sludge plus wood shaving litter (——○).

SUMMARY AND CONCLUSIONS

Highest temperatures in compost piles were obtained in ≤ 18 days, after which temperatures fell below 30°C. Nitrate-N, and ash content all increased, while the C:N ratio and NH_4-N declined with time.

In all cases, cessation of compost chemical changes were not marked by the fall in temperature. Further time was needed to stabilize both the C:N ratio and the NO_3-N concentration. Temperature patterns within the first 18 days of composting may prove to be related to the initial amount of easily assimilated C, and do not indicate chemically stable compost.

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This study of the compost process is the first phase in an evaluation of co-composted broiler litter as a potting soil and soil amendment. The characteristics described here will be correlated with plant growth and quality when the compost is used as a soil media.

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SOUTHWEST MISSOURI DEAD POULTRY COMPOSTING DEMONSTRATION PROJECT - EVALUATION OF WORKSHOPS

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Missouri's poultry industry is concentrated in the southwest part of the state. In recent years, the counties of Barry, Jasper, Lawrence, McDonald, and Newton have produced 75% of the broilers and 20% of the turkeys in the state - about 55 million birds in 1989. With ongoing expansion of processing plants in the area, increases are expected to continue at a rate of about 25% per year to about 90 million statewide by 1995. Most of that increase is expected to be in those five counties.

Poultry producers typically lose a portion of each flock (five to ten percent) to deaths from various causes. Given a conservative estimate of five percent, southwest Missouri poultry producers have approximately 5.8 million pounds of dead birds for disposal. Usual methods of disposal have included burying, burning and dumping. Each of these methods can result in significant air and/or water pollution. (DNR, 1991).

The process for disposing of dead birds by composting was developed several years ago (Murphy and Handwerker, 1988). The process has allowed growers to dispose of dead birds and lessen the potential for contamination of ground water. The Missouri Department of Natural Resources (DNR) has become convinced that composting is environmentally sound, practical, easy to use, and produces no offensive odors.

In 1990, the DNR submitted a Pollution Prevention grant proposal to the Environmental Protection Agency requesting funding for a dead poultry composter demonstration project. The purpose of the project was to establish five demonstration composter units to introduce composting to poultry producers as a practical, environmentally-sound method for disposal of broiler and turkey mortalities. The project was approved in early 1991. The total allotted to the project was $191,440 with 55% of the total coming from federal sources.

Following approval of the grant proposal, five demonstration dead-poultry composter units were constructed - one each in the five counties mentioned above. Five major poultry companies in southwest Missouri - Con-Agra, George's, Hudson Foods, Simmons Industries and Tyson Foods became cooperators in the project. Other cooperators included the Soil Conservation Service and the Cooperative Extension Service. Coordination of the project was by Southwest Missouri Resources Conservation and Development (RC&D).

The five composter units were to be constructed and operated for a two-year period for purposes of information collection and demonstration. The project required that workshops be conducted for interested producers covering size, location, design, and operation of composters.

Three workshops were held in April and June of 1992. One each was held in the counties of Barry, Newton, and Jasper. The same program and speakers were scheduled for each workshop. The following agenda was followed:

1:00	Welcome and Outline of Grant Project
1:15	Dead Animal Disposal Regulations and Alternatives
1:30	Construction of Poultry Composting Facilities
2:15	Cost Share Possibilities for Waste Facilities
2:45	Slide Tour of Grant Funded Poultry Composters
3:00	A Grower's Perspective of Composting and Dead Animal Disposal
3:15	Nutrient and Dollar Value of Litter and Compost
3:30	Litter and Compost Spreading Regulations, LOA's, Acre Requirements

A requirement of this demonstration project was to have an evaluation of each workshop. The evaluation was to be conducted by a party that had not otherwise been involved in the project. Personnel from Southwest Missouri State University were selected to conduct all evaluations.

A descriptive survey was developed to quantify the effectiveness of the poultry composter workshops. The survey was constructed on a 5-point scale:

1	means	strongly agree
2	means	agree
3	means	neutral
4	means	disagree
5	means	strongly disagree

The assessment instrument was randomly administered to participants attending all three composter workshops.

Respondents were separated into three groups: Growers, non-growers, and company representatives.

Table 1. Number of Workshop Survey Respondents

	Barry	Newton	Jasper	Overall
Growers	29	29	13	71
Non-growers	5	5	1	11
Company Reps.	5	9	2	16
Total	39	43	16	98

Survey questions were:

1. How would you describe yourself?
Grower____ Non-Grower_____ Company Representative_____

If you are a grower are you currently using a poultry composter? Yes_____ No______

If you are a grower, do you raise Broilers_____ or Turkeys?_____

2. The time of day for the workshop was acceptable.
3. The day of the week for the workshop was acceptable.
4. Adequate notice of the meeting was given.
5. Directions to the workshop location were complete and accurate.
6. Adequate parking was available at the workshop.
7. The workshop room was comfortable.
8. The speakers at the workshop could be easily heard.
9. The speakers were knowledgeable about the subject.
10. Adequate time was given to ask questions.
11. The speakers answered questions effectively.
12. Visual aids (transparencies, slides, etc.) were easily viewed.
13. In my opinion, the general public will prefer poultry composter technology, as opposed to other methods of disposing of dead birds.
14. Composting dead poultry is more environmentally sound than other disposal methods.
15. Composters are a better alternative than pit burial.
16. Composters are a better alternative than burning.
17. Poultry companies should require the use of composters.

18. Growers should pay for the cost of composters.
19. Poultry companies should pay for the cost of composters.
20. The government should pay for the cost of composters.
21. The cost should be shared by all three parties.
22. As a result of this workshop poultry growers are more likely to construct composters.
23. As a result of this workshop, I am more likely to consider constructing a poultry composter.
24. I obtained useful information from this workshop.

Table 2. Frequency of Responses-Pooled Surveys of Workshop Participants[a]

Question	Strongly[a] Agree	Agree[a]	Neutral[a]	Disagree[a]	Strongly[a] Disagree	Mean Response
2	45	38	13	1	1	1.72
3	36	47	13	1	1	1.82
4	38	41	11	5	3	1.92
5	41	49	7	0	1	1.68
6	23	31	27	14	2	2.39
7	30	39	23	6	0	2.05
8	36	45	14	2	1	1.85
9	33	53	11	1	0	1.80
10	46	47	3	1	1	1.61
11	30	54	13	1	0	1.85
12	37	51	8	1	1	1.76
13	40	36	15	2	2	1.84
14	43	32	14	4	2	1.84
15	50	39	5	1	1	1.58
16	50	32	8	1	4	1.71
17	18	17	35	12	12	2.82
18	4	19	32	17	22	3.36
19	21	16	33	12	11	2.74
20	12	18	37	14	13	2.98
21	37	13	19	8	16	2.49
22	23	47	19	4	1	2.07
23	26	31	23	3	1	2.07
24	35	52	6	0	1	1.72

[a]Number of responses.

INTERPRETATION OF DATA

Attendance of workshops was about what had been expected. The third workshop (Jasper County) was held in June and the lower attendance is probably a reflection of cropping activities. Not counting speakers and other grant officials, a total of 120 persons took part in the workshops. A total of 109 surveys were collected. Eleven surveys were discarded because they had not been completed correctly.

The survey results indicate that it was acceptable to hold the workshops during the day on weekdays. Most participants agreed that the physical arrangements for the workshops were adequate, with the exception of parking at one of the sites. Participants in the workshops agreed that the speakers were knowledgeable and that the speakers adequately answered questions.

Seventy-five percent of the participants agreed that composting was a more environmentally sound method of disposing of mortalities. More specifically, there was agreement (>80%) that composting of dead birds is a more viable method of disposal than pit burial or incineration.

Responses from the participants were quite varied as to whether poultry companies should mandate that growers construct poultry composters. Thirty-seven percent agreed that composters should be required, 37% were neutral and 26% disagreed. The poultry growers indicated a neutral to negative response on being required to have a composter on site. However, company representatives and non-growers tended to be more receptive to a composter requirement.

It appears that there is a great deal of uncertainty among the participants as to how the composters should be funded. However, the responses indicated that growers should not have to pay the full cost of the composters. Only 24% of the respondents agreed that the growers should pay for the composters, while 39% felt that the companies should pay for them, and 31% agreed that the government should pay for them. A majority of respondents agreed that the cost should be shared by all three. It is important to remember that 71% of the respondents were growers.

Most importantly, 75% of the growers indicated that as a result of the workshop, they would be more likely to construct a poultry composter. Ninety-two percent of the attendees agreed that they had obtained useful information from the workshop.

SUMMARY

Survey results indicate that southwest Missouri broiler and turkey growers have the following perceptions:

1. Composting is a more environmentally sound method of disposal than other alternatives.
2. They believe that the general public will prefer composting to other methods of disposal.

3. Growers were neutral to negative on the statement that poultry companies should require their growers to have composters.
4. There is a lack of agreement as to who should pay for composters.
5. As a result of the workshops, growers indicated that they were more likely to consider constructing a poultry composter.

The workshop format appears to be an effective means of providing information about composter technology.

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MICROBIAL DECOMPOSITION OF BROILER LITTER APPLIED TO A COASTAL PLAINS SOIL

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Alabama broiler producers marketed 847 million birds in 1990 and current production estimates makes Alabama the second-largest broiler-producing state in the nation (AASS, 1990). Associated with this production is more than 1.5 million tons of waste (litter). Present broiler litter disposal practices in some parts of the state have created a potential for adverse environmental impacts. The main problems that can occur from excessive rates of land application are leaching and run-off of nutrients to ground and surface waters and crop accumulation of metals (Kingery <u>et</u> <u>al</u>., 1992a; Kingery <u>et</u> <u>al</u>., 1992b). While it is known that application rates in areas of intensive broiler production are high, best management practices for this potential resource are presently unknown. In order to develop suitable guidelines for land application of broiler litter, it is necessary to study both specific characteristics of the waste material itself and the influence of cultural practices such as tillage systems.

Since most of the nitrogen (N) in broiler litter is present in organic forms, it requires decomposition by soil micro-organisms to release inorganic-N (ammonium and nitrate) that becomes available to plants or that may leach through the soil profile. Broiler litter is an organic material, which means that it contains carbon bearing compounds that provide the energy substrate to fuel microbial breakdown. The process of litter decomposition by microorganisms involves the production of carbon dioxide (CO_2), which is released to the atmosphere. By measuring both inorganic-N released and CO_2 evolved during decomposition, it is possible to evaluate the influence of such factors as soil type, application rate, tillage practices, and cropping patterns on N availability.

Different modern tillage systems affect the placement of land applied broiler litter. Those tillage practices that employ some combination of turning plows, disks, rotovators, and harrows, commonly referred to as conventional tillage, incorporate crop residues or litter into the soil. In no-till systems by contrast, soil is disturbed only within the zone of seed placement so that most of the litter remains on the soil surface. The degree of incorporation of broiler litter into soil may be a major factor controlling nitrogen availability to crops. It has been shown that for some Alabama soils tillage affects the potential for inorganic-N and CO_2 production (Wood and Edwards, 1992). These observations suggest that tillage can play a major role in waste management. However, no studies have been conducted that compare conventional tillage and no-till systems with respect to microbial breakdown of land-applied broiler litter.

The objective of this study was to determine the effects of tillage system and previous N source (broiler litter or commercial N fertilizer) on microbial decomposition of land-applied broiler litter.

MATERIALS AND METHODS

The field portion of the study was conducted at the Alabama Agricultural Experiment Station's Wiregrass Substation, Headland Alabama ($32^0 24'$ N, $85^0 54'$ W) during the 1990 and 1991 growing seasons. Corn was planted (36-inch row spacing) on a Dothan fine-sandy loam soil that had a pH of 5.9. The experimental design consisted of a two tillage system (conventional and strip-till) and two N source (broiler litter and ammonium-nitrate) arrangement that was replicated four times. In both tillage systems, both broiler litter and ammonium-nitrate were applied by broadcasting. Broiler litter was applied at a rate of 4 tons/A and the ammonium nitrate was applied at a rate of 130 lbs/A, which was based on the total N content of the litter. Conventional tillage consisted of chisel plowing one day prior to planting and two diskings on the day corn was planted. Both N sources were incorporated with the second disking. The strip-till system, which is similar to no-till, utilizes a planter with a leading subsoiler set at the desired row width so that only a 12-inch band, centered on the seed row, is tilled. Therefore, only a portion of the soil amendments were incorporated in the strip-till system.

Release of inorganic-N and CO_2 was determined by a 28-day laboratory incubation study conducted on soil samples from the field site that were taken prior to the 1992 planting. Samples were collected from the 0 to 4 inch depth in each tillage/N source combinations as well as from control plots that had received no N. All soil samples were kept fresh and incubated as they came out of the field or were treated with a 4 ton/A application of litter. The incubation technique followed the procedure outlined by Nadelhoffer (1990). Briefly, soils were placed in dual-chamber containers that permitted non-destructive, periodic leaching of soils for the determination of N release and gas sampling for CO_2 measurement. Soils were incubated at a constant temperature of 72^0F. The broiler litter used in both field and laboratory studies contained an average total carbon (C) content of 30.3% and total N content of 3.4%. Carbon dioxide concentrations were measure with a CO_2 Analyzer (LI-COR Inc., Lincoln, NE). Samples were leached with .01 M $CaCl_2$ and inorganic-N determined with a Lachat autoanalyzer (Lachat QuickChem Systems, Milwaukee, WI). Total C and N was determined on soil and litter samples with a LECO CHN-600 analyzer (LECO Corp., St. Joseph, MI).

RESULTS AND DISCUSSION

Soil total C and N following two years of tillage/N source treatments are shown in Figure 1. Strip-till appears to have produced higher total C concentrations than did conventional tillage for each of the N sources, especially where litter was applied. Average soil total C for conventional tillage/litter was 0.47% while for strip-till/litter it was 0.68%. For soil total N, distinct effects were seen in the control (0 N) and litter treatments. Conventional tillage/0 N had lower N concentrations than all other tillage/source combinations and strip-till/litter treatments averaged 0.06% N as compared to approximately 0.04% for all other treatments. These alterations in soil total C and N are important because they represent the sources of energy and inorganic-N involved in microbial decomposition.

Cumulative CO_2-C concentrations (Figure 2) obtained from the incubation study show a dramatic impact due to the addition of 4 tons/A of broiler litter. The cumulative CO_2-C concentrations at the end of the 28-day incubation were nearly twice as high in soils that had received the additional litter as compared to soils that received no application. These results also clearly indicate the influence of tillage on CO_2 production, where, in general, soils maintained under strip-till had higher cumulative amounts produced. The single exception was the conventional tillage/commercial N that had received additional litter (Figure 2). Also notable was the trend in all treatments for the relationship of cumulative CO_2-C where 0 N < ammonium nitrate < litter.

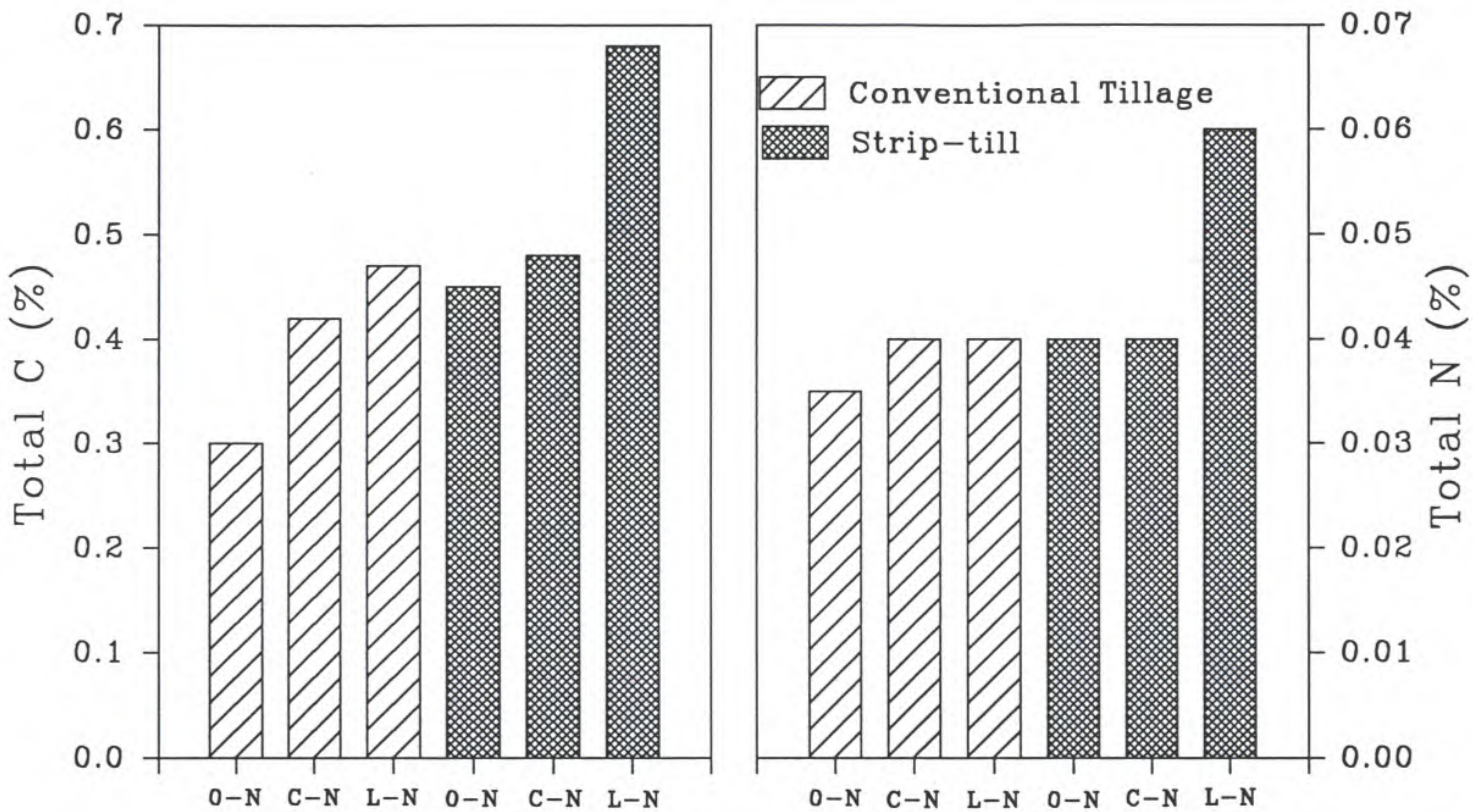

Figure 1. Total C and N for control (0-N), commercial fertilizer (C-N), and broiler litter (L-N) on a Dothan fine-sandy loam following two years of conventional tillage or strip-till.

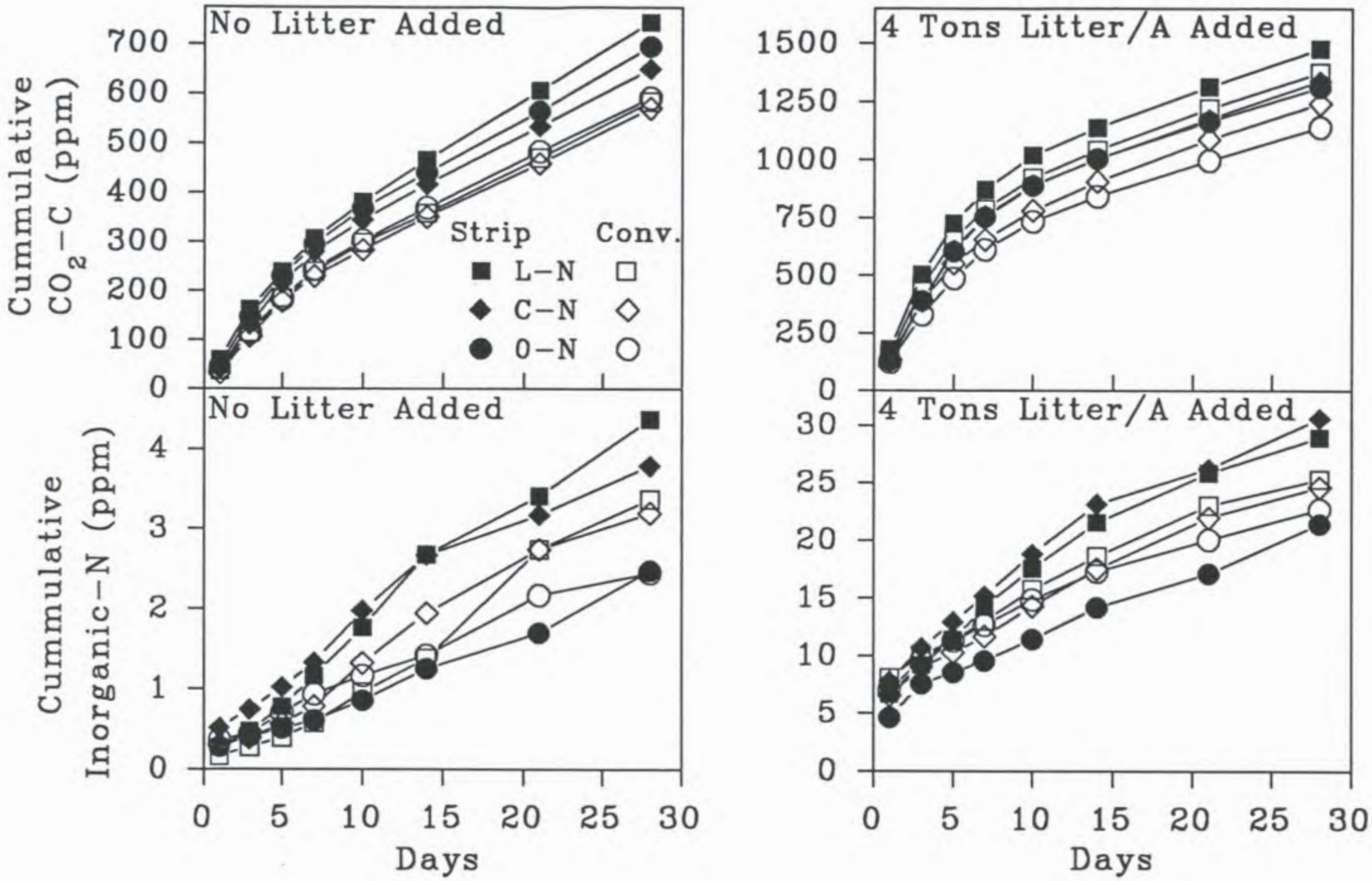

Figure 2. Microbial activity (CO_2-C) and inorganic N release as affected by tillage, previous N amendment, and broiler litter addition. C-N and L-N represent previous field applications of commercial N fertilizer and broiler litter, respectively; 0-N = no previous N application.

The results for cumulative release of inorganic-N (Figure 2) show that additional application of litter produced nearly seven-fold greater amounts than from soils receiving no additional litter. Again, tillage had a clear impact on the microbial activity as reflected in release of inorganic-N. For both laboratory treatments, strip-till produced more N from commercial and litter sources than did conventional tillage. Also, for both the 4 ton/A added and the no litter added, strip-till/0 N soils generated less N than all other combinations.

These results indicate that two years of conventional tillage and strip-till had pronounced effects on soil total C and N concentrations. Broiler litter applications produced greater accumulation of soil total C under both tillage systems, while soil total N was highest under strip-till. We also found that tillage has an influence on microbial activity. Measurements of microbial activity with no additions of litter showed that strip-till systems produce pools of energy (C source) and N that lead to greater potential activity than did conventional tillage. Also, while additions of litter caused a sizeable increase in microbial activity, differences due to tillage system were still evident, where strip-till had greater potential activity. We recommend therefore, that tillage systems should be a major consideration for any program of land application of broiler litter.

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EFFECTS OF LONG-TERM BROILER LITTER APPLICATION ON COASTAL PLAIN SOILS

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Recent studies from fields in the Sand Mountain area of North Alabama indicate that long-term, heavy applications of broiler litter to pastures have resulted in nitrate leaching to depths of 10 feet or to bedrock (Kingery _et al._, 1992). Average soil concentrations in excess of 40 mg NO_3-N kg^{-1} were found at a depth of 3 m. Once nitrates leach this deeply, they can enter groundwater aquifers. Fields with a long history of litter applications also had extremely high levels of phosphorus (P), potassium (K), and copper (Cu) in the surface horizons compared to adjacent fields where only fertilizer sources were used. Extremely high P in the soil surface could enter streams if the soil is not protected from erosion. Copper and Zn, although essential plant micronutrients, also accumulate in the soil surface and could reach phytotoxic levels.

The objective of this study was to determine the effect of long-term broiler litter application on soil nutrient levels from pastures on Coastal Plain soils of South Alabama. The information from these sites will complement data from north Alabama and help county agents and growers better manage broiler litter as a fertilizer with the goal of protecting our soil and water resources.

METHODS

Three fields with a history of broiler litter application were sampled to a depth of 48 inches during the winter of 1991

(Table 1). Two of these fields had adjacent areas of the same soil series with no history of broiler litter applications. These were also sampled. Three, 5-inch cores were taken randomly within a 1-acre, uniform area within each site. The soil cores were divided into depths of 0-6, 6-12, 12-24, 24-36, and 36-48 inches. A composite sample of each depth was analyzed for extractable NO_3-N, NH_4-N, P, K, Mg, Ca, Cu, Zn, and other metals.

Table 1. Characteristics of the Sites Sampled

Sample id.	Soil series & current crop	Adjacent no litter area	History of litter use	
			Years	Tons/a/yr
Farm A	Red bay f.s.l. (fine-loamy, siliceous, thermic Rhodic Kandiudults) Coast. berm. hay	Woods	20±	3-4
Farm B	Esto l.s. (clayey, kaolinitic, thermic Typic Kandiudults) com. berm./clover	CRP pasture[a]	14+	2-3
Farm C	Dothan f.s.l. (fine-loamy, siliceous, thermic Plinthic Kandiudults) p'nuts/winter grazing	Non sampled	5	2-3

[a]Old pasture had 2-year old pine seedlings which were planted as part of the Conservation Reserve Program.

RESULTS

Nitrate and Ammonium

Nitrate is very transient and is the form of N of most concern when it enters water used for human consumption. The surface 12 inches of fields receiving broiler litter had almost four times as much nitrate-N as adjacent "no litter" areas (See Figure). This tended to decrease with depth in Farm A where coastal bermuda hay is produced. However, there appears to be a trend for nitrate to increase again below 36 inches in the other fields. The red bay soil is a deep, well drained soil with a potential for deep rooting of a crop such as bermudagrass. The other two soils are not as well drained and may have a shallower rooting depth. This is definitely the case for winter forages (small grains and ryegrass) planted on Farm C. However, nitrate-N throughout the profiles of these three sites is substantially lower than levels found by Kingery et al. (1992) in a similar study on Appalachian plateau soils of North Alabama (>40 mg NO_3-N kg^{-1} at 3 m).

Ammonium levels were high only on Farm B. These levels could be toxic to sensitive seedlings overseeded into this pasture. Indeed, the producer had a concern about loss of vegetation in this pasture.

Phosphorus

As expected, litter treated fields had extremely high levels of extractable P in surface horizons. Field C, however, would be rated "medium" in P. A critical level of extractable P for these soils in Alabama would be 25 mg P kg^{-1} (50 pounds P per acre) (Cope et al., 1981). Farm A had more than 4 times the critical level, and Farm B had more than 7 times the critical P level for crops! Although extremely high soil P has not resulted in any documented crop production problems in Alabama, producers with such high P levels should consider using commercial fertilizer containing only N or N-K combinations and sell the litter to farmers who need the additional P. The "no litter" sites on Farm A and Farm B were quite low in P. Extractable P for these sites is barely visible using the scale necessary for the figures.

Potassium

Although broiler litter contains less K_2O than N and P_2O_5, averaging approximately the same as a 3-3-2 grade fertilizer in Alabama (Mitchell et al., 1989), high rates of application over several years have resulted in a buildup of K throughout the soil profile on Farms A and B. Current soil test calibration for sandy Coastal Plain soils in Alabama uses 40 mg K kg^{-1} as a critical level for corn and forage grasses (Cope et al., 1981). Although Farms A and B would be rated "high" or "very high" in surface soil K, this is not considered an environmental problem. Farm C would be rated "medium" in K and required additional K fertilization for most crops.

Copper and Zinc

Although broiler-litter treated fields have higher Cu levels than adjacent untreated sites, the soil levels found are below phytotoxic levels for copper-sensitive crops. Additional Cu applications to Farm B, with 6.2 mg extractable Cu kg^{-1} in the surface 6 inches, should be limited. However, Cu toxicity of oats, a Cu-sensitive crop, was not a problem in northern Florida Coastal Plain soils where Mehlich 1 extractable Cu was less than 100 mg kg^{-1} and soil pH was above 5.5 (Rhoads et al., 1991).

Broiler-litter treated fields showed a much higher level of extractable zinc compared to the "no litter" sites. Field B had 12.5 mg Zn kg^{-1} in the surface 6 inches. Acid-extractable Zn at 12 mg Zn kg^{-1} has resulted in zinc toxicity to peanuts in a Georgia, Coastal Plain soil (Keisling, 1977). Some research has shown than 0.8 mg Zn kg^{-1} in the plow layer is sufficient for most crops that often require zinc fertilization (e.g. corn). Certainly, these fields need no additional zinc applications.

SUMMARY

Based upon the three fields included in this survey, long-term broiler litter applications have resulted in very high levels of soil P, Zn, and Cu and additional applications of these nutrients should be avoided. Although nitrate levels throughout the soil profiles (1 to 7 mg No_3-N kg^{-1}) were low compared to those found in North Alabama (>40 mg NO_3-N kg^{-1}), there may be a trend toward increasing nitrates below the rooting depth in some soils. More fields should be sampled to greater depths in order to determine the potential for nitrates reaching underground aquifers.

Fortunately, South Alabama has more agricultural land for broiler litter application than the poultry-producing areas of North Alabama. Coastal Plain soils are also deeper and the potential for surface and groundwater contamination may also be less than Sandstone Plateau soils. The South Alabama broiler industry is still expanding. Broiler producers and other farmers have an opportunity to use this resource conservatively and wisely as a fertilizer source for pastures and hayfields while protecting surface and groundwater quality.

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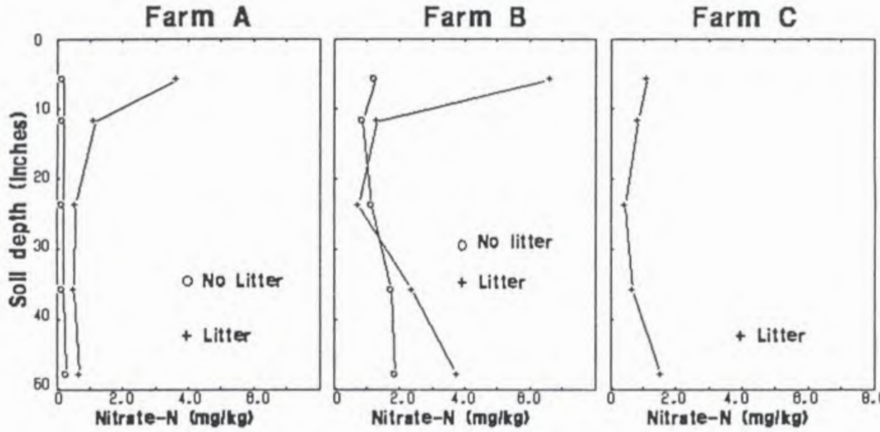
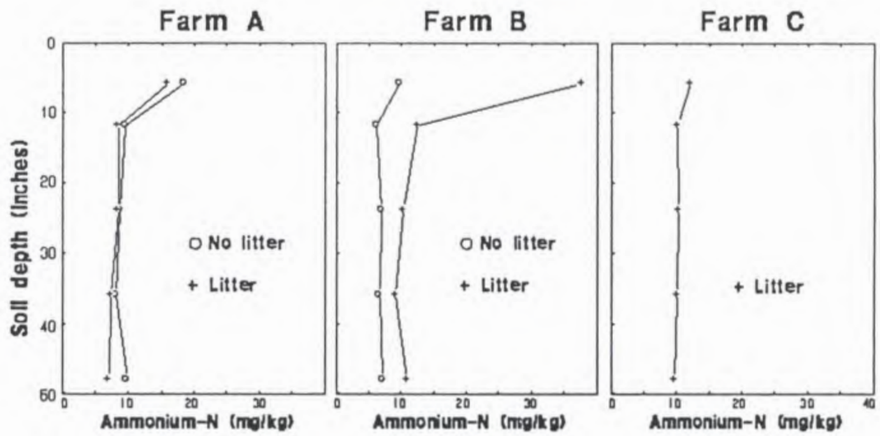
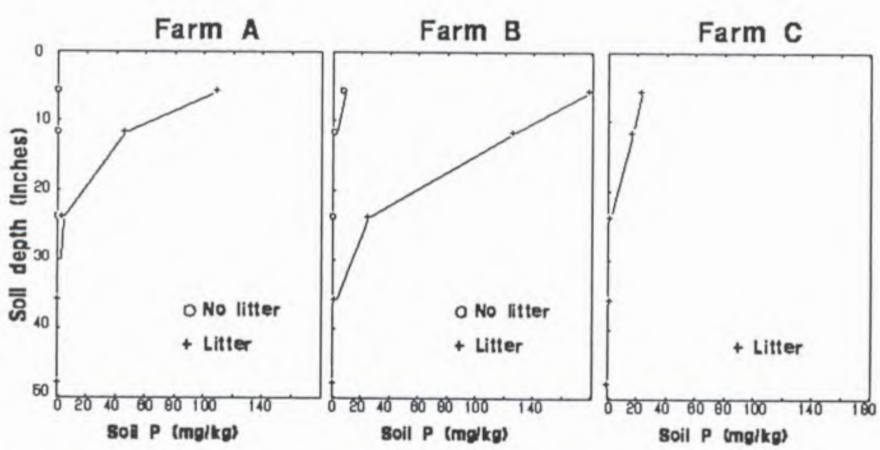


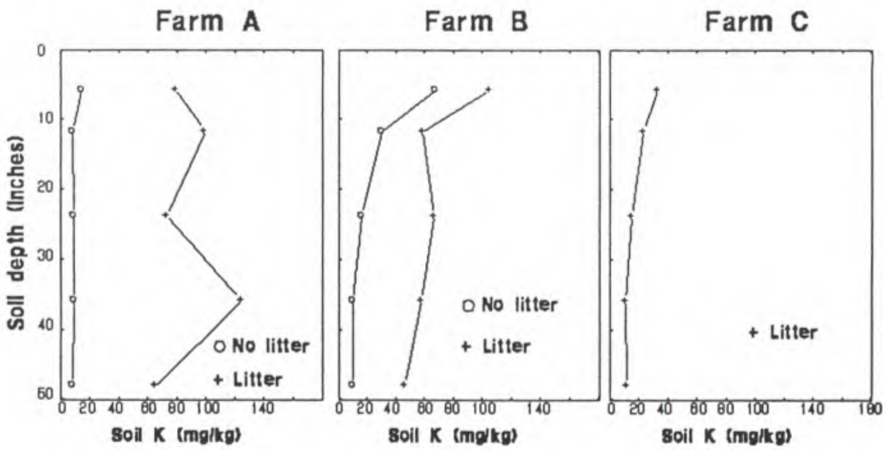
Nitrate-N



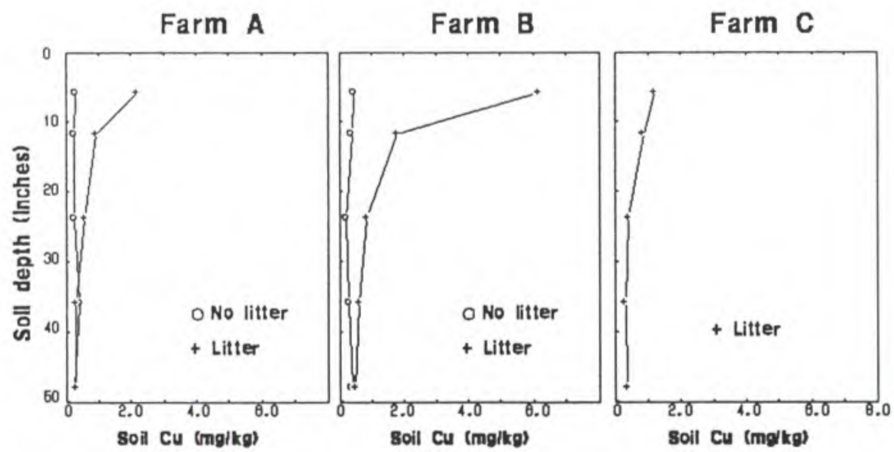
Ammonium-N



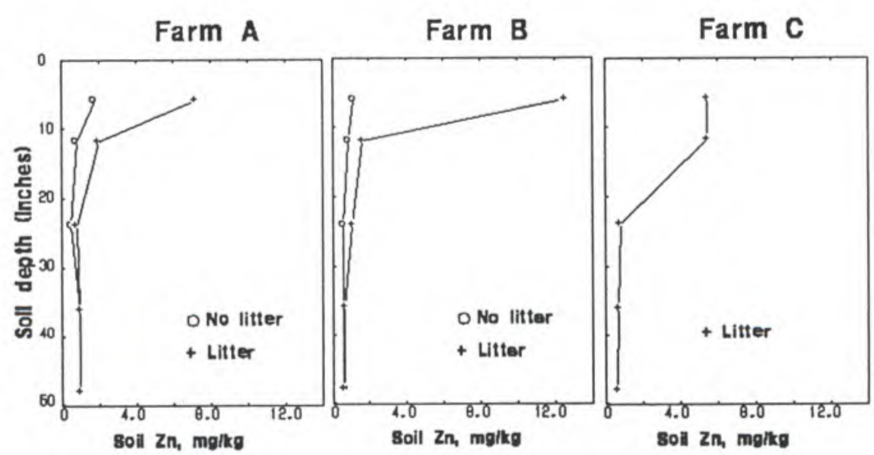
Phosphorus



Potassium



Copper



Zinc

PLANT NUTRIENT AVAILABILITY IN FRESH AND COMPOSTED POULTRY WASTES

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Land application of poultry litter and composted poultry carcasses from Alabama's large broiler industry is an environmentally sound way of disposing of large amounts of waste and utilizing nutrients for crop production (Mitchell et al., 1989). However, the rate of mineralization and crop availability of the nutrients in these wastes are unpredictable, particularly regarding the nitrogen component. This usually leads to over-application of these wastes to pasture and cropland.

Materials used as litter on the floor of poultry houses or as a source of carbon for the composting process may also affect nitrogen mineralization. The most common bedding used in Alabama are pine shavings or sawdust in North Alabama and peanut hulls in South Alabama. In addition to these, wheat straw may be used as a source of carbon in the composting process for poultry mortalities.

The objective of this study was to determine the relative mineralization of nitrogen (N), phosphorus (P), and potassium (K) from different sources of composted wastes and fresh broiler litter when used as soil amendments.

METHODS

A greenhouse bioassay was used to determine relative mineralization rates. Five types of poultry wastes were used:

1. Compost 1 (C1). Poultry carcasses composted for 6 weeks with peanut hulls.

2. Compost 2 (C2). Poultry carcasses composted for 6 weeks with straw.

3. Compost 3 (C3). Broiler litter which was well composted and aged (1 yr).

4. Broiler Litter 1 (BL1). Fresh broiler litter with wood chip bedding.

5. Broiler Litter 2 (BL2). Fresh broiler litter with peanut hull bedding.

The materials used varied considerably in composition (Table 1). Moisture ranged from 15.5 percent in the fresh broiler litter with peanut hulls to 38.6 percent in the aged compost. In general, the total nutrient content on a dry weight basis was higher in the composted birds than in any of the other materials used. The composted litter was lower in total N and total P than the other materials.

Table 1. Analyses of the Five Sources of Poultry Wastes Used on a Dry Weight Basis

Analysis	Composts C1	Composts C2	Composts C3	Broiler litter BL1	Broiler litter BL2
Moisture (%)	27.3	36.1	38.5	24.3	15.5
N (%)	3.12	3.22	1.88	2.31	2.38
P (%)	1.93	1.62	1.55	1.73	1.22
K (%)	2.66	2.41	1.72	2.32	1.75
Mg (%)	0.51	0.53	0.45	0.53	0.40
Ca (%)	2.57	2.14	2.05	2.39	1.62
Cu (mg kg^{-1})	512	448	404	774	296
Fe (mg kg^{-1})	3213	3682	5853	11650	3333
Mn (mg kg^{-1})	474	405	515	593	322
Zn (mg kg^{-1})	418	350	377	465	254
B (mg kg^{-1})	66	58	44	58	39
Mo (mg kg^{-1})	7	8	13	17	5

Each material and urea as a source of fertilizer N was mixed with dried and screened soil from the plow layer of a Marvyn loamy sand (Fine-loamy, siliceous, thermic Typic Kanhapludults). The soil was from existing plots where only fertilizer P and K had been applied for 80 years. Four rates of each material was applied based upon total N content:

1. None
2. x rate equivalent to 50 mg N kg^{-1}
3. 2x rate equivalent to 100 mg N kg^{-1}
4. 4x rate equivalent to 200 mg N kg^{-1}

The treated soil was placed in 20-cm diameter plastic pots in the greenhouse in saucers to collect and recycle any leachate. Soil was moistened to near field capacity and maintained by daily watering. Sorghum-sudangrass was planted the same day as soil mixing and later thinned to approximately 10 plants per pot. Each treatment was replicated four times.

Herbage was harvested, dried and weighed 4 weeks after planting and again 12 weeks after planting. After the initial harvest, plants grew very slowly because of an apparent K deficiency in most of the treatments. Herbage was ground and analyzed for total nutrient uptake. Soil was tested for pH and Mehlich-1 extractable P, K, Mg, and Ca at the conclusion of the experiment.

RESULTS

Dry Matter Yield

Dry matter yield at the first harvest and total yield were significantly affected ($P<0.0001$) by the source of material used, the rate used and an interaction between source and rate. As expected, fresh litter resulted in the highest, total dry matter yield during the experiment with over 25 grams per pot produced during the 12-week period (Figure 1). There were no differences in yield due to the two sources of broiler litter. Fresh broiler litter is rich in uric acid and NH_4-N, readily available N sources, whereas composted material is almost totally organic N. This is evident in the relatively low yield of the aged, composted litter (C3) compared to the fresh litter. The low yield of the urea-treatments relative to the composted birds and fresh litter is attributed primarily to a severe K deficiency which should have been anticipated. Urea at the 2x rate with a high rate of fertilizer P and K (not shown in figure) produced an average dry matter yield of 21.2 grams per pot -- equivalent to the 2x rate of broiler litter.

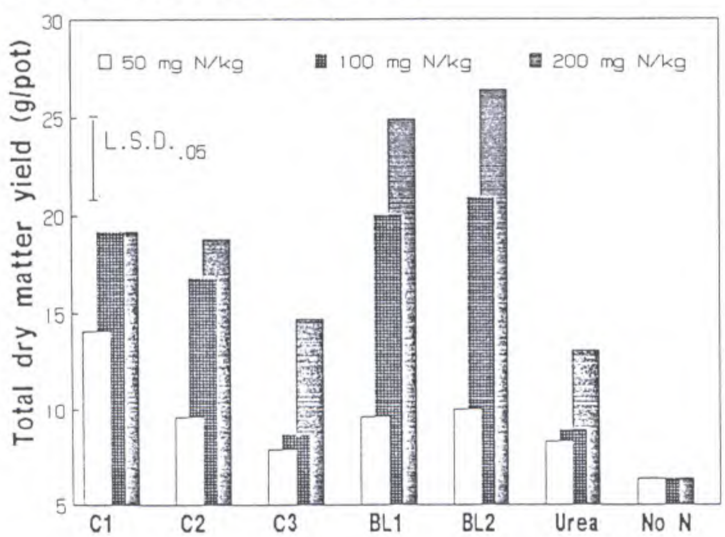

Figure 1. Effect of composted carcasses (C1, C2) aged composted broiler litter (C3), and fresh broiler litter (BL1, BL2) on the total dry matter herbage yield of sorghum-sudangrass in a greenhouse bioassay.

Percentage yield at first harvest should be indicative of the relative N availability in the sources used. There were significant differences due to source of material, rate of material, and an interaction between source and rate regarding the percentage of total yield at first harvest (Table 2).

Table 2. Percent of Total Dry Matter Yield of Sorghum-Sudangrass at 4 Weeks After Planting

Source	Total N rate (mg kg^{-1})		
	50	100	200
	---------- % at 1^{st} harvest ---------		
C1	63	69	68
C2	46	67	61
C3	35	35	63
BL1	34	70	69
BL2	43	69	71
Urea	49	46	55

(Check - no N = 25%). L.S.D.$_{P<.05}$ (source*rate) = 14%.

Soil Analyses

Analyses of soil at the conclusion of the greenhouse experiment also indicated significant differences in soil pH, P, K, Mg, and Ca due to sources, rates, and the interaction (Table 3). The highest rate of all materials, especially the aged, composted litter (C3), resulted in the highest soil pH and highest level of extractable P, K, Mg, and Ca. Because of the low N concentration, more C3 was applied than any other material. The Mehlich-1 extractant (dilute HCl and H_2SO_4) extracts primarily inorganic and/or exchangeable P, K, Mg, and Ca. High values relative to the check indicate that considerable mineralization of the extractable nutrients did occur during the 12-week period.

Higher soil pH values as a result of manure additions have been explained by Hue (1992) as an adsorption of organic anions followed by a reduction of Mn and Fe oxides under a localized, electron-rich environment created by rapid decomposition of manures. Based upon soil pH measurements, he calculated that additions of 5 and 10 tons of manure per acre were approximately equivalent to 2.5 and 5 tons of $Ca(OH)_2$, respectively.

SUMMARY

A bioassay of the mineralization rates of N and other nutrients in composted poultry wastes and fresh broiler litter confirms that N and other nutrients in fresh litter are more available than those in composted products. The source of the bedding in litter or the source of carbon in the composting of

dead birds, either wood shavings or peanut hulls, made no difference in nutrient mineralization as measured by the growth of sorghum-sudangrass in a 12-week greenhouse study. All sources of poultry wastes except old, composted litter resulted in higher yields than urea nitrogen at high N rates. This was presumably due to a K deficiency where no organic amendments were added. The high rates of litter and composts also increased soil pH.

Table 3. Soil pH and Mehlich-1 Extractable Nutrients as Affected by Soil Amendments and 12 Weeks of Cropping

Source	N rate mg/kg	Extractable nutrients				
		pH	P	K	Mg	Ca
			-------- $mg\ kg^{-1}$ --------			
Check	0	5.7	74	10	24	276
C1	50	5.9	83	9	27	286
C1	100	5.9	88	10	28	315
C1	200	6.1	109	19	40	376
C2	50	6.0	79	15	33	280
C2	100	5.9	90	11	37	338
C2	200	6.2	117	26	40	357
C3	50	6.1	86	18	36	310
C3	100	6.2	101	37	42	330
C3	200	6.4	130	50	58	398
BL1	50	6.0	72	14	39	281
BL1	100	5.9	70	9	29	270
BL1	200	6.2	113	13	40	411
BL2	50	6.0	64	13	34	251
BL2	100	5.9	79	10	32	321
BL2	200	6.1	92	11	35	382
Urea	50	5.7	70	6	27	263
Urea	100	5.8	65	6	23	232
Urea	200	5.6	74	6	19	273
Urea+P+K	100	5.2	72	10	18	263
LSD (P<.05)		0.2	12	12	7	38

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VIABILITY OF WEED SEED IN POULTRY MANURE AND MORTALITY COMPOST

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Land application of poultry production by-products, as nutrient sources, continues to be the primary disposal option utilized by poultry producers. As individual operations expand, and new operations come into existence, the competition for land resources intensifies. An alternative to using by-products on individual poultry farms is to market the nutrient value of the products at no or low costs to off-site users. While this practice is gaining popularity, there is considerable resistance from the non-poultry producer market because of the perception that poultry litter and litter by-products contain viable weed seeds.

Research evaluating the viability of weed seed in animal manures is fairly limited. In a recent literature search of the Agricola database, only 16 references could be found (Zublena, 1992). Of the literature available, only one reference (Harmon and Keim, 1934) involved poultry. In this landmark study, one thousand seeds of each of these seven weed species were fed to calves, horses, sheep, hogs and chickens: velvet weed, (Abutilon L. Rusby); field bindweed (Convolvulus arvensis L.); white clover (Melilotus alba Desv.); Smooth leaf dock (Rumex acetocella L.); annual smartweed (Polygonum pennsylvanicum L.); Wild rose (Rosa arkansana Porter); and perennial peppergrass, (Lepidium Draba L.). Results showed differences in weed seed recoveries between animal types and between weed species. The average percentage of undamaged seeds that were recovered for all weed species was 24.1, 23.1, 12.9, 10.7, and 0.3 for hogs, calves, horses, sheep and chickens, respectively. Bindweed and velvet weed were the weed species least influenced by passing through the animal's digestive tracts (23.1 and 22.8% recovered, respectively), while smooth dock sustained the greatest losses with only 6.8% of the seed recovered. These recovered seeds were then tested to determine their percent germination. By combining percent germination and percent recovery of the weed species, the authors determined the percent of viable seed that passed through the digestive tracts of calves, hogs, horses sheep and chickens as being 9.6, 8.8, 8.7, 6.4 and 0.2%, respectively. These studies clearly show poultry as having superior abilities to effectively utilize weed seed as feed sources compared to other livestock. Physiologically, feed processed by poultry must pass through the gizzard prior to entering their digestive tracts. The grinding action of the gizzard may be responsible for the major reduction of viable seeds.

The present study was initiated to determine, through a field evaluation trial, if viable weed seed were present in poultry litter and litter by-products. Our hypothesis was that litter and litter by-products from modern poultry production facilities have little contact with weed seeds since the birds are no longer range feeding, and since the quality of feed has improved with modern seed cleaning equipment and regulatory requirements to reduce the presence of weed seeds. In addition, much of the poultry industry uses pelletized feed which should reduce the viability of seeds if they are present.

METHODS AND MATERIALS

Three replicate split block field trials (4 reps/treatment) were conducted in 1991 in three major poultry producing counties in North Carolina (Duplin, Sampson and Wayne). Four randomized blocks (10 ft. X 21 ft.) in each trial were fumigated with methyl bromide (Bromomethane) and four blocks were used as non-fumigated controls. Fumigation was used to eliminate/reduce the presence of weed species that existed before treatment application. All blocks were covered with plastic for 5 days post fumigation. Plastic covers were removed 6 days post fumigation and plots were allowed to air for 8 days to assure dissipation of the methyl bromide from the fumigated blocks.

Seven treatments consisting of turkey brooder house litter, turkey growout litter, turkey mortality compost, broiler house litter, composted poultry litter, and commercial nitrogen (ammonium nitrate) were applied at rates to supply approximately 120 pounds of plant available nitrogen per acre (Table 1). A no treatment control was also included. Individual treatment plot size was 3 x 10 feet. Emergent weed species were identified and populations counted 21 days after treatment application. Weeds were harvested from a 2 X 3 foot area to determine dry matter accumulation at 49 days after treatment application.

Table 1. Treatment Application Rates

Source	%DW	%N	PAN*/Ton (lbs)	Applied (tons/ac)
Turkey brooder house	52	5.1	24.5	4.9
Turkey growout house	58	5.7	30.2	4.0
Mortality compost	50	3.4	13.7	8.8
Broiler house	69	3.4	21.4	5.6
Composted litter	59	1.7	9.3	12.9
Ammonium nitrate	--	34	--	0.02

*PAN = Plant Available Nitrogen (assumes 50% of %N available).

RESULTS AND DISCUSSION

Fumigation reduced the presence of most weed species compared to non-fumigated treatments (Table 2). The one exception was for the morning glory family (Ipomoea spp. L.) which actually showed increased populations. Morning glory generally produce large seeds that are not controlled by fumigation. Other weed species present that are generally not controlled by fumigation included nut sedge (Cyperus spp. L.) and prickly sida (Sida spinosa L.). In our study, however, fumigation appeared to reduce these populations.

No differences in morning glory populations were found between treatments in the non-fumigated blocks (Table 2). However, in the fumigated blocks the turkey growout litter and the commercial nitrogen tended to have lower populations than the other treatments.

Comparison of poultry litter and litter by-product treatments to commercial nitrogen and the no treatment control showed no differences in populations of any of the weed species present when combined across sites (Table 2). This suggests that the weed species present and the populations observed were not influenced by the addition of poultry litter or litter by-products.

Evaluation of total weed biomass 49 days post-treatment showed greater accumulation of biomass on non-fumigated compared to fumigated treatments (Table 3). These findings support the data on increased weed populations for non-fumigated treatments. Weed weights in fumigated plots were highest for plots treated with commercial nitrogen and turkey mortality compost. The same trend is visible in the non-fumigated plots, but it is not as dramatic. Increased weights with these two sources is probably due to a quicker release of nitrogen during the 49 days after application.

Table 2. Effect of Fumigation on Weed Populations

Source[2]	TRT	Weed species[1] SP	AG	MG	CW	PW	WC	NG	RW
TBH	F[3]	0.42	0.67	8.83	2.42	0.58	0.00	0.00	0.00
	NF	1.17	15.75	2.83	21.08	10.50	2.92	3.33	1.83
BL	F	0.42	0.00	8.67	2.00	1.25	0.00	0.00	0.00
	NF	2.33	16.75	3.42	16.67	7.33	3.00	4.58	0.50
TGO	F	0.17	0.08	4.50	0.08	0.33	0.00	0.00	0.00
	NF	1.25	9.75	3.17	12.92	5.08	1.17	2.75	0.42
CC	F	0.67	0.33	5.33	1.33	0.67	0.00	0.00	0.00
	NF	0.67	11.92	3.25	14.25	7.50	2.50	4.33	0.75
TMC	F	0.50	0.67	3.75	0.92	0.17	0.33	0.25	0.08
	NF	2.92	13.33	2.58	8.58	10.08	1.92	3.92	0.42
CN	F	1.17	0.17	6.33	2.50	0.42	0.08	0.00	0.00
	NF	1.33	24.08	3.17	26.50	8.42	4.08	2.67	0.42
C	F	0.75	0.50	8.83	1.08	1.17	0.00	0.50	0.00
	NF	1.92	18.33	3.67	35.08	7.08	1.42	3.75	0.83

[1]SP = Sickle pod *Cassia obtusifolia* L.
AG = Annual grasses Gramineae family.
MG = Morning glory *Spomoea* spp.
CW = Carpet weed *Mullugo verticillata* L.
PW = Spiny amaranth *Amaranthus spinosus* L.
WC = Worly croton *Croton capitatus* Michx.
NG = Nut sedge *Cyperus* spp.
RW = Ragweed *Ambrosia artemisiifolia* L.
[2]TBH = Turkey broiler house litter.
BL = Broiler house litter.
TGO = Turkey growout litter.
CC = Commercial litter compost.
TMC = Turkey mortality compost.
CN = Commercial nitrogen.
C = Control.
[3]F = Fumigated.
NF = Non-fumigated.

Table 3. Average Weed Weight Across All Three Sites

Source	Fumigated (gms)	Non-fumigated (gms)
Turkey brooder house litter	558.3	2875.1
Broiler house litter	547.5	3665.9
Turkey growout litter	424.7	3478.3
Commercial litter compost	592.0	2908.5
Turkey mortality compost	851.9	375.1
Control	530.2	2179.1

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FEEDING VALUE OF ANAEROBICALLY DIGESTED DAIRY WASTE FOR BROILER CHICKENS

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Recycling of animal wastes can be undertaken in many different ways. Each will vary in the degree to which energy and nutrient rich by-products are incorporated back into useful animal and plant systems. Anaerobic digestion has the potential to completely recycle the waste from livestock production. Experimental facilities on the island of Oahu, Hawaii have utilized dairy, poultry, swine and beef manures to demonstrate the technology. By-products produced and recovered from the system include: 1) biogas (methane) fuel to generate electricity, hot water, and hot air; 2) livestock feed supplement dried from the digester solids; 3) spirulina algae grown with carbon dioxide captured during fermentation; and 4) hydroponically grown vegetables and herbs from the digester liquid effluent.

The purpose of this study was to evaluate anaerobically digested dairy waste (ADDW) as a feedstuff for poultry. The objectives were to 1) determine if low levels of ADDW (1.5 and 3.0%) had any growth promoting or inhibiting properties in background diets composed of purified or practical ingredients; 2) determine if the organic or mineral portion of ADDW was responsible for growth effects; and 3) evaluate higher dietary levels of ADDW (3, 6, and 12%) for commercial application.

PROCEDURES

Holstein manure from a nearby dairy was exclusively used in generating biogas and ADDW feed ingredient in a series of temperature and pressure regulated fermentation tanks. The ADDW solids remaining in solution were removed by centrifugation and dried in a spray drier (750 F) to 97.6% dry matter.

Experiment 1

Based on the nutrient and amino acid composition of the ADDW (Table 1) three practical (corn and soybean meal) and three purified (dextrose and isolated soybean meal) starter diets for broiler chicks were formulated to contain 0, 1.5 and 3.0% ADDW (Table 2). Diets were prepared to be isocaloric, isonitrogenous and contain all the nutrients recommended by the National Research Council (1984). Commercial broiler chicks (180) were randomly assigned to 6 experimental diets with 3 replicates of 10 chicks per pen. Chicks were housed in electrically heated battery brooders and feed and water were provided ad libitum to 3 weeks of age.

Experiment 2

Higher levels of the ADDW (3, 6 and 12%) and an equivalent amount of minerals from ashed ADDW (1.1, 2.2 and 4.4% of the diet) were compared to a control diet in the second experiment (Table 3). Ashed ADDW was prepared by heating the product in a muffle furnace at 500 C for 8.5 hours to burn off the organic matter. Commercial broiler chicks (210) were randomly assigned to 6 experimental diets and a control with 3 replicates of 10 chicks per pen. Chicks were housed in electrically heated battery brooders and feed and water were provided ad libitum to 3 weeks of age.

Table 1. Anaerobically Digested Dairy Waste Composition

Nutrient	Amount	Amino Acid	Percentage
Dry matter (%)	97.60	Alanine	.76
Crude protein (%)	10.90	Arginine	.50
Ash (%)	40.60	Aspartic acid	1.17
Ether extract (%)	1.20	Cystine	.24
NDF1 (%)	36.30	Isoleucine	.36
Calcium (%)	4.32	Glutamic acid	1.63
Phosphorus (%)	.81	Glycine	.85
Magnesium (%)	.69	Histidine	.50
Potassium (%)	.60	Leucine	.83
Sodium (%)	.12	Lysine	.54
Iron (ppm)	3320	Methionine	.32
Manganese (ppm)	342	Phenylalanine	.58
Zinc (ppm)	198	Proline	.83
Copper (ppm)	20	Serine	.68
		Threonine	.50
		Tryptophan	.02
		Tyrosine	.51
		Valine	.43

[1]NDF = Neutral detergent fiber.

Table 2. Percentage Diet Composition (Experiment 1)

	Practical			Purified		
ADDW1(%): Ingredients	0	1.5	3.0	0	1.5	3.0
Corn	52.4	50.9	49.4	...	...	...
Soybean meal	29.5	29.5	29.5	...	...	...
Fish anchovy	3.0	3.0	3.0	...	...	...
Alfalfa meal	3.0	3.0	3.0	...	...	...
Meat meal	3.0	3.0	3.0	...	...	...
Corn oil	5.5	5.5	5.5	1.5	1.5	1.5
Limestone	.3	.3	.3	1.5	1.5	1.5
Dical	1.7	1.7	1.7	2.3	2.3	2.3
Iodized salt	.3	.3	.3	.3	.3	.3
DL-methionine	.3	.3	.3	.6	.6	.6
ADDW	...	1.5	3.0	...	1.5	3.0
Vit-min mix	1.0	1.0	1.0	1.0	1.0	1.0
Dextrose	...	...	...	48.2	46.7	45.2
Isolated soy	...	...	...	27.0	27.0	27.0
Sucrose	...	...	...	10.0	10.0	10.0
Cellulose	...	...	...	4.2	4.2	4.2
Sand	...	...	...	3.0	3.0	3.0
Glycine	...	...	...	.4	.4	.4

[1]ADDW = Anaerobically digested dairy waste.

Table 3. Percentage Diet Composition (Experiment 2)

		ADDW[1]			ADDW ash		
Ingredients	CON2	3%	6%	12%	3%	6%	12%
Corn	52.0	50.5	46.6	39.5	51.5	48.1	43.5
Soybean meal	33.0	31.5	31.5	34.0	32.4	33.8	37.6
Tallow	6.0	6.5	8.0	8.8	6.5	8.0	8.8
ADDW	...	3.0	6.0	12.0	...	...	...
ADDW ash	...	...	...	...	1.1	2.2	4.4
Fish anchovy	2.0	2.0	2.0	1.0	2.0	2.0	1.0
Alfalfa meal	2.0	2.0	2.0	1.0	2.0	2.0	1.0
Meat meal	2.0	2.0	2.0	1.0	2.0	2.0	1.0
Dical	1.5	1.5	1.2	2.0	1.5	1.2	2.0
Iodized salt	.3	.3	.3	.3	.3	.3	.3
DL-methionine	.3	.3	.3	.3	.3	.3	.3
Vit-min mix	.1	.1	.1	.1	.1	.1	.1

[1]ADDW = Anaerobically digested dairy waste.
[2]CON = Control.

RESULTS

The nutrient and amino acid composition of ADDW are reported in Table 1. Often the moisture content of digester effluents are too high, limiting the amount that can be added to poultry diets (Caldwell et al., 1988). The centrifugation and spray drying steps utilized to process ADDW eliminated most of the moisture (97.6% dry matter). Ash (40.6%) and concentrations of protein (10.9%), calcium (4.32%) and phosphorus (.81%) were correspondingly elevated with the elimination of moisture. Protein concentration and amino acid quality of the ADDW are similar to corn grain. Lysine, methionine, phenylalanine and histidine are found in slightly higher concentrations in the ADDW while more leucine, valine and tryptophan are found in corn. Steinsberger et al. (1987) determined that anaerobically digested cage layer waste was a significant source of iron (3252 ppm), calcium (18.52%) and phosphorus (3.90%) with the latter being highly available (90%) for broiler chicks. The dairy waste utilized for anaerobic digestion in this study did not contain the high calcium and phosphorus levels found in cage layer waste. This is most likely a function of the level of dietary mineral supplementation. Iron concentration of the ADDW (3320 ppm) is similar to that found in digested cage layer waste.

Experiment 1

The main effect of feeding ADDW had no influence on bird performance, while birds fed the practical corn and soybean meal diets (CS) consistently did better than birds fed the purified diets (P). Body weight at 7, 14 and 21 days of age was greater for CS fed birds compared to those fed the P diet (Table 4). Feed intake (wk 2) and weight gain (wk 1, 2 and 3) were significantly greater (data not shown) and feed/gain ratio was better ($P<.05$) for the first two weeks on the CS diet. Mortality during the entire trial was low (2%) and did not appear to be treatment related.

Feeding ADDW appeared to have no positive or negative effect on body weight, feed consumption or feed conversion in either the CS or P basal diets. Hammond (1942) hypothesized that cow manure contained a substance(s) which was responsible for stimulating the growth of chicks. However, the nutritionally complete diets used in the present study failed to reveal any beneficial effects of adding small amounts of ADDW on chick performance.

Table 4. Body Weight and Feed/Gain Ratio (Experiment 1)

Age in Days	Body weight (g)			Feed/gain ratio		
	CS[1]	P[2]	SEM[3]	CS	P	SEM
1	44.4	44.8	.21	...	...	...
7	169.2[a]	133.2[b]	1.89	1.17[a]	1.32[b]	.02
14	396.7[a]	310.0[b]	4.50	1.35[a]	1.51[b]	.02
21	668.7[a]	524.3[b]	7.40	1.46	1.48	.02

[1]CS = Corn and soybean meal diet means.
[2]P = Purified diet means.
[3]SEM = Standard error of the mean.
[a-b]Values for a row parameter with no common superscript are significantly different (P<.05).

Experiment 2

Body weight of birds fed the control diet were not significantly better than birds fed the ADDW 3%, 6%, or ashed ADDW (ADDWa) 6% and 12% diets at any time during the trial (Table 5). Birds fed ADDW 12% weighed significantly less than the other dietary treatments at 14 days (399 g) and 21 days (653 g) of age. Birds fed the 12% level of ADDWa were the heaviest treatment at 21 days of age (781 g) and significantly heavier than the ADDWa 3% and ADDW 12% fed birds.

Feed intake during the 3 week trial was not affected by the experimental diets (P>.05). Neither the ADDW or ADDWa dietary additions appeared to influence feed palatability or intake (data not shown). Weight gain was consistently depressed at 2 and 3 weeks for birds fed the ADDW 12% and ADDWa 6%, while birds fed the control diet and ADDWa 12% gained significantly more (data not shown). Feed conversion was not influenced by the experimental diets during the first week on feed. However, during weeks 2 and 3, birds fed the ADDW 12% diet repeatedly had the poorest feed conversion compared to the other dietary treatments (Table 5).

Table 5. Body Weight and Feed/Gain Ratio (Experiment 2)

	Body weight (g)				Feed/gain ratio		
Age in days: Treatment	1	7	14	21	7	14	21
Control	40	164	425ab	739ab	1.4	1.2a	1.6b
ADDW[1] 3%	40	166	423ab	750ab	1.3	1.4b	1.7b
ADDW 6%	41	172	429ab	726ab	1.2	1.3ab	1.7b
ADDW 12%	40	164	399b	653c	1.2	1.5b	2.0c
ADDWa[2] 3%	42	172	415ab	716b	1.1	1.4b	1.4a
ADDWa 6%	40	169	420ab	721ab	1.2	1.3ab	1.7b
ADDWa 12%	40	171	438a	781a	1.1	1.2a	1.6b
SEM[3]	.02	1.2	3	6	.01	.06	.15

[1]ADDW = Anaerobically digested dairy waste.
[2]ADDWa = Anaerobically digested dairy waste ash.
[3]SEM = Standard error of the mean.
[a-c]Values for a column parameter with no common superscripts are significantly different (P<.05).

CONCLUSIONS

Low levels of dietary ADDW (1.5 and 3.0%) can be fed to broiler chicks in either a practical or purified basal diet without any impact on performance (experiment 1). Higher levels (12%) of the ADDW can have a negative effect on body weight and feed conversion compared to the other treatment diets. Apparently the organic components of the 12% ADDW are responsible for poorer performance, because chicks fed an equal amount of the ashed ADDW (ADDW 12%) were significantly heavier at 2 and 3 weeks of age and had better feed conversion. These findings suggest that low levels of ADDW (6% and less) and ADDWa (12% and less) can supply a palatable source of calcium, phosphorus and amino acids when substituted for corn and soybean meal in broiler chicken diets.

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MANURE MARKETING: A TOOL FOR NUTRIENT MANAGEMENT ON POULTRY FARMS

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Lancaster County Pennsylvania is noted for intense poultry and livestock operations on small farms. Lancaster County farms are home to 8,170,000 layers and produce 50,300,000 broilers per year. Other livestock in the county includes 99,000 dairy cows, 161,000 beef cattle and dairy replacements, and 335,000 hogs. High land values have forced farmers to seek ways to increase income per acre. The solution chosen by many has been to increase animal units per acre and import purchased feed to the farm. Eggs, broilers and pullets are exported from the poultry farms, but a surplus of crop nutrients remain behind in the form of poultry manures.

Increasing environmental concerns about agricultural nonpoint source pollution makes it imperative that poultry farmers find ways to export their surplus manure for use off the farm. Since poultry manure is high in fertilizer value it is economically feasible to transport it to a distant buyer. Weaver and Souder (1990) reported that broiler litter can be economically shipped 100 miles for fertilizer use or 300 miles for feed supplement use in Virginia. Currently, two Lancaster County firms are each marketing 20,000-25,000 tons of broiler litter yearly, most of it out of the county. Some is trucked as far as 350 miles and still sold at a profit. Custom application of layer manure to buyer's fields is a growing service that is increasing market opportunities.

In order to promote redistribution of surplus manure nutrients, a manure marketing program was developed as a part of Penn State Extension's role in the Rural Clean Water Program and The Chesapeake Bay Program. To participate in the program, farmers completed a survey form indicating whether they were potential suppliers or potential receivers. Also included in the survey form were questions relating to delivery and custom spreading ability, willingness to supply free manure, and availability of composted manure. The participants names were compiled into supplier and receiver lists organized by county and township. These lists are updated and sent out in March and October. The farmers on the supplier list receive a copy of the receiver list and vice-versa.

As of March 1992, almost three times as many farmers have signed up to receive manure as to supply it (290 vs 105). This does indicate a real marketing opportunity exists for those with excess manure nutrients. In this high livestock area the lesser number of those who signed up to supply manure is not an indication of limited supply but is probably a reflection of unwillingness of farmers who have excess manure to draw attention to themselves for fear of repercussions.

A summary of the survey indicates that among the suppliers 25% are able to custom apply the manure; 13% are able to deliver the manure, but not apply it; 33% are willing to supply the manure free if the receiver picks it up; and 3% have a composted product. Among the receivers 27% are especially interested in compost; 49% are willing to pay for the manure; 39% are only interested if it is free; and 22% are only interested if the supplier can custom apply the manure. This indicates that poultry producers can increase the market opportunities for their manure by offering a composted product or custom application service. Answers to other survey questions indicate 34% have tested their manure, 73% have never calibrated their manure spreader, and 13% regularly market manure to other operations. This effort is continuing as a part of Penn State Extension's program in Lancaster County, Pennsylvania.

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FLY POPULATIONS ASSOCIATED WITH POULTRY MORTALITY COMPOSTING

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The composting of poultry mortality is currently under evaluation by N.C. State University. A number of sites across the state have been approved by the state veterinarian, and are operating successfully. One of the concerns relating to mortality composting has been the potential for increased levels of fly breeding associated with the process. This study was undertaken to evaluate the relative levels of fly populations associated with the composting of poultry mortality, and to determine the major fly species common around composting sites.

METHODS

Four sites were selected in three geographical areas of the state. Site selections were also intended to provide a reasonable representation of both composter and flock types. The following table lists the location, region, composter type and farm type selected for the study:

Table 1. Breakdown of Study Sites

Region	County	Composter	Farm
Coastal Plain	Duplin	2-Stage	Turkey
Piedmont	Chatham	2-Stage	Broiler
Piedmont	Johnston	1-Stage	Broiler
Mountains	Alexander	2-Stage	Broiler

Sticky tapes were selected as a sampling device since they were considered to be the most species neutral of the sampling methods considered, and were easily placed and collected by cooperating agents. Sampling was conducted at each site at 2 week intervals and consisted of placement of two sticky tapes (one at each end of the composter) and a single tape on the outside of the poultry house most distant from the composters. In all cases, tapes placed at poultry houses were 100 yards are more away from composters. Sampling was initiated in mid-June and continued to the end of October (weather permitting).

Sticky tapes were collected after 48 hours, appropriately labelled, wrapped in Saran Wrap and transported to the Central Crops Research Station, Clayton, NC, for examination. The number and species of flies trapped by each tape were tabulated for each sampling period.

RESULTS AND CONCLUSIONS

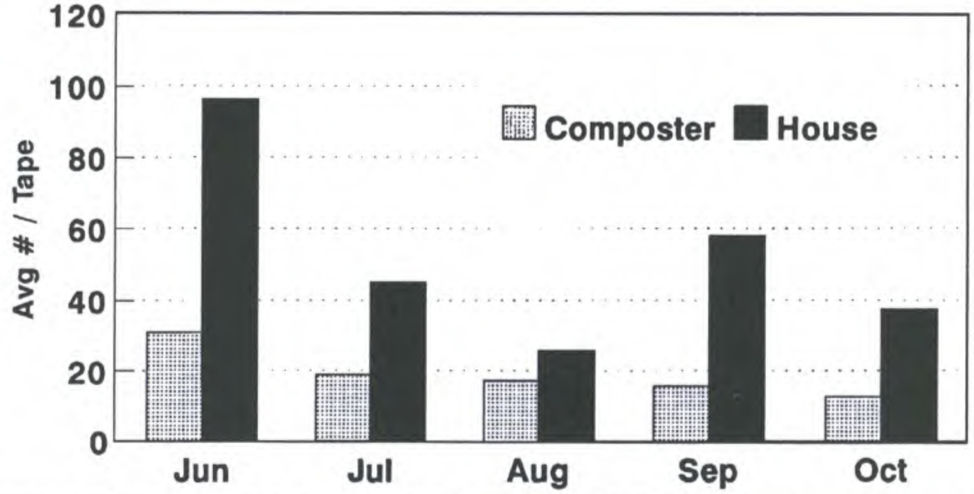
The number and species of flies associated with the composters was found to closely parallel the background fly population of the individual sites. There were no dramatic differences in the number or species of flies trapped at either single or dual stage composters. Similarly there were little or no differences between the types of poultry operations. Consequently, all sample data were lumped to determine monthly averages.

The predominant fly species associated with the composters broke down into three major groups: house flies (Musca domestica and Fannia canicularis); blow flies (Phaenicia, Calliphora and Phormia spp.); and black garbage flies (Ophyra aenescens) (Figures 1-3). A small number of black soldier flies (Hermetia illucens) were also recovered at infrequent intervals.

In general, house flies were the predominant species found around both composters and poultry houses. Since there was no indication that fly breeding was occurring in the compost, and since large numbers of house flies were collected by tapes placed at poultry house locations, it is likely that the house fly numbers were indicative of the normal background population associated with a particular farm.

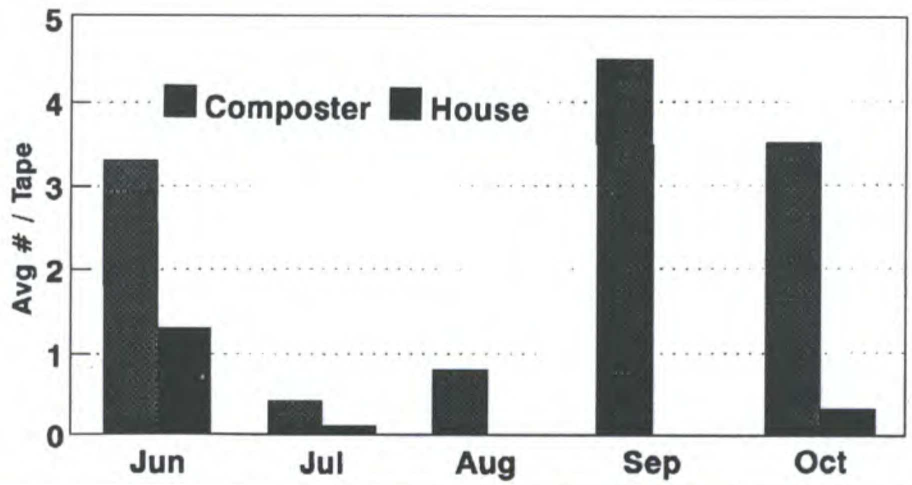
Blow flies were largely associated with the composters. Numbers were low, and their occurrence was not considered to be indicative of a problem. The nature of composting will invariably attract a few blow flies and other fly species that are drawn to carrion for oviposition.

Black garbage fly numbers were considerably higher at composter locations during the last two months of monitoring. Although the highest counts were not considered to be excessive given the background populations of all fly species, they were higher than anticipated. Since we have no information about seasonal fluctuations around compost sites



	Jun	Jul	Aug	Sep	Oct
Composter	31.0	18.9	17.1	15.6	12.5
House	96.3	44.9	25.8	58.0	37.5

Figure 1. Monthly averages of house flies recovered from poultry houses and composters at four locations.

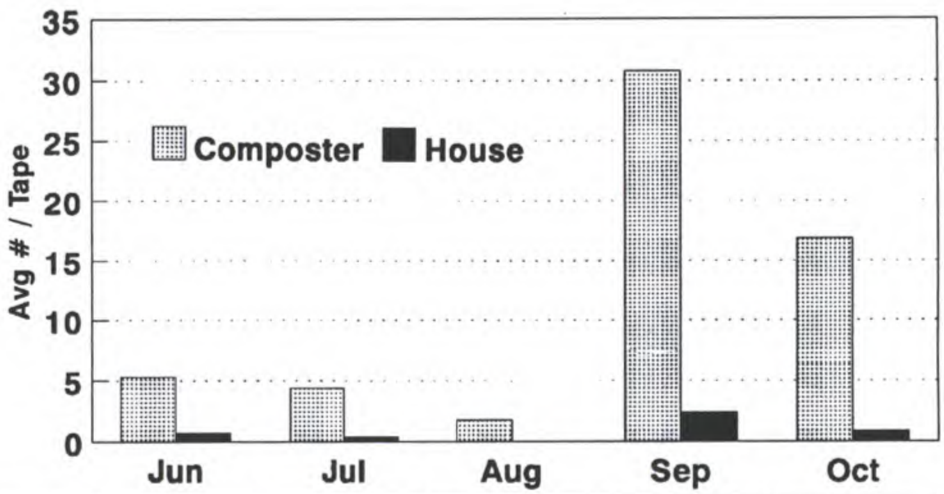


	Jun	Jul	Aug	Sep	Oct
Composter	3.3	0.4	0.8	4.5	3.5
House	1.3	0.1	0.0	0.0	0.3

Figure 2. Monthly averages of blow flies recovered from poultry houses and composters at four locations.

for this or other pest species, it is difficult to say whether this was a normal situation or was related to lapses in management of the composting process. However, it should be pointed out that the increases in black garbage fly numbers were largely associated with two of the locations (one during September, and the other during October). Given that there were similar fluctuations in house fly and blow fly numbers between periods for all of the sites, it is likely that better composter management would have reduced the number of black garbage flies.

In conclusion, it would appear that the composting of poultry mortality does not contribute to fly populations normally associated with poultry production. Properly maintained and managed composters are an effective and relatively pest free method for on-farm mortality disposal.



Composter	5.3	4.4	1.8	30.8	16.9
House	0.7	0.4	0.0	2.4	0.9

Figure 3. Monthly averages of black garbage flies recovered from poultry houses and composters at four locations.

A VALUE ADDED MANURE MANAGEMENT SYSTEM DRIVEN BY A NON-PEST FLY

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Manure accumulations at animal production facilities pose significant problems. House fly production may be very high and can bring litigation from neighbors. This may result in closure of the facility in extreme cases, and always lowers the quality of environment at the facility. Disposal of the manure is also a problem. In some Georgia counties there are not enough acres of pasture within economical hauling distance to properly spread laying hen manure as fertilizer. When manure is applied too heavily, local water quality suffers.

The black soldier fly (Hermetia illucens (L.)) is an attractive manure management agent. It can; 1) eliminate house fly breeding, 2) reduce the manure bulk by about one half that of similar unoccupied manure, and 3) produce tons of useful larval feedstuff. The native black soldier fly is abundant in the southeastern United States and across the U.S. to California. Little is known about adult biology. The only adults commonly seen are newly emerged adults and ovipositing females. Eggs are laid in batches of about 500 in dry cracks or crevices above the chosen larval media. Other adults apparently live in a wild environment and their habits are largely unknown. They do not try to enter houses and are usually not a problem. In 15 years of investigating this insect, I can remember only one complaint about adults entering a residence. They compete with house flies for larval habitat. Female house flies will not lay eggs where soldier fly larvae are moderately abundant (Bradley and Sheppard 1984). Sheppard (1983) found that soldier fly larvae gave 94-100% control of house fly breeding.

One reason soldier flies have not been widely used in animal waste management is because the dense larval populations migrate onto walkways and can cause the manure to flow, through their churning action. These two problems can be solved with a simple manure pit such as the one used in our study at the Coastal Plain Experiment Station. Since the biological principles of this system have been fairly well defined, this was primarily an engineering study to achieve these objectives:

1. Determine manure pit design compatible with:
   a. periodic manure removal with existing equipment
   b. self harvest of mature soldier fly larvae for feedstuff
   c. preventing larval access to walkways
   d. shallow flooding for early season house fly control.
2. Develop an effective low energy storage system for the larval feedstuff.
3. Determine the palatability of this larval feedstuff to swine.

METHODS

A small 600 bird caged layer facility at the Coastal Plain Experiment Station (CPES) Tifton, GA was modified with a manure pit designed to allow for shallow flooding for early season house fly control, and containment and self-harvest of soldier fly larvae. This pit was 40 inches wide, 12 inches deep and the wall away from the walk had a 40° slope. A 3 inch PVC pipe with a slit cut in one side was fitted at the top of this slope. Mature larvae leaving the pit to pupate were self-collected in this pipe and then placed into a collecting container. In order to maintain low input, drying of the larvae was not economically justified; however, preservation would be necessary in order to increase flexibility of use. Chemical treatment and ensiling were tested. A factorially arranged processing and preservation trial was conducted. The factors were whole or ground larvae, proportions of corn grain in the mixture to be preserved, mixing with corn before or after grinding, preservation with ammonia, organic acids, or lactic acid fermentation (ensiling). These treatments were periodically evaluated for pH, ammonia, and evidence of spoilage (and lactic acid content for ensiled materials).

The 600 hen experimental layer facility was fully operational by August 31, 1990. The pit design worked well, not only in the self-harvesting of these larvae, but kept nearly all of them off the walkways where they could be a problem.

A 3" PVC pipe with a 1" slit on one side was fastened at the top of the sloped wall. The slit was turned to the top of the slope so that larvae climbing up could enter directly into the pipe. This collection system worked very well and over 100 lb. of larvae were self-collected in about 2 months. In 1991, after the soldier fly population was well established production was better and about 600 pounds of larvae were self-collected. A 6" collection pipe replaced the original 3" pipe to prevent the masses of exiting larvae from blocking this pipe. Extrapolation from our small facility indicates that a moderate sized commercial facility (20,000 hens), could harvest well over 13 tons of prepupae from June through December. On a dry basis these would contained 42% crude protein and 35% fat (Newton _et_ _al_., 1977). They have been successfully used in swine (Newton _et_ _al_., 1977), poultry (Hall, 1973) and fish (Bondari and Sheppard, 1981) diets.

RESULTS AND DISCUSSION

The self-collection system for the larvae worked almost perfectly. Ten percent of collections were released to produce adults to oviposite in the pits later. Periodic flushing of the collection pipe was not necessary. The larvae continued to crawl until they exited the end of the pipe into a collection container. This was a pleasant surprise because the dry larvae will be easier to handle.

Larvae were frozen and held until chemical preservation trials began. The high percentage corn treatments were the most promising but acidification was less than expected. We suspect the larvae possess factors which inhibit the bacterial fermentation. Direct acidification trials look promising.

The push-out of manure with the special designed tractor-driven scraper went well. This system should easily transfer to a commercial facility.

Initial establishment of a black soldier fly population was not listed as an objective in this study, but was, of course, necessary. This population was easily established by a one-time inoculation of less then 20 gallons of soldier fly larvae. These were collected in one day by two workers from a deep manure pit below a beef housing unit. Emerging adults reestablished a robust population in May of 1991.

The shallow flooding capability for early season fly control was evaluated in March and April 1991. Some house fly control was achieved but a redesign will be necessary. Soldier flies eliminated house flies by late May, and control was complete through December.

The economics of this manure management system are attractive. Construction costs should be less than for a flush system and resource recovery is greater. The only insecticide able to approach the level of control achievable with this system is

Larvadex®, when house flies are susceptible. With low levels of Larvadex® resistance soldier fly larvae provide house fly control superior to Larvadex® (Sheppard et al., 1989). Larvadex® costs an egg producer 10¢ per hen if used for 6 months. Thus a conservative value to place on house fly control with this soldier fly system is 10¢ per hen per year. Manure removal and surface application costs 65¢ per hen, per year in shallow pit houses (Ritter, 1992). Assuming 50% reduction in manure build-up through soldier fly activity (Sheppard, 1983) for half the year gives a 25% reduction on an annual basis. Actual reduction may be much more if manure basins deeper than 12" are used, and soldier fly larvae can digest manure from the previous winter. At any rate, the conservative 25% reduction estimate produces an economic benefit of 0.25 x 65¢ = 16.2¢ per hen per year. This assumes the manure is a liability, which it generally is in high production areas. Value of the dried larval feedstuff has been estimated at $340-400 per ton. At 44% dry matter, the fresh larvae are worth about $160 per ton or 8¢ per pound. So, the 1.32 lb of larvae produced per hen per year is worth 10.6¢. Adding the easily measured economic benefits of this system yields a total value of 36.8¢ per hen per year. This would net our small hypothetical 20,000 hen egg producer an extra $7,360.

Overall This recent study was very successful and we think we are close to being able to recommend a sound manure management system using the black soldier fly. We need to determine how soldier flies cope with a winters accumulation of manure. Meanwhile soldier flies can still control house flies and reduce manure bulk in less intensively managed situations. This system should easily adapt to swine waste management, and a trial is currently underway. Soldier flies can degrade almost any organic waste. They have even been found breeding in ketchup and formalin preserved tuna (May, 1961), and can eliminate house fly breeding in privies (Kilpatrick and Schoof, 1959).

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COMPOSTING POULTRY CARCASSES: MICROBIOLOGICAL SAFETY

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Every poultry production facility is faced with the reality of farm mortality. Disposing of these carcasses has been identified by the poultry industry as one of the most serious environmental problems that if not solved may limit future industry expansion (Donald and Blake, 1990).

Burial pits are still commonly used for the disposal of poultry farm carcasses; however, the persistence of residues in burial pits and the ground water contamination are recognized as potential environmental hazards. Incineration is one of the more biologically safe methods of disposal; however, it can be slow, expensive, and can affect air quality.

Due to these emerging environmental concerns, alternative methods of disposal must be made available to the poultry producer. The organic farming practice of composting has emerged as one alternative that provides an environmentally and biologically safe method of converting daily mortality losses into humus-like material useful as a soil amendment (Murphy and Handwerker, 1988). Composting is a controlled, natural process in which beneficial aerobic microorganisms (bacteria and fungi) reduce and transform organic wastes into a useful end product called compost (Donald et al., 1990a). For the composting of poultry farm mortalities, a prescribed amount of carcasses, litter, straw, and water provide the necessary mixture (Donald et al., 1990b; Murphy, 1988; Murphy and Handwerker, 1988).

For composting to be a truly viable method for the disposal of poultry farm mortalities, it is paramount that the composting process results in inactivation of pathogenic (avian and human) microorganisms prior to land application. It has been documented that bacterial pathogens (e.g. Listeria monocytogenes) can be transmitted from farm animals to humans via land application of contaminated compost and manure used as fertilizer (Schlech et al., 1983). Therefore, in evaluating composting or any other method of carcass disposal, avoidance of both human and avian disease transmission must be a major consideration.

To address these microbiological questions, we have been involved in ongoing work in field and controlled studies. Early studies indicated that coliform bacteria, indicators of how enteropathogenic bacteria would respond, are rapidly inactivated at typical temperatures achieved in an on-farm composter (Conner and Blake, 1990; Conner et al., 1991a; Conner et al., 1991b). Furthermore, by enumerating several bacterial types during composting, it has been found that changes in coliform populations provide a reliable biological means of determining composting efficacy in regards to pathogen inactivation. Further research directed toward determining the survival of specific pathogenic microorganisms has been proceeding and a summary of these studies and the findings will be reported here.

COMPOSTER EVALUATION

Microbiological Survey of Composters in Alabama

A total of 36 composters, primarily located in northern Alabama, were sampled for the presence of viable Salmonella, Listeria monocytogenes, and Campylobacter jejuni. Compost samples were obtained from the secondary bins of each unit, and were material that had completed secondary heating. Samples were obtained from a depth of ca. 18-24 inches using a soil test auger, then placed in a sterile bag and transported to Auburn University for analysis. The microbiological analysis for the three bacteria were conducted using standard USDA or FDA detection-isolation protocols.

Pathogen Challenge Studies

A two-stage composting unit was constructed according to published specifications (1) at Auburn University, Department of Poultry Science Research Farm. The unit consists of three primary bins (5 x 5 ft), three secondary bins (5 x 6 ft) and a litter storage area (10 x 12 ft).

During studies conducted to investigate biosecurity aspects of mortality composting, survival-inactivation of the pathogens

Salmonella enteritidis, S. typhimurium, S. senftenberg, Pasteurella multocida, Listeria monocytogenes, Escherichia coli 0157:H7 (HEC) and Aspergillus fumigatus or A. flavus was determined during the two-stage composting process with and without added bulking materials (carbon sources) (i.e. wheat straw, peanut hulls). Each test culture was either inoculated directly onto carcasses or into tubes of brain heart infusion with 0.5% agar, and placed into the composter unit at 4 different, prescribed locations at the initiation of the composting process. For direct carcass inoculation studies, compost samples were periodically obtained and analyzed for the presence of the test culture, whereas in tube studies, sample tubes were obtained and analyzed for viability of test cultures after completion of the primary and secondary composting cycle.

FINDINGS
MICROBIOLOGICAL SAFETY

Composter Survey

None of the samples from the 36 composters yielded viable Salmonella, Listeria monocytogenes or Campylobacter jejuni. Again, all samples were from compost that had received the recommended two-stage process. These data indicate that under the various field conditions in which these composters were operated, the target bacteria were effectively inactivated. Furthermore, data suggest that these composters were managed properly to ensure a biosecure process.

Challenge Studies

In these studies, specific pathogens were inoculated or placed into the materials used for preparation of carcass compost; that is, the compost process was "challenged" with various pathogens.

In one study, carcasses were inoculated with S. typhimurium (10^6 CFU/carcass) and placed into the composting unit with varying amounts (0, 10, 20%) of wheat straw as a bulking material. Over the compost cycle, temperatures were determined using a data logger (Grant, SE, Inc., Dayton, Ohio) and compost samples were obtained periodically and analyzed for S. typhimurium. The temperature profile obtained during primary composting is shown in Figure 1. With 20% WS, which is twice the recommended level, temperatures reached 65°C; with 10% WS, 52°C; and with 0% WS, 50°C. Under these conditions, S. typhimurium were effectively inactivated (Table 1). Although S. typhimurium were inactivated in compost with no added bulking material, this compost was of very poor quality as evidenced by a strong putrified odor.

Table 1. Recovery of S. typhimurium From Compost Prepared with Artificially Contaminated Carcasses

Amount of straw	Primary Cycle Day: 0[1]	3	6	9	Secondary Cycle Day: 15	20	26	33
0%	+[2]	0[3]	0	0	0	0	0	0
10%	+	+	0	0	0	0	0	0
20%	+	+	0	0	+	0	0	0

[1]Day 0 = day last layer added to primary bin. Subsequent days from this point.
[2]Viable S. typhimurim recovered.
[3]No S. typhimurium recovered.

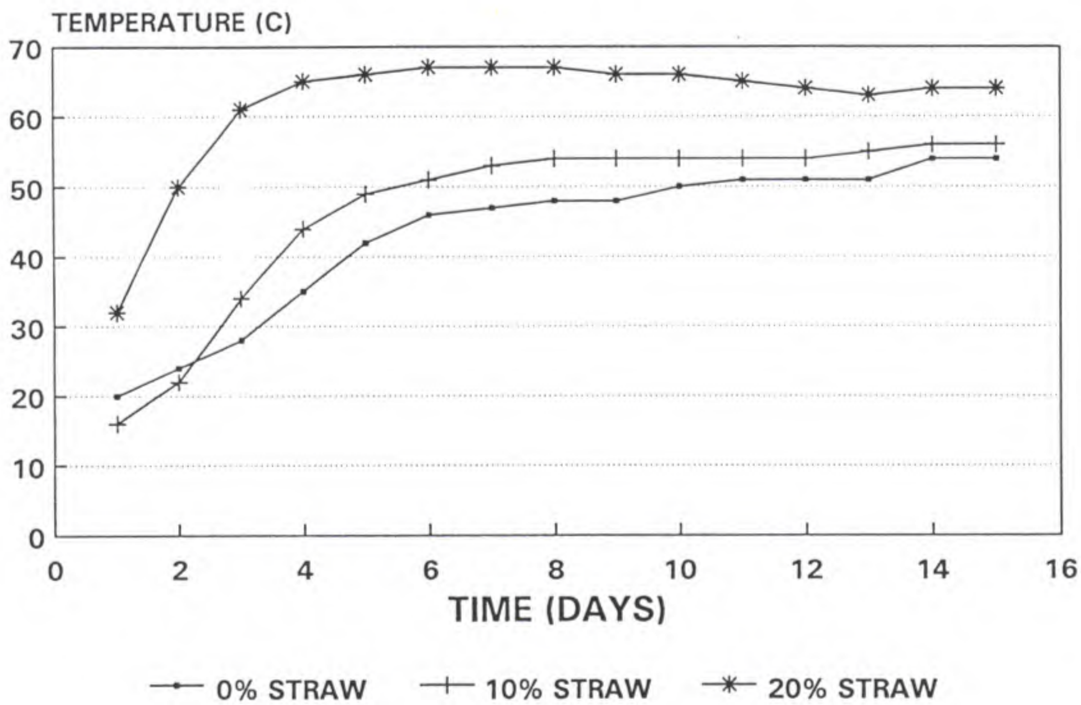

Figure 1. Effect of amount of bulking material, wheat straw, on temperature of primary mortality composting.

In similar studies, tubes containing the various cultures of pathogenic bacteria (10^9 CFU) and fungi (10^7 spores) were placed at 4 locations into the compost bins during the daily layering procedures: 4 ft deep (layer 2) at center, 4 ft deep at front slats, 2 ft deep (layer 4) at center, and 2 ft deep at front slats. At the completion of primary composting, culture tubes were retrieved and analyzed for viability. A duplicate set of tubes of each test organism was initially placed into the primary bins; therefore, the second set of tubes was removed with the compost and placed into the secondary bins at the same relative positions as in the primary bins. This second set of tubes was removed and analyzed for viability at the completion of the secondary cycle. Since WS is the most recommended bulking material, only microbiological data obtained with this material are shown (Table 2). The results were similar for compost prepared with peanut hulls. None of the bacterial pathogens were recovered following primary (or secondary) composting with 10 and 20% WS, while bacteria survived primary composting when no WS was used. However, no viable test cultures were recovered under any test conditions following the secondary cycle. This indicates that composting effectively inactivated tested pathogenic microbes.

Table 2. Recovery (summary of 3 exp.) of cultures places at various locations and subjected to composting with 0, 10 and 20% wheat straw (WS)

	Primary Cycle												Secondary Cycle											
	0% WS				10% WS				20% WS				0% WS				10% WS				20% WS			
Culture[1]	A[2]	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D
ST	0[3]	+[4]	+	+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SE	0	+	+	+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SS	0	+	+	+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
EC	0	+	+	+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PM	0	0	+	+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LM	0	+	+	+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
AF	0	+	+	+	0	+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
AFl	0	0	+	+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

[1]All cultures placed at composter site at ambient conditions were viable at both sample times. ST = _Salmonella typhimurium_, SE = _S. enteritidis_, SS = _S. senflenberg_, EC = _Escherichia coli_ 0157:H7, PM = _Pasteurella nultocida_, LM = _Listeria monocytogenes_, AF = _Aspergillus Fumigatus_, AFl = _A. flavus_.
[2]Letter designate posiiton of cultures in compost bin: A=2′ deep at center; B=2′ deep at 4" from bin front; C=4′ deep at center; D=4′ deep at 4" from bin front.
[3]No viable cells or spores detected.
[4]Viable cells or spores recovered.

SUMMARY

When properly managed, composting is a safe (biosecure), relatively inexpensive and environmentally sound means for managing poultry farm mortalities. A well managed composter will generate temperatures capable of destroying many avian and human pathogenic bacteria that may be associated with carcasses. According to various studies, two-stage composting in which the compost pile is aerated (by transferring compost) to produce a secondary heat cycle is necessary for pathogen destruction. Therefore, aeration is apparently an essential component for maintaining the biosecurity of composting. Furthermore, the field survey indicates that sampled composters are effectively providing these conditions.

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IMMOBILIZATION OF PHOSPHORUS IN POULTRY LITTER WITH ALUMINUM, CALCIUM AND IRON AMENDMENTS

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Phosphorus (P) runoff from fields receiving poultry litter has been identified as one of the primary factors affecting water quality in poultry producing regions. Each broiler produces approximately 1.5 kg of poultry litter over a 10-week growing cycle (Perkins et al., 1964). This litter contains 8-25.8 g P kg^{-1}, with soluble reactive P levels up to 4.9 g P kg^{-1} (Edwards and Daniel, 1992). Recent studies have shown that most (80-90%) of the P runoff from pastures receiving poultry litter is dissolved inorganic P, with only small amounts of particulate P (T.C. Daniel, personal communication). One solution to this problem may be chemical precipitation. Compounds such as slaked lime ($Ca(OH)_2$) or alum ($Al_2(SO_4)_3.14H_2O$) could be added to the litter before field application, resulting in P precipitation. If conducted properly, P precipitation could result in the formation of minerals which are stable over geologic time periods, reducing the threat of eutrophication of surface waters in poultry producing regions.

Precipitation reactions for aluminum, calcium, and iron phosphates are:

$$Al_2(SO_4)_3.14H_2O + 2PO_4^{3-} \text{-->} 2AlPO_4 + 3SO_4^{2-} + 14H_2O$$
alum

$$Fe_2(SO_4)_3.14H_2O + 2PO_4^{3-} \text{-->} 2FePO_4 + 3SO_4^{2-} + 14\ H_2O$$
ferric sulfate

$$5Ca(OH)_2 + 3H_2PO_4^- + 3H^+ \text{-->} Ca_5(PO_4)_3OH + 9H_2O$$
slaked lime

Poultry production provides an ideal setting for the use of chemical precipitants. At present, when broilers reach maturity and are removed from the houses, the chicken litter is collected and spread onto adjacent pastures. This material has extremely high concentrations of water soluble P (>2000 mg P/kg). When the first heavy rainfall event occurs, P is transported with runoff water into nearby water bodies. If alum or slaked lime were applied to the litter prior to removal from the houses, the water soluble P could be converted to a mineral form, which would not be susceptible to leaching or runoff. The objective of this study was to determine if P in poultry litter could be precipitated using Al, Ca, and/or Fe amendments.

METHODS AND MATERIALS

Twenty grams (dry weight basis) of fresh poultry litter were weighed out into glass bottles. The litter was amended with Al, Ca, and Fe compounds to induce P precipitation. Materials tested included alum, sodium aluminate, quick lime, slaked lime, gypsum, ferrous chloride, ferric chloride, ferrous sulfate and ferric sulfate. After the amendments were added to the litter, enough deionized water was added to achieve a water content of 20% by volume. The litter was then incubated in the dark at 25°C for one week. At the end of this period, the litter was transferred to polycarbonate centrifuge tubes, shaken for two hours with 200 ml of deionized water, and centrifuged at 6000 RPM for 20 minutes. Unfiltered samples were taken for pH. Filtered samples (0.45 um millipore filters) were taken for soluble reactive phosphorus (SRP). Soluble reactive P was determined using an ascorbic acid technique, according to APHA method 424-G (APHA, 1985).

RESULTS AND DISCUSSION

Calcium hydroxide ($Ca(OH)_2$) decreased the water soluble P levels in the litter from over 2000 mg P/kg to less than 1 mg P/kg when 1.2 g calcium oxide was added to 20 grams litter (Fig. 1). These data suggest that P runoff from fields receiving poultry litter could be decreased by orders of magnitude if the litter were treated with $Ca(OH)_2$ before applying it to the field. Calcium oxide (CaO) decreased P solubility in poultry litter in the same manner as $Ca(OH)_2$. Since $Ca(OH)_2$ is less dangerous to work with, this treatment would be preferable to CaO.

Gypsum ($CaSO_4$) decreased SRP from over 2000 mg P kg^{-1} to approximately 700 mg P kg^{-1} at the 100 g kg^{-1} rate (Fig. 1). Phosphorus removal by this treatment is probably a precipitation reaction, whereas with the other Ca amendments it is probably a mixture of adsorption and precipitation. Apparently, the lowest rate of gypsum was high enough to exceed the solubility product. Therefore, increasing rates did not influence P. Phosphorus precipitation could be enhanced with gypsum if the pH was increased to 8 or higher.

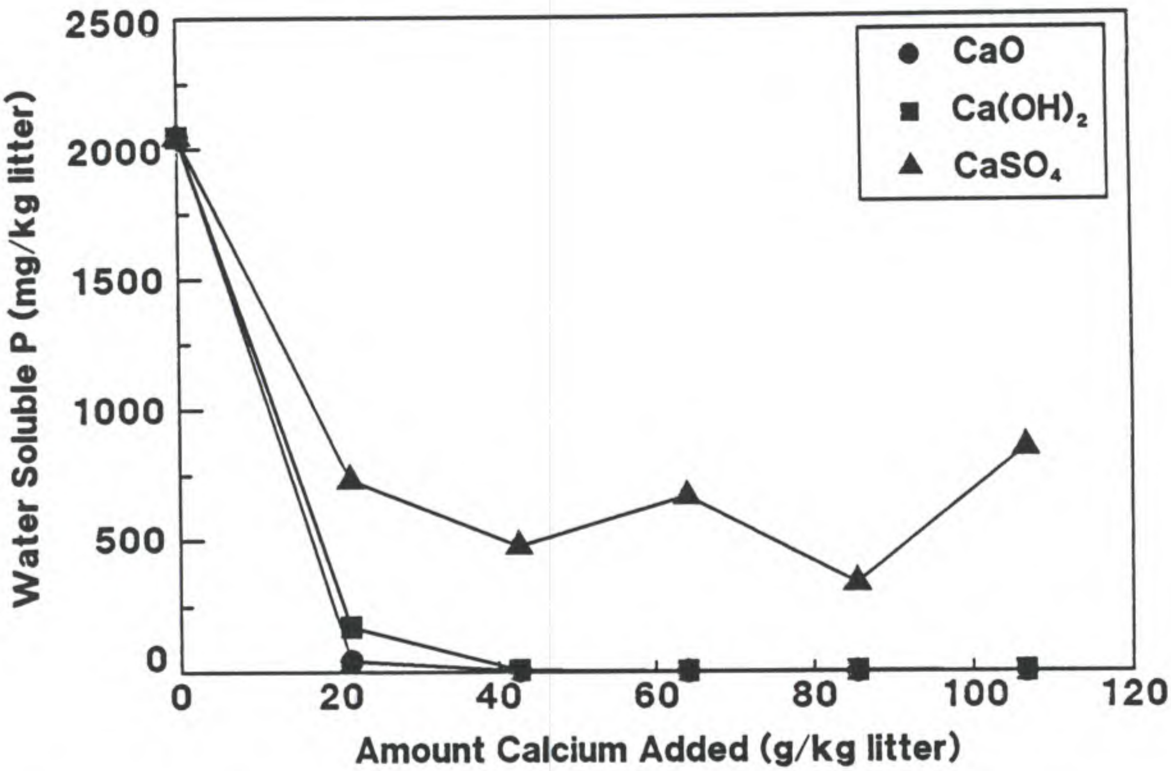

Figure 1. Water soluble P in poultry litter as a function of the amount of calcium added.

Alum additions greatly decreased water soluble P (Fig. 2). Without $CaCO_3$ to buffer the pH, water soluble P increased at the highest alum rates. This was due to the acidity created by the alum, which apparently caused acid hydrolysis of organic P, resulting in higher water soluble P in these treatments than the controls. However, when sufficient $CaCO_3$ was added with the alum to maintain a pH near 6.0, 100% P precipitation was achieved. Nesbitt (1973) indicated that the optimum pH range for P removal with alum was 6.0 to 6.3.

Sodium aluminate decreased SRP levels to around 600 mg P kg^{-1} litter at the lowest rate (Fig. 2). Increasing rates of sodium aluminate did not decrease water soluble P, which was probably due to elevated pH at the higher rates.

Additions of ferric iron as $Fe_2(SO_4)_3$ or $FeCl_3$ greatly decreased P solubility at the lower rates, but increased the solubility at the higher rates (Fig. 3). Increases in SRP at the higher rates was probably due to acid hydrolysis of organic P, since the pH of these two treatments approached 2 at the higher rates. Unfortunately, $CaCO_3$ additions were not made with these two treatments. Nesbitt (1973) indicated that the optimum pH for P removal with $FeCl_3$ additions was 7.1. Therefore, precipitation using these compounds could be enhanced if the pH of the litter were maintained near 7.

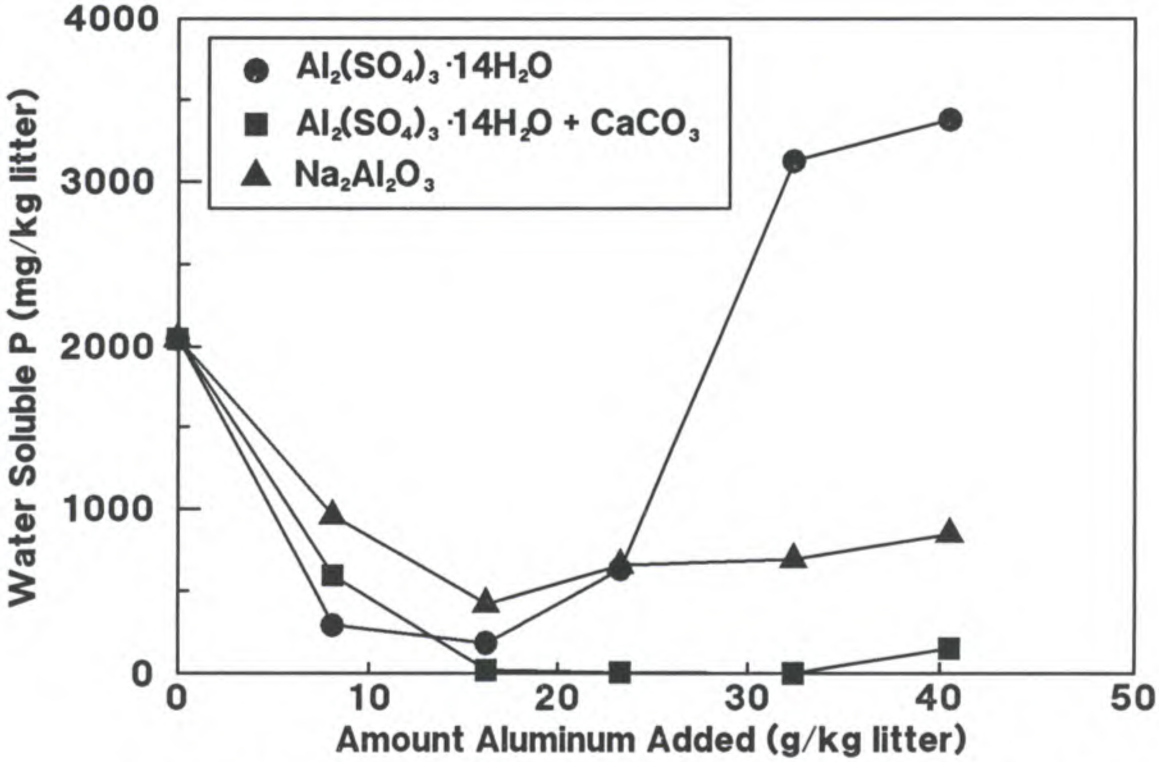

Figure 2. Water soluble P in poultry litter as a function of the amount of aluminum added.

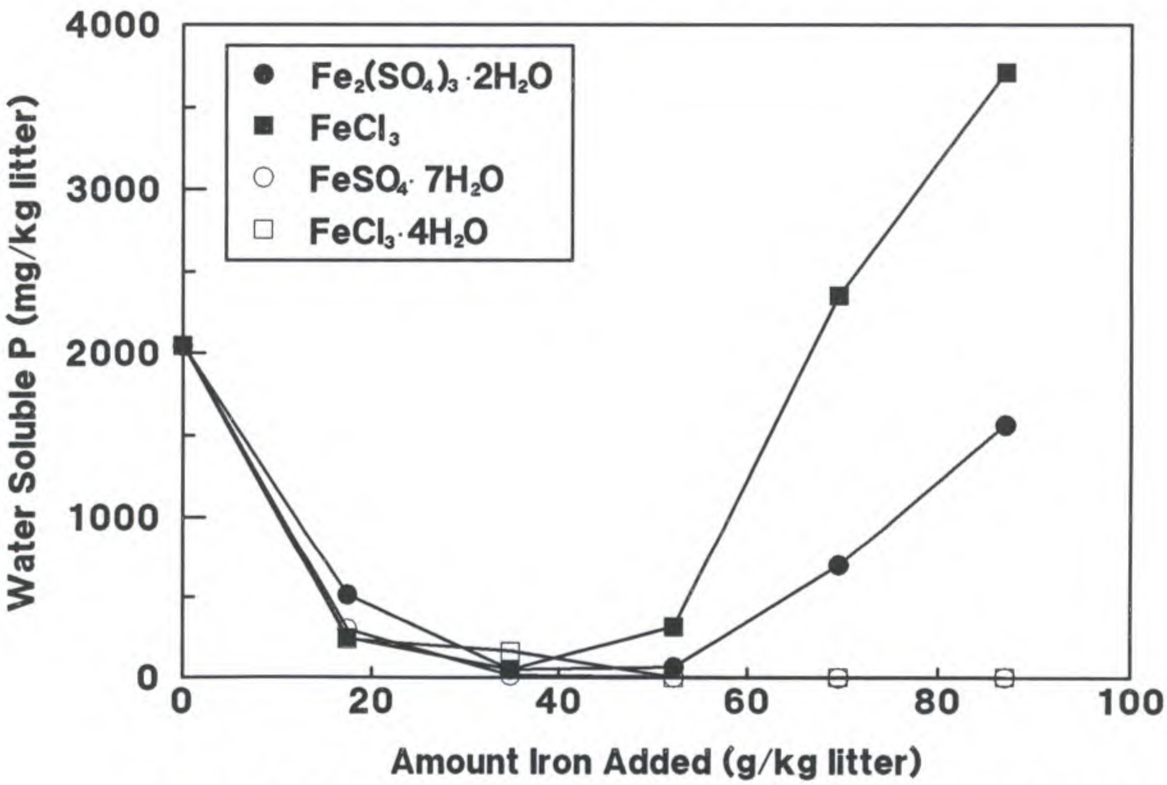

Figure 3. Water soluble P in poultry litter as a function of the amount of iron added.

Ferrous sulfate ($FeSO_4$) additions greatly decreased the solubility of P in poultry litter (Fig. 3). Water soluble P concentrations were not significantly different in the $FeSO_4$ treatment amended with $CaCO_3$, indicating that P removal with this compound is less pH dependent than with some of the other Fe compounds.

Additions of ferrous chloride alone or in combination with $CaCO_3$ greatly decreased P solubility (Fig. 3). Additions of calcitic limestone in conjunction with ferrous chloride resulted in 100% P removal at lower rates than ferrous chloride alone. Nesbitt (1973) indicated that the optimum pH for ferric chloride ($FeCl_3$) additions was 7.1. Since ferrous iron will be oxidized to ferric iron in soil and litter, the optimum pH for ferrous chloride is probably very close to that value.

The best information on P precipitation has been provided by researchers studying wastewater treatment. In a review of Swedish wastewater treatment plants, Ulmgren (1975) found that treatment with alum and slaked lime not only reduces P content in effluent water, but also decreases suspended solids, BOD, heavy metals, worm eggs and parasites.

It should be noted that alum and lime are not exotic, costly chemicals, but are rather inexpensive and locally available. Lime (CaO or $Ca(OH)_2$) costs approximately $55 per metric ton. Results from this study indicate that 50 kg of $Ca(OH)_2$ per metric ton of litter may be adequate to precipitate the P. Since there are 20 metric tonnes of litter produced per house per growout (each house contains 15,000 to 20,000 birds), then one ton of $Ca(OH)_2$ is needed per house per growout. Assuming five growouts per year, the annual cost of slaked lime for one house would be $275. Gross incomes per house normally exceed $50,000 per year. Therefore, the cost of $Ca(OH)_2$ needed for P precipitation would be less than 0.5% of the gross income, which should be economically feasible. However, before a valid economic analysis of this process can be made, on-farm experiments need to be conducted to determine if treatment levels found in this study are adequate.

The results of this study suggest that treating litter prior to field application with some of these compounds could reduce the amount of soluble P in runoff from litter-amended pastures by orders of magnitude. Phosphorus precipitation may also allow producers to increase the quantity of litter applied to a given area, which would decrease transportation costs. Soils which have received large quantities of litter in the past and are currently testing high in P could also be remediated by alum and/or lime additions, which would effectively increase the P sorption capacity of the soils.

Although the results of this study indicate that it is possible to precipitate P in chicken litter, many questions regarding chemical precipitation immediately arise. A partial list of these questions is as follows: (1) Is this practice economically feasible? (2) Would the P minerals formed by this process be geologically stable? (3) Would there be beneficial and/or detrimental side effects from this practice?

CONCLUSIONS

Although P precipitation using chemical amendments has been used for over 30 years for wastewater treatment, there have been no reports in the literature of using this technology on animal manures. The results of this study showed that P precipitation in poultry litter can be achieved using Al, Ca, and/or Fe amendments. Water soluble P levels in poultry litter were decreased from over 2,000 mg P kg^{-1} to less than 1 mg P kg^{-1} in many of the treatments. The results of this study also suggest that this practice may be economically feasible, if $Ca(OH)_2$ is used. Therefore, chemical precipitation of P in litter may be a best management practice in situations where eutrophication of adjacent water bodies due to P runoff has been identified. More research is needed to determine if there are any detrimental and/or beneficial aspects of this practice.

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PROCESSING

WORKSHOP

DEVELOPING A WATER CONSERVATION AND WASTE MINIMIZATION PLAN

Conducted by:

Roy Carawan	North Carolina State University
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Eldridge Collins	Virginia Tech
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During the previous two days, speakers have presented data that they have collected to define water use and wastewater loading patterns. In their presentations, the speakers have given only brief explanations of their data collection methods. These explanations may have been too brief to be used in the development of an in plant study. The purpose of this workshop is to give a detailed method to develop a water conservation and a waste minimization plan.

Is the development and implementation of a minimization plan worth the effort?

This will be a management decision based on individual plant situations.

A starting point will be an assumption of a broiler processing plant.

250,000 birds per day
5.5 gallons per bird
$3.00 per 1,000 gallons for water and wastewater treatment
0.08 pounds of BOD_5 per bird at 3 cents per pound for BOD_5 treatment

After water conservation and waste minimization plan implemented.

250,000 birds per day
3.5 gallons per bird
$3.00 per 1,000 gallons for water and wastewater treatment
0.04 pounds of BOD_5 per bird at 3 cents per pound for BOD_5 treatment

Cost Savings:

500,000 gallons per day at $3.00 per 1,000 gallons = $1,500 per day
10,000 pounds of BOD_5 at 3 cents per pound = $300

Total daily savings = $1,800

Annual Savings (260 days per year) = $468,000

Based on this plant assumption, there is an opportunity to reduce costs by almost a half million dollars per year. As water costs increase, the annual savings will probably approach $1 million per year by the turn of the century.

CALCULATIONS OF FLOW VOLUMES

Water Meters

Water meters commonly used in poultry processing plants measure water in 1000's of gallons, 100's of cubic feet and 100's of gallons. Water and wastewater costs are calculated either **1,000's of gallons** or **100's of cubic feet**. One hundred cubic feet of water contains 748 gallons. For simplified calculation, 750 gallons per 100 cubic feet can be used.

Reading water meters accurately seems to be a simple task, however, many times unless people are trained, the data collected is not accurate.

There seems to be four common errors.

1. The fixed zeros are not consistently recorded.

2. In reading five digits on the meter face, one digit will not be recorded.

3. A pair of digits are reversed.

4. The time when meters are read is not accurately recorded.

To accurately read water meters, the following method has been successful.

1. Denote the fixed zeros by drawing a line over the fixed zero's. Example: 089437000.

2. Have the meter reader count the number of recorded digits to insure that a digit was not omitted in recording.

3. Have the meter reader compare the number recorded with the display on the meter face to insure that a pair of digits were not reversed in recording.

4. Record the time that the meter was read to the nearest minute. If reading water meters hourly to profile a flow, a five minute variation in the time of reading will cause an 8 percent error in the flow volume calculation.

Exercise 1:

A water meter measuring in 1,000 of gallons was read at hourly intervals to determine hourly water costs. Water and wastewater was billed by the municipality at $2.25 per 100 cubic feet. What was the hourly cost?

Time	Meter Reading	100's ft^3	Cost
9:00 am	059341000		
10:00 am	059401000		
11:00 am	059463000		
9-10 am	059401000		
	059341000		
	60,000 gallons		
10-11 am	059463000		
	059401000		
	62,000 gallons		

Exercise 2:

Water meters that read in 100's of gallons are placed on two inside/outside bird washers. The meters were read at the beginning of processing (7:00am) and again at the end of the second processing shift (11:00pm). If water and wastewater cost $2.25 per 100 cubic feet, how much did it cost to operate each inside/outside bird washer each day?

	Meter Reading		Cost/day	
Time	M1	M2	M1	M2
7:00 am	472300	646200		
11:00 pm	481900	665400		

FLUMES

Flumes are flow measuring structures made to a geometrical shape so that a flow height at a certain point can be converted to a flow volume. The most common flume installed in the waste stream of poultry processing plants is the Parshall flume. Although many plants have Parshall flumes installed in the waste stream, few plants use them to calculate flow patterns. The flume can be a valuable device to calculate flow and waste loading patterns.

To accurately measure, the Parshall flume should be properly installed.

1. The flume should be installed so that the bottom of the throat section is level in both the long axis and cross axis.

2. Free flow conditions should exist in the Parshall flume. To determine if free flow conditions exist, the flow height should be measured at point Ha and Hb. If the ratio of flow height between Ha and Hb is greater than 0.60 then free flow conditions do not exist and the equations for free flow conditions will not give accurate flow measurements unless flow heights at both Ha and Hb are measured simultaneously. The calculations for submerged flow conditions are more complicated than free flow conditions. It is probably easier to modify the flume to give free flow conditions than to do the more complicated calculations required for submerged flow conditions. When free flow conditions exist, the flow height at Ha is measured and converted into flow volumes.

The most common Parshall flume used by poultry processors seems to be the 6 inch flume although some 9 and 12 inch flumes are used.

To calculate the flow volume through a Parshall flume, the flow height at Ha is measured in inches and the flow height is converted to decimal feet.

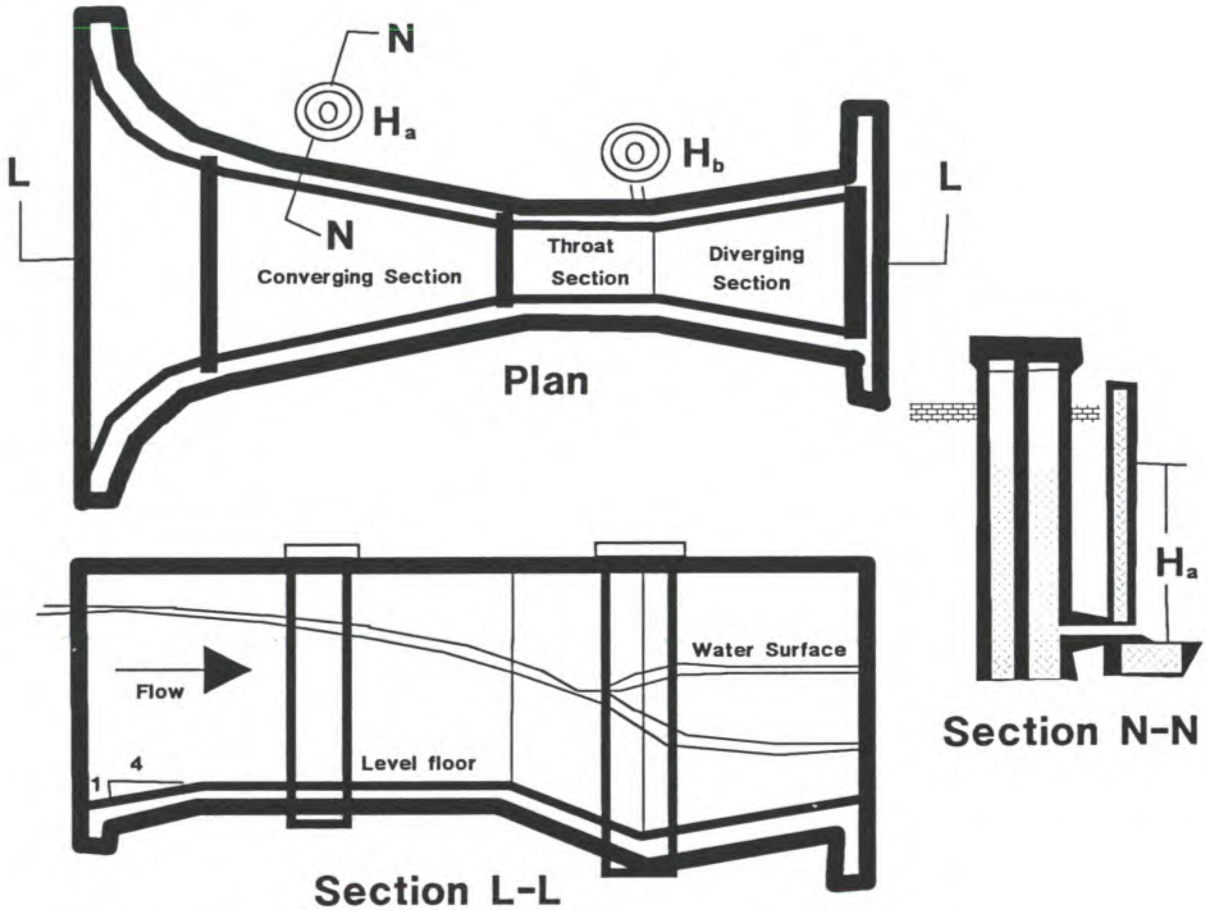
Example:

A flow height of 6 inches is measured at Ha in a 6 inch Parshall flume.

$$\frac{6 \text{ inches}}{12 \text{ inches}} = 0.50 \text{ feet} = H$$

This value is plugged into the equation for a 6" Parshall flume for "H".

$$CFS = 2.06\ H^{1.58} = 2.06\ (0.5^{1.58}) = 0.69\ CFS = \text{cubic feet/sec}$$



The Parshall Measuring Flume

Legend

H = Flow height   L = Length

N = Depth of depression in throat below crest

The solution to the equation gives flow volumes in cubic feet per second.

Tables can also be used.

Exercise 3:
The flow height through a 6" Parshall flume was measured at:

A. 6"

B. 9"

C. 12"

What was the flow volume in gallons per second at each of these flow heights?

WEIRS

A weir is a geometrical shape cut into a flat surface. Based on the geometrical shape, like the Parshall flume, a measured flow height can be converted to a flow volume. There are several types of weirs, however, for the purposes of this exercise the "V" notch weir will be used because it is the most common type used in poultry processing.

A. To properly install a "V" notch weir there must be sufficient change in elevation of the water so that a free air space can form under the discharge of the weir.

B. The weir should be installed perpendicular to the flow.

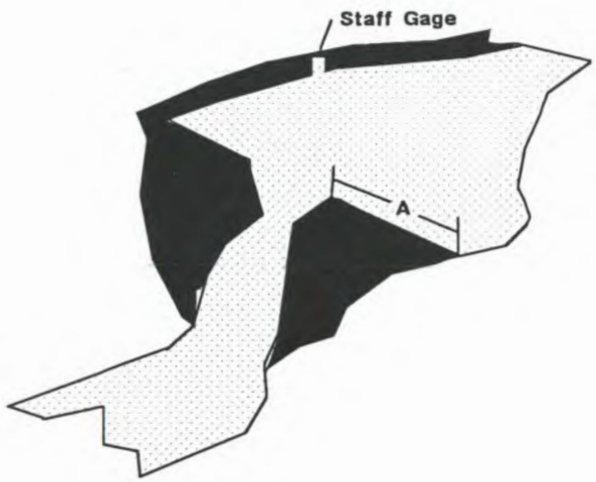
C. The edge of the weir should be sharp and debris must be kept from the crest for accurate measurement. A "V" notch weir will not accurately measure flows that have large solids such as feathers and viscera as they will rapidly plug the "V" notch.

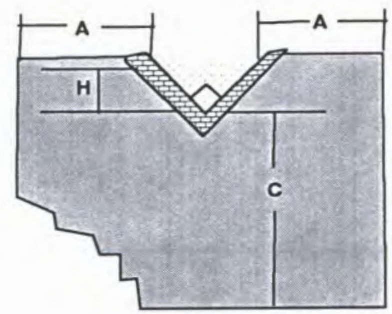
D. A clean out plug should be installed in the weir plate at a point below the "V" notch. Solids tend to settle behind the plate. When this space fills with solids, measurement accuracy is reduced.

E. Flow height through the weir is measured at a point behind the "drawdown" point of the weir. The flow height should be measured no closer to the weir plate than 3-4 times the maximum flow height through the weir.

To calculate the flow volume through a 90 degree "V" notch weir, measure the flow height in inches and convert it to decimal feet as in the Parshall flume.
Example: Flow height = 6"
6/12 = 0.5 feet of flow height

90° V Notch Weir





upstream side

Legend

A = Greater than twice H

C = At least twice H

H = Maximum head

To determine the flow volume through a 90 degree "V" notch weir use the equation 2.5 $H^{2.5}$ where H is the flow height in decimal feet.

$2.5\ (0.5^{2.5})$ = Flow volume in cubic feet per second (CFS) = 0.44

<u>Exercises 4</u>:
What is the flow volume in gallons per second when the flow height through a 90 degree "V" notch weir is?

3"

6"

9"

12"

PIPES

Flow volumes through pipes can be determined by measuring the flow height through the pipe, the flow velocity and the slope of the pipe, however, the method is complicated and would require more time than is available in this workshop.

FLOOR DRAINS

An estimation of flow through a rectangular floor drain can be calculated by measuring the width of the floor drain, the flow depth and the flow velocity.

Example:
The depth of water flowing through a 12 inch wide rectangular floor drain is measured at 6 inches. A 10 foot section of the floor drain is laid off. Dye is added into the water and the time required for the dye to move 10 feet is measured at 10 seconds. What is flow volume?

$$\frac{10 \text{ feet}}{10 \text{ seconds}} = 1.0 \text{ ft per second}$$

$$\text{Flow height} \quad \frac{6 \text{ inches}}{12 \text{ inches/ft}} = 0.5 \text{ ft}$$

$$\text{Flow width} \quad \frac{12 \text{ inches}}{12 \text{ inches}} = 1.0 \text{ ft}$$

Width x Height x Velocity = Cubic feet per second
1.0 x 0.5 x 1.0 = 0.5 cubic feet per second

This procedure should be repeated 4 to 5 times and an average flow calculated.

Exercise 5:

	Drain Width	Flow Height	Flow Velocity	Flow Volume gal/sec
A	12 inches	6 inches	1.0 ft/sec	
B	12 inches	4 inches	0.75 ft/sec	
C	12 inches	12 inches	1.5 ft/sec	
D	12 inches	8 inches	1.25 ft/sec	
			Average Flow	

MEASURING VOLUMES BY TIMING

Flow volumes from hoses, pieces of equipment, goosenecks, etc. can be determined by measuring the time required to collect a volume or weight of water.

A. Time required to collect a volume. A container that is calibrated in quarts is placed under the flow and the time required to collect a volume is measured.

Exercise 6:
A plant processes eight hours per day 260 days per year. What is the annual cost of operating these four goosenecks? Water cost $3.00 per 1000 gallons.

	Volume Collected	Time	Gallons per Minute	Annual Cost
1.	3 quarts	30 seconds		
2.	2 quarts	45 seconds		
3.	5 quarts	20 seconds		
4.	2 quarts	30 seconds		

(a) Divide seconds by 60 seconds per minute to determine the fraction of a minute required to collect the measured volume.

$$\frac{30 \text{ sec}}{60 \text{ sec/min}} = 0.5 \text{ minutes}$$

(b) Divide volume by fractional minute.

$$\frac{3.0 \text{ quarts}}{0.5 \text{ minute}} = 6.0 \text{ quarts per minute} = 1.5 \text{ gal/min}$$

(c) Calculate annual cost.

1.5 gal/min x 60 min/hr x 8 hrs/day x 260 processing days/yr = Annual gallons

$$\frac{\text{Annual gallons}}{1{,}000 \text{ gallons}} \times \$3.00/1{,}000 \text{ gallons} = \text{Annual Cost}$$

B. Weight of water collected in a measured time.

Flow volumes can also be calculated by measuring the time required to collect a weight of water and then converting the weight of water to a volume of water. WATER WEIGHS 8.34 POUNDS PER GALLON.

Exercise 7:
The container weighed 3 pounds.

	Weight Collected	Time	Gal per Minute	Annual Cost
1.	7.5 lbs	20 secs		
2.	6.5 lbs	15 secs		
3.	9.0 lbs	30 secs		
4.	10.0 lbs	40 secs		

(a) Measure weight of water and divide by 8.34 to give volume in gallons.

(b) Divide seconds by 60 to give fractions of minutes.

(c) Divide volume by fraction of minute to give gallons per minute.

(d) Calculate annual cost as in previous problem.

Measuring flow volumes by weight is a more accurate method than measuring by volume, however, the weighing method requires a scale that can be moved around the plant. Carrying buckets of water to a central scale will be very time consuming. When selecting a method, the ease of data collection versus accuracy should be considered.

CALCULATION OF VOLUMES OF ROUND AND SQUARE TANKS

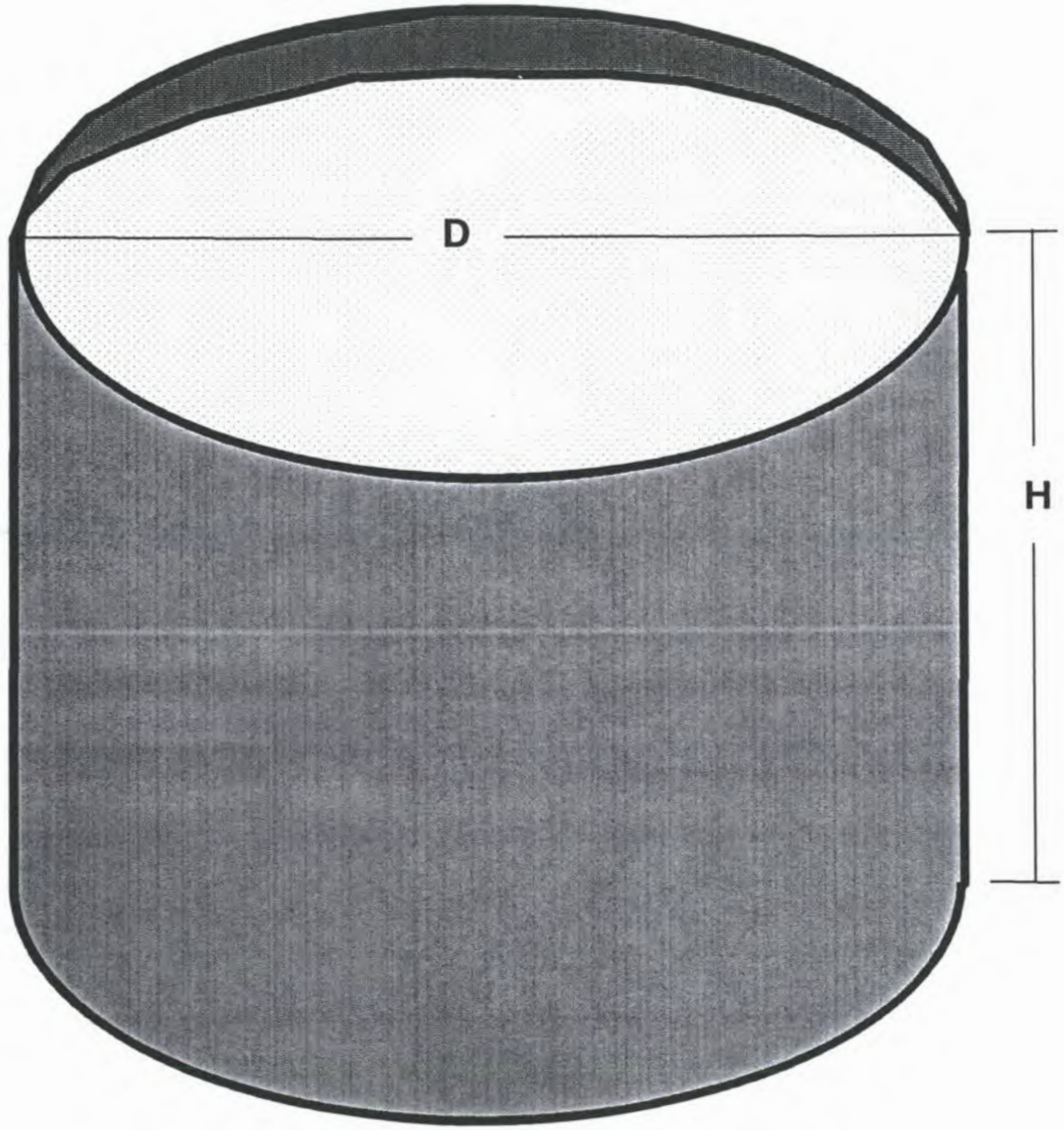
Calculation of tank volumes is important so that detention times for treatment can be determined. Round, square or rectangular tank volumes are determined by calculating the cubic foot volume of the tank. Gallons are calculated by multiplying the cubic foot volume by 7.50 gallons per cubic feet.

Volume of Round Tanks

To determine the volume of a round tank the following equation is used.

Volume in cubic feet = area of round top of the tank x depth of the tank

Round Tank



Legend

441

D = Diameter

H = Height

R = Radius = D/2

Area of top of the tank = π(radius ^{2}) = πr^2
The radius is the distance from the center of the tank to the outside wall. π(pi) is a constant and equals 3.1416

Example problem:
A round tank is found to have a radius of 25 feet and a depth of 10 feet. How many gallons of water will it hold?

Cubic feet = $\pi(25^2) = \pi(625)$ = 3.1416 (625) = 1964 square feet
1964 square feet x 10 foot depth = 19,6450 cubic feet
19,640 cubic feet x 7.50 gal/cubic foot = 147,725 gallons

Exercise 8:

Tank depth	Tank radius	Volume ft^3	Volume gallons
5 ft	10 ft		
10	30		
20	25		

Volume of Square Tanks

To determine the volume of square or rectangular tanks the height (H), length (L) and width (W) of the tank is measured in feet. The equation, HxLxW = cubic feet, will calculate the volume.

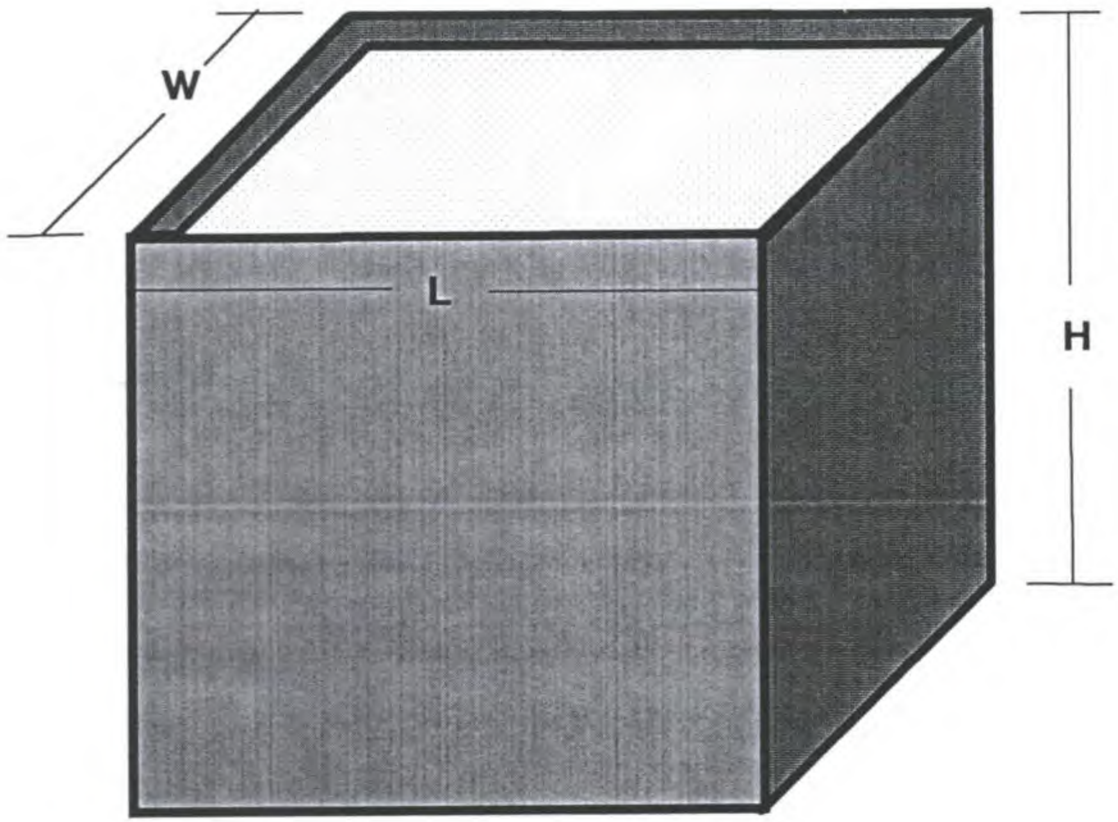
Example:

Length = 40′
Width = 10′
Height = 10′

L x W x H x 7.50 gal/ft^3
40 x 10 x 10 x 7.50 = 30,000 gallons

Exercise 9:
A DAF tank has a length of 30′, a width of 12′ and a depth of 8′. Water flowing into the tank is flowing through a 90° "V" notch weir. The flow height through the "V" notch weir is measured at 9". What is the detention time of the tank at this flow rate?

Square Tank



Legend

H = Height

L = Length

W = Width

BIOCHEMICAL OXYGEN DEMAND

Biochemical Oxygen Demand (BOD) measures the amount of oxygen required for microorganisms to digest organics in the waste stream to a stable form. When organics are discharged into a water course, the naturally occurring aerobic microorganisms digest the organics. In the digestion process, they consume oxygen dissolved in the water. If oxygen consumption is more rapid than it can be replaced from the atmosphere then the dissolved oxygen is depleted and aquatic organisms such as fish die from oxygen starvation. When dissolved oxygen concentrations are depleted below 1-2 mg/L the anaerobic microorganisms begin to digest the organics. Anaerobic digestion is not as complete as aerobic digestion and produces toxic compounds such as ammonia and H_2S. These anaerobic digestion compounds also produce noxious odors.

The BOD test was developed to determine the amount of oxygen required by the aerobic microorganisms to digest the organics. The test is performed by measuring the concentration of dissolved oxygen in a wastewater sample and incubating the sample at 20° C for 5 days in a sealed bottle. The difference in the Day 0 (DO_0) and Day 5 (DO_5) oxygen concentration is the amount of oxygen consumed and is called the BOD_5.

Example:
$DO_0 - DO_5 = BOD_5$ (mg/L)
$8.2 - 3.2 = 5.0$ mg/L of BOD_5

The microorganisms required 5.0 milligrams of oxygen to digest the organic matter in 1 liter of this wastewater.

Oxygen is poorly soluble in water. Only 8.0-8.4 mg of oxygen will dissolve in one liter of water. The organics in processing wastewater require much more than 8 mg/L of oxygen for microbial digestion. If undiluted wastewater is incubated, the microorganisms will rapidly deplete the oxygen and after 5 days of incubation there will be 0 mg/L of dissolved oxygen. The only thing you know is that the BOD_5 is greater than 8.2.

$DO_0 - DO_5 = BOD_5$
$8.2 - 0 = >8.2$ mg/L BOD_5

To solve this problem, the wastewater is diluted with water that has no oxygen demand. The dilution or series of dilutions are made so that all of the oxygen will not be depleted during incubation. Poultry processing final plant effluent normally has a BOD_5 of 1500 - 2000 mg/L. An appropriate dilution for this wastewater would be a 1:500 dilution, i.e., 2 mls of the wastewater is added to 998 mls of dilution water. The oxygen depletion over 5 days is measured and the depletion is multiplied by the dilution factor to give the BOD_5.

$DO_0 - DO_5$ x dilution factor = BOD_5
8.2 - 4.2 x 500 = 2,000 mg/L BOD_5

Exercise 10:

	DO_0	DO_5	Dilution Factor	BOD_5
1.	8.2	5.2	250	
2.	8.2	3.4	500	
3.	8.2	2.5	1,000	
4.	8.2	6.0	100	
5.	8.2	3.3	250	

CHEMICAL OXYGEN DEMAND

Chemical Oxygen Demand (COD) is a rapid method (2 hrs) of determining the concentration of organics in a waste stream. The test is based on using an oxidizing agent, potassium dichromate, sulfuric acid and catalysts (mercuric chloride and silver chloride) to chemically oxidize the organic matter. As the organic matter is oxidized the orange dichromate ion is reduced to the green chromium ion. The amount of organic matter oxidized is in proportion to the reduction of dichromate to chromium ion.

The color change is measured in a colorimeter or a spectrophotometer and expressed on a scale as mg/L COD.

COD is a rapid method of estimating the BOD_5 of a wastewater sample. The ratio of BOD_5 to COD in final plant effluent is about 2:1. To estimate BOD_5 divide COD by 2. Waste streams high in fat tend to have a higher BOD_5 to COD ratio, whereas, those low in fat have a tendency to have a lower BOD_5, COD ratio. Both tests should be run on a waste stream to establish the ratio.

TOTAL SUSPENDED SOLIDS (TSS)

Total Suspended Solids (TSS) is a procedure to measure the concentration of particulate matter in a wastewater sample. The TSS concentration is determined by filtering a measured volume of wastewater through a preweighed glass fiber filter. The filter is then dried at 103°C for 1-2 hours and reweighed. The weight picked up by the filter is the amount of particulate matter removed from the wastewater.

Example:
One hundred mls of wastewater was passed through a glass fiber filter that weighed 0.2500 grams. The filter was dried and reweighed at 0.3000 grams. What was the TSS (mg/L) of the wastewater sample?

$$\frac{\text{Filter + Sample Wt. - Filter Wt.}}{\text{mls of wastewater sample}} \times 1{,}000{,}000 = \text{mg/L TSS}$$

$$\frac{0.3000 - 0.2500}{100} \times 1{,}000{,}000 = 500 \text{ mg/L TSS}$$

Exercise 11:

Filter + Sample	Filter Wt.(gms)	Volume(mls)	TSS (mg/L)
1. 0.2727	0.2500	100	
2. 0.2844	0.2494	50	
3. 0.3133	0.2500	100	
4. 0.2903	0.2487	75	

TOTAL VOLATILE SOLIDS

Total Volatile Solids (TVS) measures the concentration of organic matter in a wastewater sample. The results can be obtained in 24 hours. TVS has an advantage over BOD_5 and COD because larger samples of wastewater can be used. BOD_5 is limited to 2-4 mls of wastewater and COD is limited to 2 mls. Many times it is difficult to accurately sample a wastewater sample using only 2 mls of sample. The sample volume of TVS is limited only to the practical size of a crucible.

TVS concentrations are determined by delivering a measured volume of wastewater into a tared clay crucible. The crucible and sample are dried to dryness at 103° C, usually 12-24 hours. The crucible is then cooled and weighed. It is then ashed in a muffle furnace at 550° C until the organic matter is burned, usually about 30 minutes. The crucible is then cooled and reweighed. The weight lost in the ashing process is the amount of organic matter in the wastewater sample.

Example Problem:

$$\frac{\text{Dried wt(gms) - Ashed wt(gms)}}{\text{sample volume}} \times 1{,}000{,}000 = \text{TVS mg/L}$$

Dried crucible + sample	62.1922
Ashed crucible + sample	62.1244
Sample Volume	100 mls

$$\frac{62.1922 - 62.1244}{100} \times 1{,}000{,}000 = 678 \text{ mg/L TVS}$$

Exercise 12:

	Volume(mls)	Dry wt(gms)	Ashed wt (gms)	TVS mg/L
1.	100	59.9203	59.7727	
2.	100	55.5544	55.4000	
3.	100	61.7727	61.6011	

DEVELOPING A WASTEWATER PROFILE

To develop a wastewater profile, two types of data are necessary.

1. The volume of wastewater discharged.
2. The concentration of contaminants in that wastewater.

Such a profile can determine such things as the amount of organics being discharged into a waste stream, the amount of sludge that will be produced by a DAF, or the amount of biological treatment required to treat a wastewater.

The following equation will determine the pounds of a contaminant in a volume of wastewater:

$$\frac{\text{Gallons of wastewater} \times 8.34 \text{ (wt of 1 gallon of water in pounds)} \times \text{Concentration of contaminants}}{1{,}000{,}000} = \text{Pounds}$$

Example Problem:

The height of wastewater flowing through a 90 degree "V" notch weir was measured at 10 inches during a 1 hour period. Wastewater was sampled during the hour and analyzed for BOD. The sample was diluted 1:500. The DO_0 was 8.2 mg/L and the DO_5 was 5.2 mg/L. How many pounds of BOD_5 flowed through the "V" notch weir during this hour?

Flow volume equation for "V" notch weir:

$CFS = 2.5\ (H^{2.5})$ CFS=Cubic feet per second

$CFS = 2.5\ (10/12^{2.5})$

$CFS = 2.5\ (0.634)$

$CFS = 1.59$

CFS x 7.50 = gal/sec

1.59 x 7.50 = 11.93 gal/sec

gal/sec x 60 = gallon/min

11.93 x 60 = 716 gal/min

gal/min x 60 = gal/hr

716 x 60 = 42,960 gal/hr

$DO_0 - DO_5 \times$ dilution factor = BOD_5 mg/L
8.2 - 5.2 x 500 = 1,500 mg/L BOD_5

$$\frac{42,960}{1,000,000} \times 8.34 \times 1,500 = 537 \text{ pounds BOD/hour}$$

Exercise 13:
Wastewater flowing through a 6" Parshall flume was measured at a flow height of 13 inches for a 1 hour period. Wastewater was sampled during this time and analyzed for BOD_5, COD, TSS and TVS. The following lab data was obtained. How many pounds of each contaminant flowed through the Parshall flume during this hour?

BOD			mg/L	Pounds
DO_0	DO_5	Dilution		
8.2	4.3	1:300		

COD

2,400

TSS

Filter Wt.	Filter + Sample Wt.	Volume
0.2525	0.3115	100 mls

TVS

Dry weight(gms)	Ashed weight(gms)	Volume
67.4107	67.2537	100 mls

By developing this type of data set over a 24 hour period, wastewater costs can be determined by measuring when and why excessive water is used and excessive contaminants are added into the waste stream. The data can be used to help answer the following types of questions.

1. What is our pounds per bird BOD_5 discharge? Pound per bird BOD_5 discharge has been shown to vary between 0.03 and 0.25. Could pretreatment cost, DAF sludge volume, aeration capacity etc. be reduced if less water was used and less contaminants added to the waste stream?

2. Can we increase plant capacity without expanding the waste treatment facility if we are more efficient in water use and contaminant exclusion from the stream?

3. In cook plant, can we determine excessive edible product being wasted by analyzing the waste stream?

EXERCISE SOLUTIONS

Exercise 1:

A water meter measuring in 1,000 of gallons was read at hourly intervals to determine hourly water costs. Water and wastewater was billed by the municipality at $2.25 per 100 cubic feet. What was the hourly cost?

Time	Meter Reading	100's ft^3	$Cost
9:00 am	059341000		
10:00 am	059401000	80.0	180
11:00 am	059463000	82.7	186

9-10 am
059401000
059341000
60,000 gallons

10-11 am
059463000
059401000
62,000 gallons

Exercise 2:
Water meters that read in 100's of gallons are placed on two inside/outside bird washers. The meters were read at the beginning of processing (7:00am) and again at the end of the second processing shift (11:00pm). If water and wastewater cost $2.25 per 100 cubic feet how much did it cost to operate each inside/outside bird washer?

	Meter Reading		Cost/day	
Time	M1	M2	M1	M2
7:00 am	472300	646200		
11:00 pm	481900	665400	28.80	57.60
gallons	9600	19,200		

Exercise 3:
The flow height through a 6" Parshall flume was measured at:

A. 6" 5.17

B. 9" 9.81

C. 12" 15.45

What was the flow volume in gallons per second at each of these flow heights?

Exercise 4:

What is the flow volume in gallons per second when the flow height through a 90 degree "V" notch weir is:

3"   0.59

6"   3.31

9"   9.13

12" 18.75

Exercise 5:

	Drain Width	Flow Height	Flow Velocity	Flow Volume gal/sec
A	12 inches	6 inches	1.0 ft/sec	3.75
B	12 inches	4 inches	0.75 ft/sec	1.86
C	12 inches	12 inches	1.5 ft/sec	11.25
D	12 inches	8 inches	1.25 ft/sec	6.28
			Average Flow	5.78

Exercise 6:

A plant processes eight hours per day, 260 days per year. What is the annual cost of operating these four goosenecks? Water costs $3.00 per 1000 gallons.

	Volume Collected	Time	Gallons/minute	Annual Cost
1.	3 quarts	30 seconds	1.50	561.60
2.	2 quarts	45 seconds	0.67	250.85
3.	5 quarts	20 seconds	3.75	1404.00
4.	2 quarts	30 seconds	1.00	374.40

Exercise 7:

The container weighed 3 pounds.

	Weight Collected	Time	Gallons/minute	Annual Cost
1.	7.5 lbs	20 seconds	1.62	$606.65
2.	6.5 lbs	15 seconds	1.69	$628.50
3.	9.0 lbs	30 seconds	1.44	$538.70
4.	10.0 lbs	40 seconds	1.25	$471.35

(a) Measure weight of water and divide by 8.34 to give volume in gallons.

(b) Divide seconds by 60 to give fractions of minutes.

(c) Divide volume by fraction of minute to give gallons per minute.

(d) Calculate annual cost as in previous Exercise 6.

Exercise 8:

Tank depth	Tank radius	Volume ft^3	Volume gallons
5 ft	10 ft	1,571	11,780
10	30	28,274	212,058
20	25	39,270	294,525

Exercise 9:

A DAF tank has a length of 30′, a width of 12′ and a depth of 8′. Water flowing into the tank is flowing through a 90° "V" notch weir. The flow height through the "V" notch weir is measured at 9". What is the detention time of the tank?

30 x 12 x 8 = 2880 ft^3 x 7.50 gal/ft^3 = 21,600 gallons
2.5 ($H^{2.5}$) = 2.5 ($0.75^{2.5}$) = 1.22 cfs x 7.50 gal/ft^3 = 9.13 gal/sec

$\frac{21{,}600 \text{ gallons}}{9.13 \text{ gal/sec}}$ = 2366 secs $\qquad \frac{2366}{60 \text{ sec/min}}$ = 39.4 min

Exercise 10:

	DO_o	DO_5	Dilution Factor	BOD_5
1.	8.2	5.2	250	750
2.	8.2	3.4	500	2400
3.	8.2	2.5	1,000	5700
4.	8.2	6.0	100	220
5.	8.2	3.3	250	1225

Exercise 11:

	Filter + Sample(gms)	Filter Wt.(gms)	Volume(mls)	TSS(mg/L)
1.	0.2727	0.2500	100	227
2.	0.2844	0.2494	50	700
3.	0.3133	0.2500	100	633
4.	0.2903	0.2487	75	555

Exercise 12:

	Volume(mls)	Dry wt(gms)	Ashed wt(gms)	TVS(mg/L)
1.	100	59.9203	59.7727	1476
2.	100	55.5544	55.4000	1544
3.	100	61.7727	61.6011	1716

Exercise 13:

Wastewater flowing through a 6" Parshall flume was measured at a flow height of 13 inches for a 1 hour period. Wastewater was sampled during this time and analyzed for BOD_5, COD, TSS and TVS. The following lab data was obtained. How many pounds of each contaminant flowed through the Parshall flume during this hour?

BOD				mg/L	pounds
DO_o 8.2	DO_5 4.3	Dilution 1:300		1170	616
COD 2400				2400	1264
TSS Filter Wt. 0.2525		Filter + Sample Wt. 0.3115	Volume 100 mls	590	311

TVS

Dry weight (gms)	Ashed weight (gms)	Volume 1570	827
67.4107	67.2537	100 mls	

6" Parshall flume equation 2.06 ($H^{1.58}$) = CFS
CFS = 2.06 ($1.08^{1.58}$) = 2.06(1.135) = 2.338 CFS
2.338 x 7.50 gal/ft^3 = 17.53 gal/sec x 3600 sec/hr
= 63,130 gal/hr

Pounds

BOD

$\frac{63,130}{1,000,000}$ x 8.34 x 1170 = 616

COD x 2400 = 1264
TSS x 570 = 300
TVS x 1570 = 827

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