NATIONAL POULTRY WASTE

MANAGEMENT SYMPOSIUM

Columbus, Ohio

April 18 and 19, 1988

Supported by

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FORWARD

At the meeting of the Poultry Science Association held at Oregon State University during August, 1987 an informal meeting of poultry scientists interested in poultry waste management was held. As a result of discussions held at this meeting, a decision was made to organize and hold a national symposium on this topic. It was felt that the time had arrived for a national educational effort on poultry wastes. A nationwide program advisory committee was established to provide inputs on the nature and format of the program as well as on program topics and potential speakers. Industry support for the program was also solicited. Considerable feedback was obtained both from educational and industry sources.

As a result the Symposium was organized to discuss the issues, problems and potential solutions to problems with poultry waste management and utilization. Growth and concentration of the poultry industry has resulted in large volumes of manure, used litter, hatchery wastes, dead birds, offal and wash water that need to be utilized or disposed of in way that minimize undesirable environmental impacts. Increasing concern for these matters is evident within the industry and by the public. While odor and insect nuisances are frequent problems, the long run problems with water pollution are becoming more important. More regulatory action can be anticipated in the future.

The program for the Symposium was organized on the basis of a general session to cover broad topics related to poultry wastes followed by simultaneous sessions on specific aspects of production wastes and processing wastes. The Symposium Proceedings is organized on the same basis. We wish to thank all those persons and firms that helped to make the Symposium successful and well attended.

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Nicholas Turkey Breeding Farms, Sonoma, California

Ohio Poultry Association, Columbus, Ohio

Tennessee Chemical Company, Atlanta, Georgia

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California Turkey Industry Board, Modes, California

Ciba-Geigy Corporation, Greensboro, North Carolina

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J. S. West Milling Company, Modesto, California

We wish to thank the supporters, sponsors, contributors, section chairmen and speakers for their efforts.

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Welcome

National Poultry Waste Management Symposium
April 18 and 19, 1988

Gerald Havenstein
Ohio State University

On behalf of the U.S.D.A.'s Cooperative Extension Service, the Ohio Cooperative Extension Service, many of the Poultry Extension specialists from around the nation, and the Department of Poultry Science here at the Ohio State University, it gives me a great deal of pleasure to WELCOME you to this NATIONAL SYMPOSIUM ON POULTRY WASTE MANAGEMENT. The symposium that you are about to participate in is the culmination of a great deal of effort by a large number of people from around this great nation of ours. The seed that eventually sprouted this effort was planted many months ago by Dr. Rich Reynnells during conversations with a number of researchers and poultry extension specialists from around the country who have been watching the fantastic expansion that has occurred in the size of the operations that we collectively refer to as the poultry industry. Those individuals indicated that although these large operations were certainly efficient, there was reason to be concerned about a number of potential problems associated with them and that the industry and university personnel should be jointly looking at solutions for such problems.

Potential problems that one might cite included such things as: 1) the inherent problems associated with the handling of the huge quantities of poultry manure and used litter produced by such operations; 2) problems associated with the control of flies and odors associated with the disposal of large amounts of poultry wastes; 3) problems related to the potential risks of stream and ground water pollution associated with such operations; 4) problems associated with the disposal of large numbers of dead birds, especially during periods of high heat stress or during the time of government-decreed depopulations from disease outbreaks; 5) problems associated with the humane disposal of cull chicks and poults and unwanted cockerels from egg-type hatcheries; 6) problems associated with the disposal of other hatchery wastes; 7) problems associated with the treatment and control of processing plant offal and waste waters, etc. Increasing concern related to these matters is clearly evident both from within the industry as well as from the private and public sectors; and unless the industry clearly demonstrates its willingness to address these problems, more and more regulatory legislation will undoubtedly be brought to bear on the industry in the future. It behooves all of us, therefore, who are intimately involved with this industry to continue to explore the best possible avenues towards the solution of these problems.

Obviously, a great deal of research has already been conducted on some of these potential problems, so it was thought by many of us that it was time to attempt to put together a conference where the leading researchers in each of these areas could summarize the state of the art as to where we are in having solutions to such potential problems, and possibly more importantly where we could have those researchers lead us in a discussion of where the industry should be going as we face these problems in the future. Dr. Reynnells' discussions eventually led to the formation of an ad hoc meeting of extension specialists which was held during the annual Poultry Science meetings in Corvalis, Oregon this past summer. That meeting in turn led to our department's agreeing to host this symposium, and to the formation of an ad hoc committee of about 50 individuals from all around the nation. Their input was discussed by the program committee via a conference telephone call to hammer out a tentative agenda for the symposium. Dr. Ed Naber, former chairman of the Department here at Ohio State headed up the program committee. He, the other members of the program committee, and our department Secretaries, Gayle Swinger and Anna Forman whom most of you met at the registration desk either yesterday or this morning, have done yeoman's work in carrying out all of the details required to get us here today. Without their efforts we simply wouldn't have been able to put this program together for you.

I would be remiss if I didn't also greet you on behalf of the Ohio State University. For those of you who haven't been here before, we welcome you and we hope that you enjoy your stay. If you aren't familiar with the Ohio State campus, the main campus is located directly across the street from the front of the Holiday Inn, and we hope that you feel free to take a walk over to see it. Ohio State is one of the largest university campuses in the nation, having some 57,000 students enrolled. The College of Agriculture, and the College of Veterinary Medicine are located a couple of blocks to the west of here just on the west side of the Olentangy River. The Department of Poultry Science is housed in Dakan Hall, which is located about 3 blocks west on Lane Avenue. We hope that some of you will have time to stop by and visit with us in the department. In case some of you aren't aware, about half of the faculty in the College of Agriculture, including about half of our Poultry Science Faculty, are located about 90 miles north of here at the Ohio Agricultural Research and Development Center at Wooster, Ohio. So, if you are interested in seeing Drs. Bacon, Foster, Lilburn, Nestor or Saif, it is more than a few blocks walk to where their offices and laboratories are located! Several of them will be here at various times during the meeting, however.

Getting down to the matter at hand, the program has been designed to cover a number of different topics, some general in nature, and some more specific. This morning's topics are the more general ones; this afternoon and tomorrow's topics will be given in break out sessions and will be directed at some of the specific problems associated with poultry production facilities and with poultry processing facilities. We certainly hope that all of you will find the program stimulating, informative and thought provoking; and that you will feel free to participate in the discussions that the formal sessions are bound to generate. The program committee and I hope that all of us leave this conference with better ideas as to how our industry can best face and implement strong programs related to the solution of these potential industry problems.

Before I turn the podium back to Dr. Reynnells, I would like to add that those of us involved with the administration of University programs have heard a great deal during the past six months to a year about a new Federal initiative generally referred to as <u>low input</u> or <u>sustainable</u>

agriculture. This new program has many interpretations and connotations, but let me just throw out as food for thought, that the poultry industry may have a real opportunity to benefit from this effort. One of the reasons for the low input or sustainable agriculture effort has come about due to the growing concern by the public over the continuing use of high levels of chemical fertilizers and pesticides by our nation's grain farmers, and their potential effects on ground water and/or stream pollution. The poultry industry has a product that has been used for centuries as an excellent source of plant fertilizer, so we just need to learn to produce and package it in a manner that is acceptable to the farm and gardening public. There may be far greater opportunities available for properly marketing such problem wastes than many of use realize, and I'm sure that some of the speakers will be addressing that issue during their presentations. Wastes may in fact produce economic opportunities, rather than problems, if approached in the right manner.

Again, WELCOME to the Symposium, please let myself or Dr. Naber know if we can be of help in making your stay a more enjoyable one.

The Political Economy of Waste Management

Fred J. Hitzhusen*

Materials Balance

Poultry waste is one of the many residuals of production and consumption activities prevalent in a contemporary society. As the gross national product (GNP) or value of goods and services of a society grows so does the variety and volume of residuals. In fact, it has been suggested that GNP might more appropriately refer to "gross national pollution." Political controversy surrounds rivers periodically catching on fire, chemical dumps such as Love Canal forcing relocation of people, soil sediment accumulating in lakes and harbors, acid rain from coal and gasoline combustion impacting fish and tree populations hundreds of miles away, chlorofluorocarbons impacting the earth's protective ozone shield and waste from large confinement livestock systems creating odor and affecting water quality.

Much of the controversy over the foregoing residuals and the environment stems from the tendency to treat the environment as a free good or God-given right rather than a source of raw materials and a waste disposal "sink" with limits. In the simplest materials balance model (Figure 1), Freeman et al. view the environment as a large shell surrounding the economic system. It has the same relationship to the economy as does a mother to an unborn child--it provides sustenance and carries away wastes. Raw materials flow from the environment, are processed in the production sector (that is, converted into consumer goods), and then--at least in part--pass on to the household sector. The materials returning to the environment from the household sector are wastes or residuals. They are the unwanted byproducts of the consumption activities of households. Similarly, not all of the material inputs that enter the production sector are embodied in the consumption goods flowing on to the household sector. These are the wastes or residuals from production. Thus, there is a flow of residuals from both the production and consumption sectors back to the environment.

These materials flows must obey the basic law of physics governing the conversion of matter. In an economy with no imports or exports, and where there is no net accumulation of stocks (plant, equipment, inventories, consumer durables, or residential buildings), the mass of residuals returned to the natural environment must be equal to the mass of

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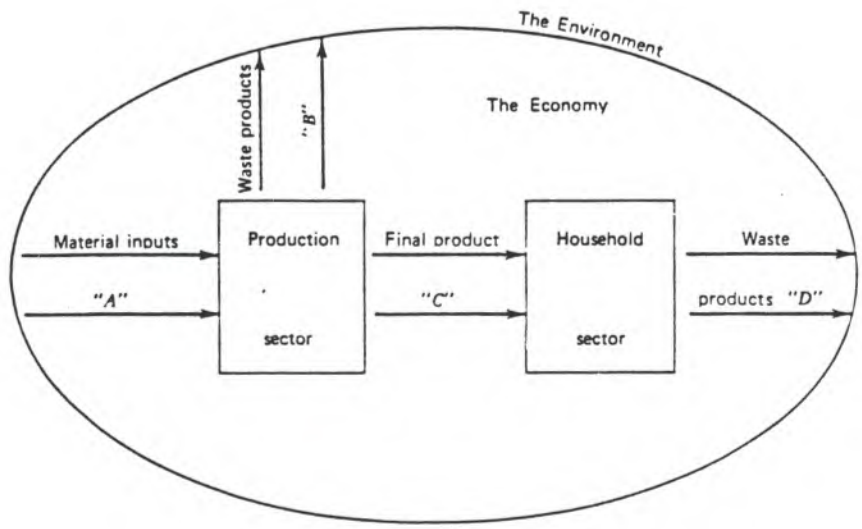
Figure 1. Materials Balance and the Economy. The materials balance for: [1] The production sector, A = B + C; [2] The household sector, C = D; [3] The economy, A = B + D (flows are measured by mass).



basic fuels, food, materials, and other raw materials entering the processing and production system, plus gases taken from the atmosphere. Of course, this neglects the conversion of miniscule amounts of matter into energy by nuclear reactors producing electricity. This is the principle of materials balance. This principle must hold true for each sector of the economic system taken separately, and for the economic system as a whole. Thus, in the absence of inventory accumulation, the flow of consumer goods from the production sector to the household sector must be matched by an equal mass flow back to the environment.

If the environment's capacity to absorb or assimilate wastes or residuals were unlimited, there would be no pollution problem and waste management would be a nonissue. However, the assimilative capacity of the environment is limited and in the case of some residuals like mercury it has no assimilative capacity. One of the limits of the environment's capacity to assimilate is the conflict or competition with other environmental services such as human habitat, amenities and materials inputs to the economic system.

The materials balance model and the notion of a service producing environment provide critical insights for the proper management of wastes or residuals. Examples suggested by Haveman et al. include (1) identification of the full range of technical options, (2) recognition of the interdependency among the various kinds of residual flows, (3) illumination of the relationships among population growth, economic growth and pollution, and (4) emphasis in public environmental institutions on broad jurisdiction over air, water and land pollution and over major physical systems such as river basins.

With increasing evidence of wastes or residuals exceeding the assimilative capacity of various environmental "sinks," it is important to first identify the major technical alternatives for either reducing wastes or altering assimilative capacity. Examples include the following:

1. Reducing the rate of throughput of materials and energy by reducing production, increasing the efficiency of production, converting residuals to new products or recycling them as inputs, or by changing the composition of GNP to lower residual products.

2. Biologically, chemically or mechanically treating or changing the waste or residual to a more benign form for discharge to the environment.

3. Altering the time and place of residuals discharge.

4. Man-made investments to increase the residual assimilative capacity of the environment such as dams to store water for dispensing heavy waste loads and paddle wheels to augment the natural supplies of dissolved oxygen.

Principles from Political Economy

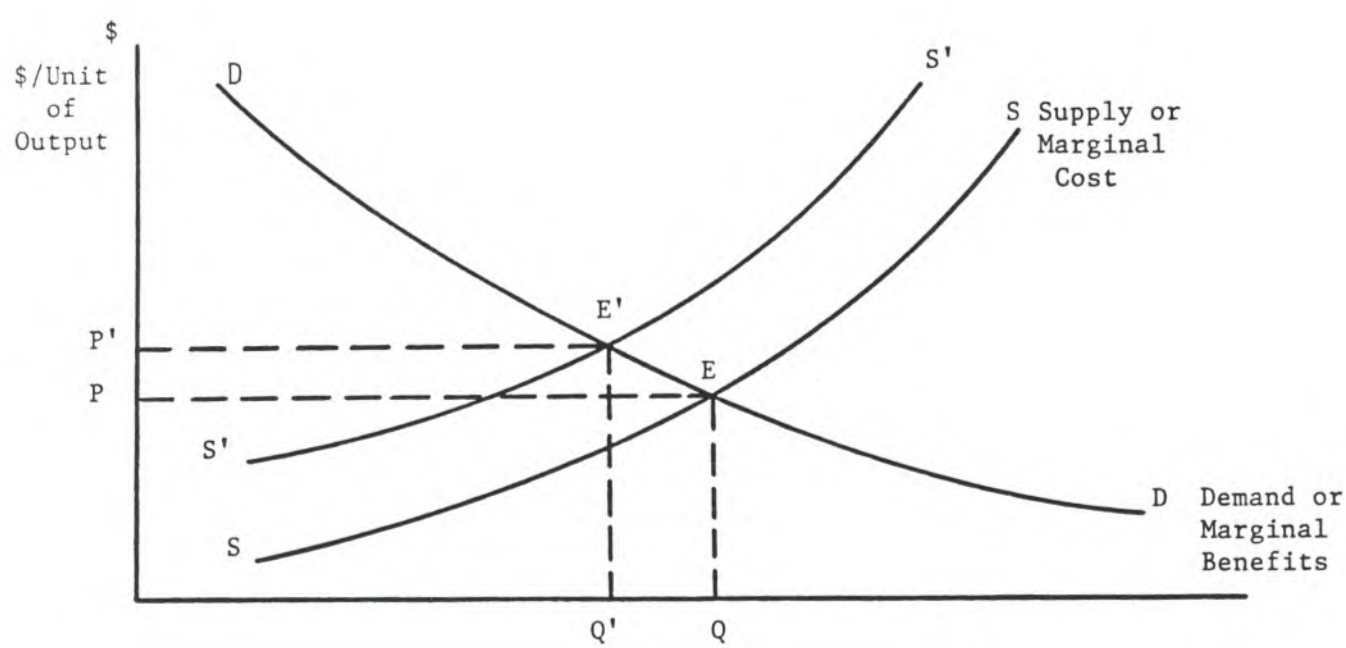
The foregoing characteristics of the physical environment and technical options for pollution control suggest an important role for the principles of political economy in residuals or waste management. Political economy in this context refers to a broader notion of resource allocation than just the private market. It harkens back to the terms describing economics before efforts in the early 1900s to focus neoclassical economics predominantly on market phenomena. Political economy concerns itself with the constitutional rules and property rights or entitlements (see Appendix A for examples of property, liability and inalienability rules) fundamental to the functioning of any economic system, particularly those dominated by private market activity. It also recognizes and incorporates the important nonmarket economic activity in the system including that occurring in the public sector, the study of which is called public choice economics.

In addition to the notion of ownership or assigning of property rights is the charging of prices or user charges through markets, governments or combinations of both. Prices allocate and ration scarce resources to their highest use and ownership determines who benefits and who pays for a given environmental service such as assimilative capacity.

The logic of political economy further suggests that the marginal social benefits (DD in Figure 2) and costs (S'S' in Figure 2) of many small steps within the array of technical options available must be estimated and compared for poultry and other production activities. Differences between private (SS in Figure 2) and social costs arise from what economists call externalities or spillovers such as waste impacts on water quality from poultry and other production activities. Another way of viewing spillovers is those costs (and benefits) included in a social as opposed to private accounting stance. The social accounting stance must take a long (time) and wide (space) view. The spillovers must be internalized to ensure that the least costly (from a social or total societal perspective) or most efficient combinations of options will be utilized to reduce environmental pollution or enhance environmental quality as shown at Point E' in Figure 2.

Proponents of the public choice view argue that individuals participate in political-government interactions as well as market interactions. Furthermore, these citizen/consumers exhibit rational utilitarian behavior and reveal preferences by joining or leaving clubs, and voting by ballot and with their feet.[1] Elected representatives maximize the chance of reelection by appealing to the median voter and engaging in vote trading to accommodate unequal preference intensities. The appointed or civil service bureaucrat maximizes size of budget and number of employees (status) as well as salary and perks. Superiors purchase obedience and subordinates trade and complete among themselves. An equilibrium concept is demonstrated via stability of public markets or governments.

Figure 2. Private and Social (Externality*) Costs and Benefits of Poultry Production



Poultry Output

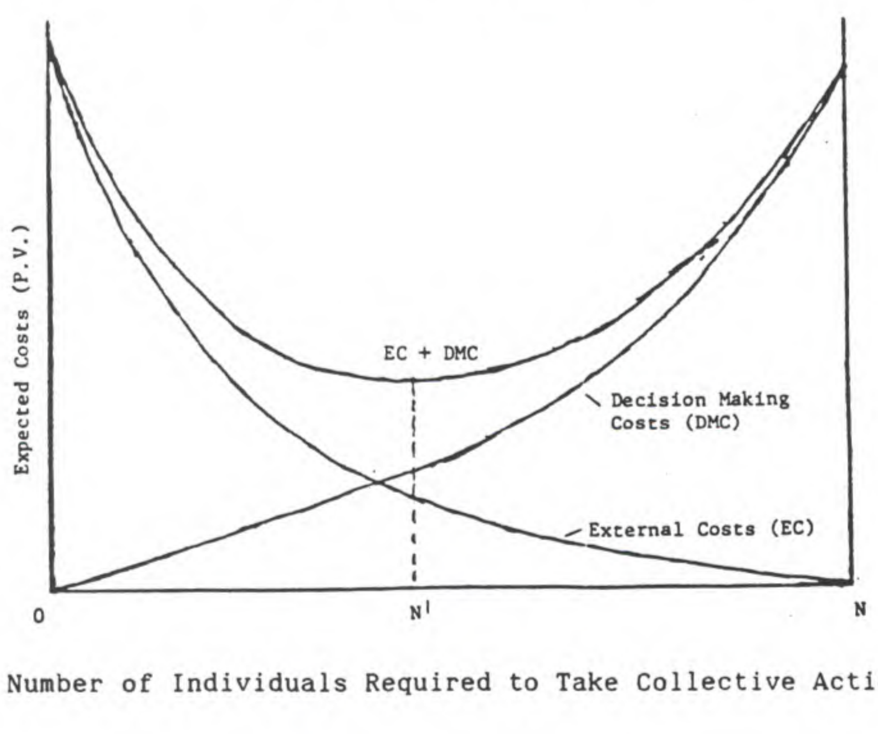
*Physical interdependence with other producers or consumers, which is not fully priced or compensated.

Buchanan and Tullock argue that a good or service is provided publicly when the collective of individuals decides that it is more efficient to do so. Rational individual citizens attempt to minimize the sum of external costs (e.g., cost of maintaining a safe supply of drinking water due to livestock wastes) and decision making or transaction costs (e.g., the costs of mobilizing citizens concerned with a safe supply of drinking water) as they move from individual action to voluntary organization to collective organization or action. The model assumes the existence of mechanisms to aggregate the appropriate group. Figure 3 illustrates the model.

Rather than casting government as a drain on resources or at best a necessary evil, collective action or government in the Buchanan-Tullock context is the end point of a logical progression in search of more efficient provision of a particular good or service that is provided less efficiently in the private market. This approach makes some rather heroic assumptions on the adequacy of constitutional or decision rules and the availability of information on decision making and external costs. But, as an unconventional way of viewing government, it may provide some insights for more innovative alternatives for managing residuals or wastes.

McDowell contrasts this public choice view with the consolidation reform tradition on optimal local government organization.[2] The public choice view first argues that since economies of size are good/service and technology specific, the simultaneous optimization of all services for any

Figure 3. Decision Making and External Costs of Collective Action



size unit of local government is unlikely. Public choice also recognizes the possibility of diseconomies of size and rejects the presumption that the consuming unit of government must produce the good or service. Intergovernmental production arrangements such as contracting, mutual aid agreements and joint ventures as well as publicly regulated private provision allow for production economies of size without necessarily increasing the size of the consuming decision making unit or government.[3] This is particularly true in the case of waste management contractual arrangements between units of government and between private and public decision making units.

The consolidation reform view is critical of the dramatic increase in the number of special government districts (many of them have been created for waste management in Ohio) and their overlapping boundaries. This criticism is based in large part on the presumption that the transaction costs (bickering and haggling) will be lower when multiple jurisdictions are subsumed under a single authority. _A priori_ evidence of this issue is difficult to generate. It is likely that the transactions within a single, large governmental unit will be less visible than would be the case in transactions between several smaller units.

The range of strategies or options within the political economy for acting individually or collectively to manage the wastes or residuals of production and consumption activities is wide, including:

1. Voluntary action within existing property rights such as evasive action, mergers and bribes to avoid or reduce waste impacts.

2. Lobbying for property rights changes in light of the magnitude and incidence costs imposed by disposal of wastes.

3. Government monetary penalties and rewards such as taxes against polluters, subsidies to the "pollutee" and payments to clean up.

4. Auction of pollution or sink rights for waste disposal up to the assimilative capacity of various environmental sinks.

5. Government nonmonetary intervention such as regulation, directive and prohibition related to wastes.

6. Direct public ownership of waste management facilities and development of new technology for improved waste management.

Some Implications for Poultry Waste

In going from the general to the specific, there appear to be several important implications for poultry waste management from the foregoing discussion. First, poultry waste including manure, used litter, hatchery waste, offal and wash water is an example of an external diseconomy or spillover and is an integral part of a larger waste or residual stream impacting land, air, and water or the specific environmental "sinks." As such it must be managed as an integral subset of these other waste streams if efficient solutions are to be realized. This management includes assigning of appropriate property rights, pricing or establishing user charges, and recognition and estimation of alternative accounting stances.

Another implication relates to the problem of suboptimizing or making a decision without looking at all of the available options. Increased poultry production efficiency, recycling and treating of poultry waste (particularly as feed for ruminant animals, compost and energy), altering the time and place of discharge and investing in man-made enhancers of environmental assimilative capacity can all contribute to improved poultry waste management.

The combination of the foregoing implications and the notions from public choice economics provides some insights for the design and operation of public institutions for waste management. They need to recognize the additive and interdependent nature of waste streams impacting more than one environmental sink; they need to facilitate the aggregation of the relevant waste generating groups or sources; they need to have adequate scope of jurisdiction over both geographic space and alternative sinks; and internal incentives such as zero-based budgeting and competitive bidding must be developed to minimize transaction costs in realizing goals for improved environmental quality.

Finally, innovative alternatives to prohibition or regulation of poultry wastes should be explored. These might include auctioning of pollution rights or rights to the use of specific environmental assimilative capacities to the most efficient producers, incentives for recycling and treatment of poultry wastes (e.g., expanding the markets for compost, energy and feeding to ruminants) and investments such as water impoundments to enhance stream flows and assimilative capacity.

Footnotes

[1] Tiebout developed a "voting with one's feet" hypothesis to suggest how a private market equivalent might operate in citizens' decisions to locate in a given local government jurisdiction after evaluating the mix and quality of services compared to the level of taxation.

[2] The tradition views small units of government as unprofessional and inefficient. Fragmented authority and multilayered, overlapping jurisdictions are diagnosed as the fundamental sources of institutional failure in the governance of many areas. Consolidation is purported to lead to economies of scale and the fixing of political responsibility making it possible for citizens to hold officials accountable.

[3] The satisfaction of consumer-citizens is presumed to be more readily achieved under multiple, smaller consuming units. This would seem to be particularly true where goals and preferences of citizen consumers are changing.

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Appendix A. Alternative Rules of Entitlement

Rule I (property rule)	A <u>may not</u> interfere with B without B's consent; B is protected by a property rule, e.g., private residence
Rule II (liability rule)	A <u>may</u> interfere with B but must compensate; B is protected by a liability rule, e.g., public right-of-way
Rule III (property rule)	A <u>may</u> interfere with B and can only be stopped if B buys off A; A is protected by a property rule
Rule IV (liability rule)	B <u>may stop</u> A from interfering but must compensate A; A is protected by a liability rule, e.g., soil erosion control
Rule V (inalienability rule)	A <u>may not</u> interfere with B under any circumstances, and the stopping does not imply compensation; B is protected by inalienability.

SOURCE: From Guido Calabresi and A. Doublas Melamed, "Property Rules, Liability Rules, and Inalienability: One View of the Cathedral," <u>Harvard Law Review 85</u> (April 1972): 1089-1128.

Water Quality and Environmental Concerns

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Introduction

Recent expansion in poultry production nationwide and its potential environmental impacts have placed poultry operations under greater public scrutiny than in the past. Poultry waste management is a process that covers all three EPA program areas: air, solid waste, and water. My remarks are focused on the water quality aspects of poultry waste management.

Water Quality

Poultry wastes are a potential hazard to ground and surface waters; and their water pollution potential includes impairment of bacteriological quality, depletion of dissolved oxygen, increased nutrient enrichment, and complications in water treatment (Lin, 1972). Under the Clean Water Act (CWA), poultry waste can be treated either as a point (Title 40, Subchapter N; Part 412) or as a nonpoint source (Section 319).

Point Source

A poultry operation is considered a point source when it's a concentrated, confined poultry growing operation for meat or egg production, in pens or houses wherein poultry are fed at a place of confinement and crops or forage growth or production is not sustained in the area of confinement. The point source regulations for poultry operations were not intended to establish operating criteria for feedlot waste control facilities. Rather, the regulations establish a performance standard; "there should be no discharge of process waste water pollutants to navigable waters" (Part 412.12). There are two exceptions to this regulation, for existing facilities with best practicable technology the exception pertains to the discharge of pollutants associated with rainfall events greater than 10 years; 42-hour rainfall event (Part 412.12), for new sources the associated rainfall event has to exceed a 25-year, 24-hour rainfall event (Part 412.15). The operator is free to choose any method of operation, providing the method of operation results in the facility containing the process generated waste water and runoff from rainfall events less than the exception levels.

These regulations apply to operations as large or larger than the following capacities for the following categories:

Category	Capacity
Turkeys	55,000
Laying hens or broilers when a facility has unlimited continuous flow watering systems	100,000
Laying hens or broilers when a facility has liquid manure handling system	30,000
Ducks	5,000

Ducks are a special subcategory in Title 412 (412.20) and have the following effluent limitations based upon the application of best practicable control technology:

	(lb/1,000 ducks) Max for 1 day	30 day average
BODs	3.66	2.00

Fecal coliform: not to exceed mpn of 400/100 ml at any time.

Toxics: A Special Concern

A special concern of poultry operations relate to ammonia toxicity. In general, we speak of two types of toxicity for aquatic organisms--acute and chronic. Acute generally means that the source of toxicity kills at least 50% of the test organisms within a short time frame (e.g., 48-96 hours of exposure common). Chronic toxicity means that organism's exposure is to lower concentrations of a toxin for longer periods of time and result in deleterious effects. Toxicity is also measured by the potential threat a pollutant poses to human health.

The Water Quality Act of 1987 focused attention on toxics controls developed by application of State water quality standards and implemented through National Pollutant Discharge Elimination System (NPDES) permits. Section 402 authorizes EPA or State (if delegated) to issue NPDES permits to implement EPA's effluent guidelines or State water quality standards.

The authority of EPA to control toxic pollutants is found in Section 301 of CWA. Section 303 authorizes States to promulgate water quality standards consistent with Federal requirements and a process for EPA's approval and "Federalization" of those State water quality standards. It is important for interested and/or affected parties to become involved early on in the water quality standards setting process. States may adopt water quality more stringent than EPA guidance requires (Section 501). It is important to note that failure to put specific control measures into NPDES permits for any pollutant known or believed to be present in the discharge provides an unlimited license to discharge that pollutant.

Toxic pollutant controls can take two forms--controls on specific compounds and controls on general properties. Specific controls on toxics or toxic material may be imposed as a result of data generated through whole effluent toxicity test, EPA/State inspections, NPDES permit applications or other investigations. General knowledge of the industry and process can also justify permit limits without any further testing or analysis.

Section 304(1) of the CWA requires States to identify all water resource segments not meeting water quality standards or designated uses because of toxics, by February 4, 1989. For those areas strictly impaired due to point sources of toxics, an Individual Control Strategy (ICS) is required. ICSs are NPDES permits with a three-year compliance date. Interested parties are encouraged to work with the State Water Quality Management Agency in the development of the 304(1) list.

Nonpoint Source

If a facility is smaller than the size requirements for an NPDES permit, is not covered by an NPDES or State permit and is causing a water quality problem associated with the land application of manure, we expect the State to handle it through their NPS Management Program. Authorization for State NPS Programs is provided in Section 319 of the CWA. This Section mandates the development of a State Assessment Report that identifies impacted waters, sources and NPS best management practices. These Assessment Reports will serve as the foundation for the development of a State NPS Management Program. The Management Program is optional (EPA, 1987). The potential surface and ground water problems caused by the improper storage or use of poultry wastes have been documented by both USGS and USDA-SCS (B. Kirshner pers. com.).

The primary focus of these NPS activities will probably be related to proper land management and nutrient management. Fortunately, with proper management and utilization, poultry wastes can be utilized to not only reduce the need for chemical fertilizers but to improve soil characteristics for plant growth. Federal and State cost-sharing programs have promoted both manure storage and proper nutrient management. However, according to a new EPA document on the Chesapeake Bay Nonpoint Sources Programs (EPA, 1988), payment for best management practices such as manure storage may not be cost-effective. This same document raises the possibility that permit programs for confined animal operations may be expanded with cost-sharing only used to provide technical assistance for nutrient management.

In light of increasing scrutiny and, particularly for the smaller producer, the possibility of less cost-share incentives, it appears that it would be highly desirable for producers who currently manage their waste in an efficient manner to continue to do so and those producers who may have potential problems to address these problems before they are singled out as a potential problem.

In terms of NPS control, producer groups should work with the State Water Quality Management Agency in the development of the State NPS

Management Programs. As a service to individual producers, groups should develop an active information/education program on related regulations and improvements in poultry waste management technology. It is much easier to prevent problems and protect water resources rather than to correct problems and restore water resources.

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Industry Efforts to Maintain a Clean Environment

Joe Claybaugh
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As a poultryman that spends part of each day in a chicken house, I have very personal experience on the right way and the wrong way to manage a cage layer operation. As research people, educators or enforcement personnel, you each have an opinion on what constitutes a clean environment and what needs to be done to obtain it.

I'll start with one of the simplest and most easily corrected practices--that of dead birds. These can be piled on the ground or on a dock and if that area is next to a road where everyone can see them, they draw their own conclusions. A plastic bag can be used to conceal them and even better a container that somewhat hides the distraction. Fortunately, we have a rendering plant that provides almost daily pickup service. I can see many challenges if we had to burn or otherwise dispose of them.

Flies and rodents are a challenge and their control must be tailored to each operation. Over the years we have tried pesticides, larvacides and biological control. Last year we thought it worked with partial cleanout but not completely. With an influx of flies this winter we went back to a larvacide for about three weeks and so far have had good control.

Two of our buildings have concrete walls and one has steel. This limits the nesting and hiding places but mice will find someplace to multiply. You do have to be as smart as a mouse to have successful control. One is to bait in the area where they are, for a mouse won't come to the end of a 500' chicken house just to each your poison. Switching baits, supplying both liquid and solid bait, all have to be used as needed to obtain a proper level of control.

Satisfactory handing of manure is the largest challenge to all poultrymen. This is especially true out of a complex, and if that complex is located in a nonfarming area near developing real estate, then it's more challenging. The answer to those units might be a commercial compost unit. We have lots of corn and bean ground around our units. We also have neighbors with hogs and cattle and a basic understanding that odors, flies, manure dropped on roads is one of the acceptable challenges of being a farmer and living in the country. We also are located away from well traveled roads and highways. Therefore, passing motorists don't have the opportunity to associate smell just by seeing the buildings. However, we fully realize we have a responsibility and we don't want to exceed the understanding and tolerance of our neighbors. Cage layer manure in a high-rise unit varies in consistency by ration, temperature, water consumption, amount of air exchange and air flow over the manure. During winter conditions, air exchange is reduced to maintain a high inside temperature which reduces feed consumption. This does not allow moisture to be evaporated from the manure, so after 3-4 months a nicely coned manure pile will start to seep and soon will be 2-6" of semiliquid material under the walkway.

The use of circulating fans in the pit can provide drying of the manure. In a test, we found the following moisture reduction with the use of 36" 1/2 HP fans.

Distance from fan	20'	80'	120'
% moisture	26	50	77

This tremendous reduction in moisture can be of great benefit to reduce the number of loads of manure removed.

Example - 60,000 bird house:

% Moisture	No. of loads of manure per year	No. of days required per year	Cost of removal @$25/load
77	332	11.1	$8,300
50	192	6.4	4,800
26	164	5.5	4,100

(1) based on a capacity of 7.3 tons per load
(2) 30 loads per day

In addition it takes fewer days. The manure spreader can be filled to a greater volume since dryer manure can be heaped up on the spreader and our cost of $25.00 per load would be reduced to about one-half of the cost as compared with the 77% moisture material. True, the installation cost of the circulating fans amount to about 5 cents per bird or $3,000 per 60,000 bird house. The operating cost at 5 cents per KWHr is 4.4 cents per bird per year plus .8 cents for fixed cost on a 10-year basis. Perhaps some lowering of that cost could be achieved by operating the fans intermittently.

Odors are directly related to dryness of the manure. Although they will be reduced if the manure is dryer, odors will not be eliminated completely.

Will feathers and dust be objectionable in our future perfect environment? Hopefully, this will be the last phase of the campaign for it could be the most expensive and difficult to obtain.

POULTRY WASTE UTILIZATION AND MANAGEMENT IN EUROPE

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Background

One of the objectives of a professional leave taken from The Ohio State University during the period from July 1, 1986 through December 31, 1986 was to conduct descriptive research on methods and systems used to manage and utilize poultry manure in Western Europe that may be applicable to the emerging situation in many parts of the United States. During this period of time visits were made with many individuals, research institutions, companies and farms.

The northwest section of West Germany and the whole of The Netherlands are manure surplus areas. This means that the livestock and poultry density in these areas is so high that the manure from these animals cannot reasonably be used as fertilizer and spread on agricultural lands even when all such land is available for soil application. In these areas problems with odors, insects and water pollution are very serious. As a result, animal production, manure distribution on land, and water pollution are subject considerable government regulation.

Regulations in West Germany

Current regulations in West Germany limit animal production to 3 animal units per hectare (1 animal unit per 0.8 acres) of land owned or controlled by the farmer or company. If the farmers or a company want to produce more animal units than this limit, they must show how the manure is to be distributed using other land areas or other methods for manure utilization. In West Germany, one animal unit = 100 laying hens, 300 broilers or 100 growing turkeys. The law in West Germany also requires that liquid manure (pure manure or pure manure plus water) must be stored between November and March. Because land application of liquid manure is limited to seven months during the year, there is a need for considerable manure storage facilities and/or facilities for converting manure by composting or biogas production. Nitrate levels in ground water above 50 ppm are investigated and are subject to legal action.

Research in West Germany

Discussions with scientists at the Institute for Technology at Braunschweig revealed that currently odor problems are a key point in many legal actions in West Germany, but that nitrate in ground water is building up and will be the focus of future regulation. They indicated that many livestock and poultry producers are discussing going back to solid manure systems (manure + litter or dry manure) rather than the liquid manure system used by many producers at the present time to avoid the storage needs for the liquid manure. In most cases (outside of the northwest are of West Germany) it is still possible to utilize manure completely by proper land distribution within 6 to 9 miles of the production site.

Research at the Institute for Technology over the past 20 years has placed considerable emphasis on fermentation of manure both through controlled composting and biogas production. Pilot plants for composting and drying manure and for biogas production have been built and extensively evaluated. In general, and because of the nature of manure production on the farm and its composition, biogas anaerobic fermentation is easier with swine and cattle liquid manures while aerobic fermentation involved in composting is easier with poultry solid manures. Evaluation of the pilot plant for composting and drying manure concluded that the process costs 2 to 3 times more than aeration of liquid manure. Therefore this process would be of interest only for special cases, such as laying hens, giving relatively dry manure. The final evaluation of the system concluded that it would be economically viable for large poultry farms in West Germany. These conclusions were reached in 1979 prior to the regulation of manure utilization on land previously discussed.

Current research at the Institute for Technology involves 6 years of work with a completely automated biogas pilot plant using liquid dairy manure.

Research at Hohenheim University has explored the effects of antimicrobial agents on both aerobic and anaerobic manure fermentation in pilot plant digester systems. Concern was for the potential retardation of microbial activity due to feeding of antibiotic or other antimicrobial drugs and the use of disinfectants in the sanitation program for animal housing that would be found in the manure. While investigations with poultry manure were not conducted, experiments with swine and cattle manure in aerobic systems show that antibiotics used as feed additives or for therapeutic purposes delay aerobic microbial activity for 2 days while disinfectants delay microbial action for as long as 4 days. However, following this lag phase, normal microbial activity resumes and the fermentation proceeds normally. Therefore, the presence of certain antibacterial agents in manure could cause an increase in fermentation time of up to 4 days in making a fermentation derived product. Anaerobic systems for biogas production are inhibited by certain agents, notably the feed additive Monensin.

Due to the regulatory and legal situation in West Germany some of the egg producers are now using inhouse manure drying systems. These are now available from the major poultry equipment manufacturers for use in battery cages with manure belts for the transport and removal of manure from the poultry house. Farms with and without inhouse manure drying installations were visited near Krefeld and Breckerfeld in the north western section of West Germany.

Regulations in The Netherlands

In an attempt to reduce pollution associated with animal manure disposal, the Dutch government has formulated new regulations that soon will require or establish:

1. Use of manure on land only to meet defined fertilizer needs.

2. Prohibition of manure applications to land during the months of November through March.

3. Air and water pollution limits.

4. For the poultry industry, wet or slurry manure systems will probably be outlawed.

The Dutch government has given a very high priority to solving their country wide manure surplus problem. Funds for research by universities and institutes as well as funds for industry innovation have been made available.

RESEARCH IN THE NETHERLANDS

Composition and Handling of Poultry Manure

Current research emphasis at the Spelderholt Institute in Beekbergen is being placed on minimizing fertilizer element (N,P,K) output in poultry manure by reducing protein and phosphorous intakes of growing poultry and laying hens to those needed only to support productivity. Such studies will emphasize amino acid balance to avoid excesses of non essential amino acids from poorly balanced proteins and improved digestibility of protein sources along with improved availability of organic phosphorous sources.

Housing and ventilation systems for poultry will be tested using a variety of variables all designed to reduce the moisture content of manure as quickly and as far as practically possible. Among the most advanced research in this area is the development of an inhouse manure drying system at the Institute of Agricultural Engineering for caged laying hens in batteries using a manure belt under the cases equipped with a ventilation tube that direct air onto the belt. With commercial installations of this type (Big Dutchman and others) it is possible to routinely dry the daily output of fresh manure to 50 percent or less moisture. One Dutch farm visited exports such a product weekly to France where it is in demand as a fertilizer with little odor or fly problems. The manure drying system involves distribution of air from outside the house through appropriate metal or plastic dusts under 50 m.m. water pressure at the inlet for 30 or 40 m.m. water pressure at the point of distribution. Enough heat is added to the incoming air by some type of heat exchange system to prevent moisture condensation in the outlet ducts under the cages. This heating aids in drying but more importantly prevents plugging of the 3 m.m. diameter outlet holes in the air distribution ducts under the cages. (If moisture condensation takes place, the moisture combines with dust particles to plug the holes in the ducts.) Practical research on this system has determined that about 25 percent of the total ventilation air should be directed through the manure drying system. This means moving about 0.4 to 0.5 cubic meters of air per hen per hour through the manure drying system. Under current economic conditions in The Netherlands, the costs of equipment and operation is being recovered through sale of the dried manure product. The design objective of the system is to dry fresh cage layer manure to less than 50 percent moisture in 16 hours. On a second Dutch farm visited, the dried manure was stockpiled in a covered shed for one to 2 weeks and composting action caused further drying of the product, with very few odors or fly breeding problems.

Other research is in progress at the Institute of Agricultural Engineering to control ammonia release from poultry manure to avoid air pollution and conserve N in the manure for fertilizer use. Conservation of N in manure for utilization as fertilizer is important because P or K usually limit use of poultry manure for crop production and other sources of N are needed when the manure application is limited to needs for fertilizer elements. Ammonia release from manure can be limited by drying or by acidic conditions. Insulation of manure pits or littler floors contributed to drying as well as ventilation. These variables are under study both at Beekbergen and Wageningen.

Dried cage layer manure that has been pelleted is also being tested as a feedstuff for growing-fattening bulls. In Lelystad at the Research and Advisory Institute for Cattle, Sheep and Horse Husbandry an experiment was observed in which 20, 40, or 60 percent of dried cage layer manure pellets were fed with corresponding reductions in corn silage. The bulls fed 20 percent of this product were growing as well as controls fed 100 percent corn silage. However, problems with acceptability and gain at the higher levels of manure in the ration were being encountered.

Further Processing of Poultry Manure to Produce Special Products

Interest in anaerobic fermentation of poultry manure in Europe is rapidly declining. While biogas is a useful and valuable product such fermentations require heat and result in a liquid end product for disposal or fertilizer utilization that has all the problems associated with slurry or liquid manure. This such processing of manure for biogas production many be better adapted to swine or cattle manure where the total solids is much lower than in poultry manure and where drying is less feasible.

Poultry manure, on the other hand, has been used successfully to produce corn silage with better oxidative stability than silage without the poultry manure additive. At the Institute for Livestock Feeding and Nutrition Research in Lelystad considerable research has demonstrated corn silage with cage layer manure additions during ensiling leads to good weight gains in beef bulls and silage of improved stability due to buffering capacity of the manure and increased acetic and lactic acid production.

Greater interest in aerobic fermentation of poultry manure is evident. Aerobic fermentation, which involves controlled composting of manure with other materials, acts to further dry the product and to convert it to a product with more uses than that of a fertilizer alone.

Mushroom growing requires a compost substrate that has, in the past, been made from horse manure and bedding materials, mainly straw. In recent years, the composts for mushroom production have been made with more poultry manure and the firms making compost have extensive experience on compost production. Research on these composts has also been conducted. At the Mushroom Growers Cooperative near Ottersum that was visited, 10,000 tons of compost are prepared each week from horse manure, poultry manure, straw and small amounts of gypsum. The product is made under a roofed structure containing 48,000 square meters of space. While the product for the mushroom growers is of good quality and meets their needs, air pollution in the vicinity of the composting operation is high and research is being started on closed systems for composting that will control emission of undesirable gasses to the air. A visit to the Mushroom Experiment Station at Horst revealed that some research is underway to study composting in closed or partially closed systems. The systems under study make it possible to recycle air, conserve heat, and control rate of composting within the introduction of limited amount of fresh air and emission of limited amounts of exhaust air. Such systems for the conversion of poultry manure to composts should be studied for future application. Ideal conditions for thermophilic bacteria are established at 45 to 50^{o}C. At desirable C to N ratios, it appears that uric acid N should slowly be released as NH_3 for protein synthesis by the thermophilic bacteria. Regulation of this process must recognize that both anaerobic and aerobic reactions will go on simultaneously even though considerable oxygen is used and carbon dioxide and water appear as byproducts to the activity.

Although commercial feeding of poultry manure in The Netherlands and West Germany is illegal, interest was expressed by the largest Dutch feed processor and manufacturer (Cebeco-Handelsraad) in Rotterdam in biological conversion of poultry manure to feedstuffs. It is the feeling of many research scientists and poultry industry persons in The Netherlands that the conversion of some poultry manure to stable products with several potential uses is a key element in reducing their manure surplus problem.

Summary

Research institutes, universities and industry locations in West Germany and The Netherlands were visited to investigate past and present research and development activities on poultry manure management and utilization. Intensive poultry production as well as production of other animals in areas of high human population have led to greater concerns and more regulation in these countries over manure disposal and methods for manure management and utilization than in the United States. Inhouse drying of cage layer manure is less than 50 percent moisture is in commercial practice to avoid odor and fly problems and to improve handling characteristics of the manure for distribution as a fertilizer or as a ruminant feed supplement. Further processing of poultry manure by bacterial conversions may yield other products of value for export to manure deficit areas. Current research in this geographical area seems to favor controlled composting involving mainly aerobic bacteria to convert and process manure for specialized uses in making fertilizers, soil conditioners and feedstuffs. Anaerobic production of biogas and making of silage containing cage layer manure are also possible but research activity on these conversions has been discontinued and most thinking favors controlled composting as a partial solution to making products from poultry manure that may be recycled in part and distributed for use as a fertilizer in deficit locations to relieve the manure surplus.

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LAGOON DESIGN AND MANAGEMENT FOR LAYER WASTE TREATMENT AND STORAGE

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The trend away from small dispersed poultry production units to larger concentrated operations has increased management requirements for manure and wastewater. Utilization systems which conserve fertilizer nutrients often are more sophisticated, expensive and laborious for handling concentrated wastes. Systems which pretreat raw waste for management ease usually result in a loss of fertilizer nutrients. Any waste handling system must meet existing stream pollution regulations which stipulate that pollutants not be discharged from concentrated animal feeding operations directly into surface waters.

Lagoons became popular for poultry waste treatment as historic interest to utilize manure fertilizer nutrients by direct land application was replaced by desires to have more convenient waste management systems. Originally viewed as a total disposal system; it has become recognized that in moisture excess regions, lagoons are just one pretreatment process in the overall waste management plan. Lagoons usually fill to capacity after two or three years due to the waste volume being added and a rainfall surplus. When the filling process is complete, overflow will occur unless the operator is in a position to apply the excess liquid back to field crops, grassland or woodlots.

Lagoons act as biological digesters in which two major types of bacteria decompose organic matter into gases, liquids and sludge. Anaerobic bacteria, present in the intestinal tract of warm-blooded animals, do not survive in the presence of free oxygen. Aerobic bacteria require free elemental oxygen.

ADVANTAGES AND DISADVANTAGES

Advantages of lagoon systems for treatment of poultry waste include:

1. Waste treatment ease and convenience
2. Storage and disposal flexibility allows opportune field spreading.
3. Less land is required for the total treatment system.
4. Liquid can be recycled for flushing wastes from building pits or land applied by simple irrigation.
5. Lower labor requirements and operating costs

Disadvantages of lagoon systems are:

1. Appreciable loss of manure fertilizer value.
2. Offensive odors if improperly designed and managed.
3. Frequent sludge removal may be required if lagoon is undersized.
4. Groundwater protection considerations.
5. High energy costs if mechanical aeration is used.

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ANAEROBIC LAGOONS

Design

Anaerobic lagoons are most commonly used for poultry waste treatment. Anaerobic bacteria can decompose more organic matter per unit lagoon volume than aerobic bacteria and are predominantly used for treatment of concentrated organic wastes. Since the anaerobic process is not dependent on maintaining dissolved oxygen, lagoons can be much deeper and require less surface area. Anaerobic decomposition of poultry waste, can result in the production and emission of odorous gases, primarily hydrogen sulfide, ammonia, and intermediate organic acids. An anaerobic lagoon can be properly sized and managed, however, to operate with a minimum of disagreeable odor.

Liquid volume, rather than surface area, is the basis for anaerobic lagoon design. Sizing criteria should emphasize major operational needs to control odor, minimize sludge buildup and manage nitrogen. As lagoon capacity increases, odor potential, rate of sludge buildup and pathogenic organisms decrease while nitrogen losses increase. Table 1 gives suggested poultry lagoon design treatment capacities for mild climates.

The minimum total capacity of an anaerobic lagoon should include the appropriate design treatment capacity given in Table 1, additional surface storage for a 25-year, 24-hour rainfall, and an additional foot of freeboard to prevent embankment overtopping. Some producers desire extra lagoon capacity for temporary storage of rainfall and wastewater inputs and for sludge accumulation. Providing this additional storage extends the lagoon sludge life expectancy, provides better and more uniform waste treatment, and decreases the frequency of irrigation. Table 1 estimates poultry lagoon liquid accumulation rates. The normal wastewater storage capacity should be figured for at least 90 days. Sludge accumulation rates given in Table 1 should be utilized to design a lagoon life expectancy of 15-20 years.

Because bacterial activity increases at higher temperatures, anaerobic lagoons work best in areas without cold winters. Lagoons in colder areas require more design treatment volume. Lagoon loading rates are determined by the amount of volatile solids (VS) in manure. Table 2 shows the maximum

Table 1. North Carolina Poultry Anaerobic Lagoon Design Criteria

Bird type	Unit*	Average Bird Live Weight lbs	Lagoon Contents Accumulation: liquid** gals/day	Lagoon Contents Accumulation: sludge*** ft3/yr	Recommended Lagoon Design Treatment Capacity: minimum ft3	mean ft3	maximum ft3
Layer	per bird	4.0	0.07	0.63	10.0	12.5	15.0
Pullet	per bird	1.5	0.03	0.22	3.8	4.7	5.6

* One-time bird capacity.
** Does not include fresh flush water or account for lagoon seepage.
*** No manure solids removal prior to lagoon input.

lagoon loading rates for the United States recommended by the American Society of Agricultural Engineers (ASAE Engineering Practice EP403) ranging from 2.8 to 4.8 lbs VS / day / 1000 cubic feet of lagoon liquid volume for cold to warm climates, respectively. This translates to a design treatment volume range of 10.1 cubic feet of lagoon liquid per bird in warm climates to 17.2 cubic feet per bird in cold climates for layer operations.

Lagoons may be round, square, rectangular, or irregularly shaped to fit existing terrain provided the perimeter does not contain unusually deep bays or pockets. Length-to-width ratios for rectangular lagoons should not exceed 4:1 to encourage even distribution of waste. Sideslopes generally vary from 1:1 in clay soils to 3:1 in sandy soils. A mimimum liquid depth of 6 feet should always be maintained in an anaerobic lagoon. Maximum depths are dictated by soil and groundwater site constraints but may range up to 20 feet to minimize the surface area and to encourage dissolution of anaerobic gases. A level lagoon bottom is desirable but not absolutely necessary.

A site investigation by an agency with soils expertise such as the Soil Conservation Service should be made to determine the soil characteristics and suitability of the site for lagoon construction. Location on highly permeable soils which will not seal or shallow soils over high water tables or fractured or cavernous rock may allow groundwater contamination. Several studies have shown that most livestock and poultry lagoons receiving raw manure quickly seal limiting soil permeability to as low as 1e-6 cm/sec. The sealing mechanism is mainly physical, i.e., organic solids are trapped within soil pores at the soil surface. Biological mechanisms also help bind manure solids to soil particles thus strengthening the seal. Chemical constituents of manure such as sodium also tend to disperse soil particles. The predominance of professional opinion suggests that with proper initial site selection poultry lagoons have very little potential for groundwater contamination.

Management

Figure 1 outlines a lagoon management scheme. New lagoons should be filled one-half full with water before waste loading begins. Start-up during warm weather and seeding with bottom sludge from a working lagoon will speed

Table 2. U.S. Poultry Anaerobic Lagoon Design Criteria

Bird type	Average Bird Live Weight lbs	Recommended Maximum Lagoon Loading Rate*			Recommended Minimum Lagoon Design Treatment Capacity		
		Warm**	Mild***	Cold****	Warm	Mild	Cold
		--lbs VS/day/1000 ft3--			---------ft3/bird---------		
Layer	4.0	4.8	3.8	2.8	10.1	12.7	17.2
Pullet	1.5	4.8	3.8	2.8	3.8	4.8	6.5

* American Society of Agricultural Engineers Engineering Practice EP403
** Southwest border, central TX, north FL; no ice formed during winter.
*** Northern CA, northern NM, central MO, northern NC; some ice.
**** Northern WA, northern SD, northern WI, southern ME; considerable ice.

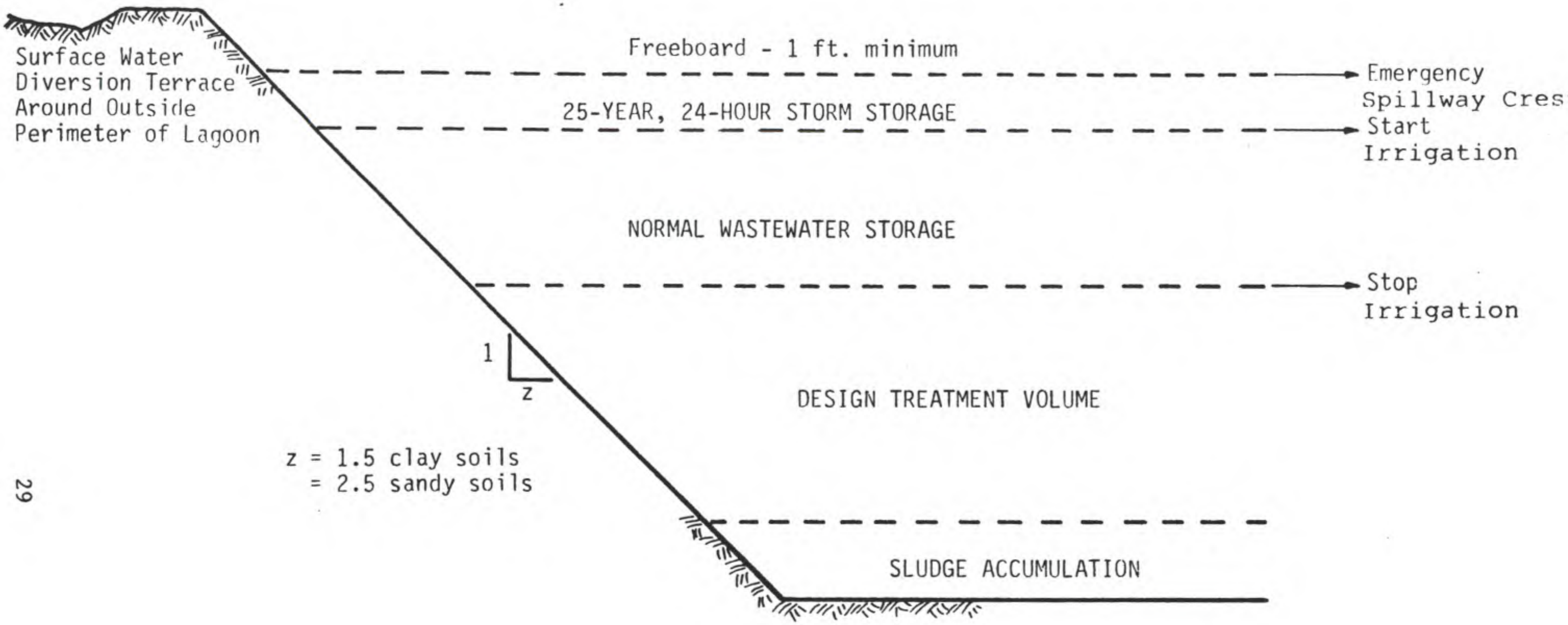

FIGURE 1. ANAEROBIC LAGOON DESIGN AND MANAGEMENT

Notes:
1) Lagoon Length to Width Ratio should not exceed 4:1.
2) Normal storage liquid depths should be at least 6 feet.
3) Sludge accumulation capacities should be designed for a lagoon life expectancy of 15-20 years.
4) Normal wastewater storage capacities should be figured for at least a 90-day storage.

establishment of a stable bacterial population. Manure should be added to anaerobic lagoons as frequently as possible, preferably at least daily. Infrequent shock loadings can cause sharp increases in odor production and wide fluctuations in nutrient content. Lagoon liquid drawdown by irrigation should begin when the liquid reaches the maximum normal wastewater storage level. Liquid should not be pumped below the design treatment level so that adequate volume is always available for optimum bacterial digestion.

An anaerobic lagoon in proper balance will have a pH ranging from 7 - 8 (slightly basic). The pH in new lagoons without adequate dilution water or in overloaded lagoons can be reduced to 6.5 or less (acidic), thereby creating odor problems. This condition can be temporarily corrected by evenly distributing agricultural lime (preferably hydrated) to the liquid surface at the rate of one pound per 1000 cubic feet of lagoon volume.

Land Application

Lagoon liquid can provide substantial amounts of nutrients to grassland, cropland, or woodlots, with application rates based on matching the available nitrogen content of the lagoon liquid to the fertilizer requirement of the crop being irrigated. Nutrient concentrations vary widely among different lagoons and within individual lagoons seasonally. Applicators are strongly encouraged to periodically have lagoon samples analyzed to more accurately determine the amount of nutrients being land applied. Table 3 gives typical characteristics of anaerobic lagoon liquid in lieu of actual test results.

Liquid from lightly-loaded anaerobic lagoons can be applied through sprinkler nozzles 1/4 inch or larger. Single-nozzle, straight-bore sprinklers are recommended. Pump suction intakes should be floated approximately 18 inches underneath the lagoon liquid surface. Liquid from moderate to heavily loaded lagoons can be applied through 1/2- to 3/4-inch nozzles. Larger gun-type sprinklers with 3/4- to 2-inch nozzle diameters should be used for lagoons with high concentrations of solids or liquid sludge irrigation.

For solids contents under 4%, standard centrifugal irrigation pumps are recommended over specialized chopper pumps or cutter attachments. If a lagoon contains an appreciable amount of long-stemmed vegetation or large debris, this material should be removed and efforts made to to prevent its recurrence.

Sludge Removal

Even with good bacterial digestion, significant amounts of sludge

Table 3. Poultry Anaerobic Lagoon Liquid Characteristics

Bird type		Total Solids %wb	Chemical Oxygen Demand, COD mg/L	Nitrogen N	Phosphorus P2O5	Potassium K2O
				---------lbs/acre-inch---------		
Layer	mean	0.47	2700	183	45	230
	std. dev.	0.26	1700	110	28	142

accumulate in an anaerobic lagoon. A lagoon can be designed with enough storage (Table 1 and Figure 1) to avoid having to remove any bottom sludge throughout its life. The rate of sludge buildup can be reduced by mechanical solids separation or gravity settling of the waste prior to lagoon input.

At some point the treatment capacity of most lagoons will be severely diminished by sludge accumulation. Table 4 reports some of the characteristics of poultry anaerobic lagoon sludge. Organic nitrogen compounds and phosphorus tends to accumulate in the sludge causing nitrogen levels to be 3 times higher than lagoon liquid levels and phosphorus to be up to 45 times higher than liquid levels. In addition to higher nutrient levels, the bottom sludge may also contain significant concentrations of heavy metals, salts and other trace elements. These factors dictate the need to have the sludge analyzed and expert agronomic advice sought prior to land application.

Lagoon sludge solids contents average almost 10 percent requiring careful selection of removal equipment. The most frequently used method consists of vigorous mixing of the sludge and lagoon liquid using a chopper-agitator impeller pump or pto propeller agitator. The sludge mixture is pumped through a large bore gun-sprinkler slurry irrigation system onto cropland followed by soil incorporation. Another alternative consists of partial lagoon dewatering followed by sludge agitation and finally pumping the slurry mixture into a liquid manure spreader for field spreading. A third alternative is lagoon dewatering followed by dragline dredging. The sludge may be hauled and applied directly to cropland by spreaders equipped to handle slurries, or stockpiled near the lagoon and allowed to further drain before spreading.

AEROBIC LAGOONS

Naturally Aerobic (Oxidation Ponds)

The main advantages of aerobic lagoons are that bacterial digestion tends to be more complete than anaerobic digestion with relatively odor-free end products. In naturally aerobic lagoons, oxygen diffusion occurs across the water surface. Algae also generate oxygen through photosynthesis which takes place when sunlight can penetrate the water depths. Water depths are rather shallow ranging from 3 to 5 feet. Because of the need for oxygen transfer, naturally aerobic lagoons are designed on the basis of surface area rather than volume. The USDA Soil Conservation Service recommends a maximum daily loading rate in North Carolina of 50 pounds of 5-day biochemical oxygen demand (BOD5) per acre of lagoon surface. Using these design criteria, Table 5 gives the surface area required to maintain naturally aerobic lagoon conditions.

Table 4. Poultry Anaerobic Lagoon Sludge Characteristics

Bird type		Total Solids %wb	Chemical Oxygen Demand, COD mg/L	Nitrogen N	Phosphorus P2O5	Potassium K2O
				---------lbs/acre-inch--------		
Layer	mean	9.4	13000	558	2015	266
	std. dev.	7.7	-	212	281	80

Table 5. North Carolina Poultry Aerobic Lagoon Design Criteria

Bird type	Unit*	Average Live Bird Weight lbs	Naturally Aerobic Lagoon Surface Area ft2**	Mechanically Aerated Lagoon Surface Area ft2***	Mechanically Aerated Lagoon Aeration Horsepower hp****
Layer	per bird	4.0	11.6	0.30	0.00030
Pullet	per bird	1.5	4.3	0.11	0.00011

* One-time bird capacity.
** Loading rate = 50 lbs BOD5/surface acre/day; mean liquid depth = 4 ft
*** 1000 ft2/hp of aeration and a minimum liquid depth = 10 ft.
**** 50% satisfaction of waste COD and oxygen transfer rate of 3 lbs/hp-hr

Vast amounts of land are required for naturally aerobic lagoons - as much as 25 times more surface area and 10 times more volume than an anaerobic lagoon 10 feet deep. Thus, naturally aerobic lagoons are impractical for primary treatment and are generally not recommended for livestock and poultry manures.

Mechanically Aerated

Mechanically aerated lagoons combine the odor control advantages of aerobic digestion with relatively small surface requirements. Aerators are used mainly to control odors in sensitive areas and for nitrogen removal at limited land disposal sites. Aerated lagoons have successfully met these objectives by providing enough oxygen to satisfy 50% of the waste chemical oxygen demand (COD) assuming an aerator oxygen transfer rate of 3 pounds per horsepower-hour. The lagoon liquid surface should not exceed 1000 square feet per horsepower of aeration for floating surface aerators to insure complete surface influence. Liquid depths should be at least 10 feet. Table 5 gives mechanically aerated lagoon design criteria for poultry.

A major disadvantage of mechanically-aerated lagoons is the expense of continually operating electrically-powered aerators. Larger anaerobic lagoons may provide similar performance with less expense. Aerated lagoons also yield more sludge than anaerobic units because more input organics are converted to biomass. Suspension of bottom sludge by the aerators can cause increased lagoon liquid concentrations and stimulate foaming. Solids traps such as a septic tank type settling chamber between primary aerated and secondary lagoons can provide a convenient mechanism for solids collection and removal. Mechanically-aerated lagoon liquid nitrogen levels are significantly reduced.

TWO-STAGE LAGOONS

Two-stage lagoons provide certain advantages over single primary lagoons. More than two lagoons in series is rarely beneficial. Secondary lagoons provide temporary storage prior to land application. Aerobic systems need a second lagoon to provide storage and allow the primary lagoon to function solely for biological treatment. A second lagoon also allows a maximum liquid volume to be maintained in primary anaerobic lagoons for stabilizing incoming wastes. Pumping from a secondary lagoon reduces the solids pickup common in primary lagoons due to seasonal water turnovers and biological mixing.

Sizing of secondary lagoons is not clearly defined or critical. North Carolina recommendations are that the second lagoon have a minimum of 90 days storage of wastewater generated as indicated in Figure 1 plus enough volume for the combined 25-year, 24-hour rainfall storage from both lagoons.

POULTRY LAGOON MANAGEMENT SUMMARY

1. New lagoons should be filled one-half full with water prior to waste input, and the liquid maintained at or above the design treatment level.

2. When possible, manure loading of a new lagoon should begin in the spring to permit a good bacterial population to develop during the warm season.

3. Lagoons should be loaded on a frequent regular basis avoiding large shock loadings which cause excessive odors and nutrient level fluctuations.

4. Apply one pound of agricultural lime per 1000 cubic feet of lagoon volume when the lagoon liquid pH falls below 7 to optimize bacterial digestion.

5. Mechanical aeration can be used to control odors, reduce nitrogen content, and reduce surface area but only at high operating costs.

6. Solids separation and removal from raw wastes either mechanically or by gravity settling can reduce the sludge buildup and organic loading rate.

7. Remove sludge from lagoons when 75% of the design treatment volume has accumulated.

8. Prevent additions of bedding materials, long-stemmed vegetation, molded feed, egg flats and other foreign material or debris to lagoons.

9. Maintain strict vegetation, rodent and varmint control near lagoon edges.

10. Plan lagoon liquid drawdowns such that adequate wastewater storage is available during wet seasons.

11. Do not lower the lagoon liquid level below the seasonal groundwater table

12. Irrigate lagoon liquid with equipment selected to handle the particular waste characteristics, whenever the lagoon fills to the top of the normal wastewater storage level, on field crops or grassland at agronomic rates.

13. Locate pump intakes approximately 18 inches underneath the liquid surface and as far from the waste inlet to the lagoon as possible.

14. Electric pump housings should be adequately grounded to prevent stray voltage from contributing to salt deposits on pump internal surfaces.

15. Irrigate when odors are apt to be least offensive, on days with low humidity, or when breezes are blowing away from neighboring residences.

Insect and Fly Control in Poultry Waste

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There are many possible problems that can be caused by flies and arthropods that are associated with poultry waste. Perhaps the most severe of these are when large numbers of unwanted insects are pests of poultry workers and of the surrounding human dwellings. Under normal circumstances, insects associated with poultry waste will remain at the poultry house; however, when populations expand rapidly or the environment of the house is disturbed by clean out, these insects may disperse and cause nuisance complaints against the poultry farm. With the increasing number of large poultry farms concentrating in small geographical areas and concurrent encroachment of human dwellings in the same geographical area, the importance of proper poultry waste management to minimize fly and insect production becomes apparent.

The most successful approach to minimizing fly and insect problems is an integrated management approach. The key to a successful arthropod management program approach is to use all possible tools available to reduce and manage pests to below problem levels. The techniques used to insure low numbers of pests are fully compatible with good poultry house management and center around three key control practices: cultural, biological and chemical.

Insect control in poultry waste begins with the implementation of cultural controls. Cultural controls are those that attempt to make the waste as unsuitable to the insects as possible, which means keeping the manure and litter as dry as possible. Beginning with the building site, the building should be located such that all surface water drains away from the building. Improper grading around the building or improper building locations allow water to flow into the building and add moisture to the manure. Roof overhangs should be large enough to prevent rain water from blowing into the building. Fan moved or natural air movement over the waste should be sufficient to aid in drying. The style of drinkers and feed system should be considered with the housing type, ease of repair and service record. In a modern high rise layer house, there are more than 25,000 drinkers; with only a small percentage leaking, a tremendous amount of water can be added to the waste. It is very important that watering systems be checked on a regular basis and serviced as needed to keep leakage to a minimum. Water lines should be equipped with a night shut-off valve to decrease the problems of leaking waterers or of not finding a burst water line until the waste is flooded. The type of waste handling system, pit-storage, gutter flush, under slats, etc., should be considered and the possible weakness for the building location with each system. As an example, gutter flush housing rarely presents any problem with flies breeding in the poultry house. However, if we use the type of cages that utilize dropping boards that cannot be manually scraped, there can be problems with flies breeding on the manure on dropping boards that cannot be maintained with a limited amount of manure on them. While this type of problem seems remote when the poultry house is being constructed, it can turn out to be a major problem to deal with later and, if the house is located in a "fly sensitive" area, could result in legal action and closing of the house or a substantial input of time for repair and reworking.

The time of year the waste is removed from the house is important. If possible, waste should be removed in the winter months or when land application is possible and insects cannot breed due to cool temperatures. By cleaning out during the cool months there will be enough time for a new pad of manure to accumulate under the birds that will be a reservoir for biological agents and act as an absorbent pad. Cleaning out of a poultry house that has a fly problem during the fly season may not be the best choice for control. By removing the waste, the pupae existing in the waste are also applied to the land the waste is spread on. While proper spreading of the waste will kill the larvae, the pupae will remain and adult flies emerge and migrate to other sites. By removing all waste, there will be no pad to absorb the moisture from new waste, and all the biological control agents are removed. In many cases when the waste is removed in the summer, the producer must rely on chemicals to control the fly population. Waste can be stock piled; however, if this is done, it must be located where water does not accumulate in the waste. the waste should be covered with plastic that will keep water out of the pile and cause the waste to "heat," killing most of the insect larvae in the waste.

Biological controls are comprised of parasites, predators and pathogens of insects. These biological control agents are most effective in production units that utilize built up or stored waste. When this waste is maintained in a dry state, predators and parasites will feed and prey on fly eggs, larvae and pupae. While at this time it is still difficult to augment the levels of these predators by releasing predators and parasites reared at another location, this technology has an excellent future and may become quite important. The most important aspect of utilizing these predators is to make their environment as favorable as possible. This includes maintaining the waste in a dry state and not treating the waste with the type of insecticides that will harm predators and parasites. Cyromazine (larvadex) as an example, can be used in the manure and does not harm the beneficials in the manure. Any time the total surface of the waste is treated with a broad spectrum insecticide, the population of predators and parasites is decimated. Due to the biology of these arthropods, time will be required for the populations to build up to levels that are once again effective in controlling flies. During this time lag, the producer will have no option but to rely on chemical control techniques.

The third segment of insect management in poultry waste is the use of chemicals. Chemical insecticides can be used in the waste by being applied directly to the waste or be fed to the birds. Using chemicals to control these pests is usually effective for only a short period of time, and historically chemicals that have been used widely have had flies develop resistance to the chemicals. The use of chemicals is also costly and should be used carefully to reduce the total cost as well as exposure to birds for residue consideration.

Poultry housing that utilize lagoons for manure storage can also have insect problems if the lagoon is not managed properly. If there are any floating mats of manure in the lagoon they can serve as breeding sites for a variety of flies. These mats should be broken up and the material dispersed. The area around the edge of a lagoon should be kept free of weeds and grasses. If weeds and grasses are allowed to grow into the water they will serve as sites for mosquitoes to lay eggs in. By keeping the weeds and grass clipped short or using a herbicide these breeding sites can be eliminated.

The problems caused by insects in poultry waste are primarily as pests of people who work around the production unit or those that live near the unit. When poultry units were isolated from human populations, few problems were encountered with nuisance complaints. However, in recent times, these nuisance complaints have increased in frequency. In the future, producers must be aware of possible problems from these unwanted insects breeding in mismanaged poultry waste. In some cases, legal complaints from neighbors have resulted in closing of facilities or restrictions on waste disposal in terms of the time of year waste is disposed of and the location of land used for disposal. In the planning stages of a production facility, waste management should be considered. How will it be handled, where will it be disposed of and what possible problems might be encountered. In the end, an issue as unthought of as fly control can have a major impact on the operation of a production facility.

Drying Poultry Manure - World Conditions

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The problem of practical poultry excreta disposal has become a major consideration facing the commercial poultryman. The waste disposal problem has been brought into focus by increased concentrations of poultry in relatively small areas under single management, the lack of public acceptance to land spreading and legislation to minimize or prevent environmental odors, water pollution, dust, flies and rodents. The route to the final disposition of poultry excreta has taken several paths.

Land spreading has historically been the only practical and feasible technique for poultry excreta disposal. Among the recently emerging techniques to improve the acceptance of poultry excreta disposal is drying. Some of the more apparent reasons favoring poultry excreta drying are reduced total material, a stable easy to handle product, nearly odor free and useable material, reduction or near elimination of flies and a possible reduction in pollution potential. Conversely, input costs can be high (including equipment and fuel), the poultry industry may need to develop special markets to take advantage of the resulting dry product and the drying process itself can produce particulate and/or odor emissions unless steps are taken to prevent such potential inadequacies in the particular drying system utilized.

Review of Poultry Excreta Drying Techniques

Perhaps the most ancient poultry excreta drying system was to let the birds self spread their droppings as they wandered about in search of their food. This air drying system is still employed and is being revitalized in areas of the world where confined housing of poultry is being limited. Air drying of poultry droppings in very large commercial poultry operations is also being practiced today in arid and semi-arid climates. Under these conditions, a dry product capable of storage by bagging is being produced in about three days.

Other more complicated (and expensive) poultry excreta drying systems were investigated in the 1960's and 1970's. One such technique involved electro-osmotic moisture migration or the application of two electrodes in wet manure and a direct current is passed between them. The water then moves from the positive to the negative. Test results indicated that this technique resulted in moisture reduction (57% more than control samples) however, uneven drying occurred due to unequal shrinkage of the samples and lengthy drying periods (13-40 days) were required, thus limiting the practical application of the technique.

Another system involved the use of electrical heat tapes inbedded in concrete under cage battery systems. This technique was also effective in reducing moisture in poultry droppings to 10% moisture or less on a daily basis. The drying in this system was very costly and removal of the dried product was not feasible with commercially available scraper systems; therefore commercial application of this system was not practical.

During the late 1960's and early 1970's, extensive research was completed involving the use of fossil-fueled drying systems that included rotary drum dryers, triple pass dryers, floating bed dryers and other more or less complicated drying systems. About the time most of these fuel consuming dryers were perfected to work reliably, the world price of fossil fuels skyrocketed making this a very costly system to dry poultry excreta.

Economics (the high cost of manure drying by the use of fossil fuel and/or electricity) has dictated the development of more cost effective poultry manure drying techniques in recent years. One of the first such systems was the sloping wire floor system. In this system, fans were directed to blow under the wire pen where the birds were housed. The excreta was periodically stirred by a mechanical stirring device and moisture was carried off in the ventilation air. This system resulted in a drying capability that varied seasonably and did not dry the product sufficiently to be stored by bagging. In addition, the adaptability of this system to battery cages was not possible. However, poultrymen did place fans under battery cages to induce drying and many also used some tilling device to stir the battery manure under the cages to further encourage drying.

Another practical application of the use of ventilation air to reduce excreta moisture was developed in England. This system was utilized in the high-rise house (a poultry house constructed to have battery laying system in the upper story and a manure storage pit in the lower story of a two story house). In the lower story or manure storage area, a set of wooden drying racks were constructed. These drying racks provided an enlarged surface area on the accumulating poultry excreta for the drying of the manure by the ventilation air. The manure racks were collapsible for cleanout. This system resulted in a greatly reduced moisture content of the excreta and a minimum of nutrient loss in the resulting product.

The most recent poultry manure drying systems have made use of solar energy, heat of composting, ventilation air directed over the manure in a drying chamber separated from the laying chamber, heating of outside air using the body heat of the birds and then directing the heated air on to the excreta and/or a combination of two or more of these systems.

Summary

Although there are several advantages to drying poultry excreta, the use of this technique by the commercial poultry industry has been limited due to cost and mechanical adaptation, except in arid and semi-arid climates where outside drying is practical. However, there are certain areas of the world where population density or other local conditions exist making poultry manure drying a viable alternative due to those advantages inherent in the drying system.

COMPOSTING MANURE AND SLUDGE

by John M. Sweeten[1]

Processes

Composting involves the microbial conversion of biodegradable organic materials into a relatively stable humus by thermophilic organisms under controlled conditions. The organisms are primarily bacteria, actinoycetes, and fungi.

Composting is generally conducted under aerobic conditions, in which atmospheric oxygen is present. Aerobic decomposition by microorganisms converts biodegradable organic matter in manure to oxidized end products, primarily carbon dioxide and water. Thermophilic temperatures of 130°F to 160 °F are commonly achieved, providing pathogen kill and dessication of weed seeds. Detrimental characteristics associated with aerobic composting process are usually limited to odors in the initial stages. Aerobic composting generally produces a product with an inoffensive odor generally characterized as musty and sweetish.

By contrast, anaerobic decomposition occurs without atmospheric oxygen and achieves mesophilic temperatures of less than 130°F. Anaerobic digestion yields partially oxidized and reduced compounds which may continue to undergo decomposition. The end products of anaerobic decomposition include organic fatty acids, aldehydes, alcohols, hydrogen sulfide, and ammonia. These compounds can result in serious odor nuisance. Anaerobic conditions occur when sufficient oxygen cannot enter pore spaces (voids) due to excess moisture, fine particle size, or compaction.

Only aerobic thermophilic composting will be considered further in this paper.

Advantages and Disadvantages

Composting is an important treatment process for many organic wastes and residues including animal manures, municipal and industrial sludges, and crop residues that are in solid or semi-solid form initially.

The major advantage of composting is the production of a stabilized product that can be stored or spread with little odor or fly breeding potential. Improved physical properties include low moisture content (usually below 35 percent), uniform particle size, friable texture, reduced materials volume, and reduced weight. These improved physical properties lower the uniformity of hauling costs and enhance spreading. Aerobic thermophilic composting kills most pathogens and weed seeds. Phosphorus, potassium and other mineral elements are retained. While ammonia nitrogen may be volatilized, total nitrogen usually remains stable. These advantages result in greater market potential for compost as compared to unstabilized organic wastes.

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The major disadvantage of composting is cost for equipment and labor. Market demand for compost may be temporal. Malodor is usually produced during the initial stages of composting, and some states require a permit for the construction of such facilities.

Factors Affecting Composting Rates

The primary factors that influence biological activities and affect composting rates include: moisture content, physical structure and consistency, aeration, nutrient balance, pH, and temperature.

Moisture Content

Moisture is required for microbial activities that cause composting to occur. Moisture content for aerobic thermophilic composting should be 40 to 60 percent initially. If the composting material is too dry, below about 35 percent moisture, the decomposition rate will be much slower than at 40 to 60 percent moisture. Supplemental water may need to be added to dry manure to initiate composting.

If the moisture content is too high, anaerobic conditions are promoted due to the exclusion of oxygen from void spaces. Excess moisture levels will result in lower temperatures and increase the time needed for composting. In mechanical systems, moisture contents of over 65 percent can cause the composting material to agglomerate ("ball up") and restrict air flow.

Prior to composting, wet organic materials should be mixed with a dry material (bulking agent) to reduce the initial moisture content. Suitable bulking agents include cotton burrs, saw dust, peanut hulls, corn cobs, wood chips, and rice hulls. These materials also provide a source of carbon as will be discussed later.

Finished compost usually has a final moisture content of 20 to 40 percent. Some of this product can be recycled as a bulking agent.

Structure and Consistency

To promote aeration, composting materials should have adequate porosity (voids) to allow passage of air. Bulking agents are usually necessary to increase porosity of fine-textured materials such as sewage sludge or poultry manure as well as to absorb excess moisture. The amount of bulking agent may range from less than 1:1 (volume/volume) to more than 5:1 depending on particle size and initial moisture content.

Aeration

Aeration is necessary to (a) support aerobic microbial activity, (b) remove released moisture, and (c) remove excess heat that can otherwise reduce microbial activity. Generally more air is required for moisture and temperature control than for microbial activity. Air within or exhausted from the composting materials should contain 5-15% oxygen.

Aeration is normally provided by two methods. First, the compost pile can be turned using mechanical equipment. The pile should be turned several times per week initially, with the turning frequency reduced in subsequent weeks. The compost should then be stockpiled for curing, during which final degradation occurs. The latter stages may be marked by the appearance of fungi and actinomycetes, which primarily digest hemicellulose.

The second aeration method is a forced-air system, in which air is either blown or drawn through the compost. Aeration rates should be sufficient to create measurable free oxygen in the exhaust air. Aeration rates can be reduced as composting progresses. Subsequently, the compost should be aged in a stockpile for about two months to complete the stabilization process.

Carbon-Nitrogen Ratio and Other Nutrients

Microorganisms which decompose organic residues require nitrogen and other nutrients for metabolism and reproduction. The amount of nitrogen required per unit of organic matter varies with the type of microorganisms involved in the process. It is generally accepted that the carbon/nitrogen (C/N) ratio of the wastes will influence the rate of decomposition. Carbon is used to build microbial cells and to supply energy for microorganisms. Much of the carbon is converted to carbon dioxide which is liberated to the atmosphere. Thus, decomposition of organic material leads to a large decrease in carbon, but usually a smaller decrease in nitrogen occurs.

If the nitrogen content is low and the C/N ratio is high (above 30), microorgansms must recycle the nitrogen through many generations of bacteria as the carbonaceous matter is decomposed. During composting, most nitrogen is immobilized and stored in the bodies of the microorganisms while some nitrogen is liberated as ammonia or nitrogen gas. The overall effect is that the C/N ratio decreases during the composting process.

An optimum C/N ratio, below which nitrogen ceases to be a rate-limiting factor, can be established for carbonceous materials. It depends partially on the potential rate of decomposition of the carbon source. For example, a readily-available carbon source creates an immediate nitrogen demand and requires a low threshold value for C/N ratio. On the other hand, cellulose and lignin are more slowly degradable and would have a low nitrogen demand, requiring a higher C/N ratio.

Ideally this initial C/N ratio for most composting manure and sludges is around 20 to 30. By comparison, the carbon-nitrogen ratio for livestock manures is typically in the neighborhood of 10:1. Therefore, it is often desirable to add carbonaceous material such as crop residues or sawdust to raise the C/N ratio. As previously discussed, these materials may also reduce the moisture content and increase porosity of the compost.

Adequate phosphorus and potassium must also be present to compost organic wastes. Phosphorus is a constituent of the microbial protoplasm, and potassium is necessary for regulating osmotic pressure relationships within bacterial cells. Ideally, phosphorus should be present in amounts of about 20 percent that of nitrogen. Potassium content should be about 8 percent of nitrogen.

Consequently, a C:N:P:K ratio of approximately 25:1: 0.2: 0.08 is desirable for common types of organic wastes.

Acidity vs. Alkalinity (pH)

The pH should be 6.5 to 7.2 initially for best composting results. At the start of composting of wet manure or sludge, the pH may drop below 6.0 due to the formation of organic acids. These acids are odorous and they retard the activity of aerobic thermophilic bacteria. Little heating will occur with a pH below 6.0 since bacteria will work sluggishly until they manage to elevate the pH to a more desirable level. Hence, at the outset it may be desirable to provide a buffering agent or lime. Final pH values of finished compost will range from 7.5 to 8.5 or greater.

Toxic Substances

Some organic materials (e.g. industrial sludges) may contain substances that are toxic to aerobic thermophilic bacteria. Heavy metals such as manganese, copper, zinc, nickel, chromium, and lead may be toxic to certain microorganisms. Heavy-metals may be immobilized chemically prior to composting. Heavy metals are not present in appreciable concentrations in manures but they may be worth considering in some municipal or industrial sludges.

Temperature

Temperature is the main determinant of the rate of composting, and it serves as a guide to the relative degree of stabilization of the composting materials. Organic materials usually start out at ambient temperatures and encounter a few hours or days of lag time before temperature begins to increase. During the digestion phase, the microorganisms multiply and actively metabolize the available food and release heat. Aerobic thermophilic composting is said to begin when the temperature reaches 113°C, and the rate of ascent is usually rapid thereafter as heat is released through breakage of chemical bonds within complex molecules of organic matter, reducing them to simpler compounds. The temperature may begin to peak at 130 to 140°F or in many cases may climb to exceed 150°F. Temperatures as high as 185°F are not unusual. Through process control involving turning and/or aeration, the operator should try to avoid temperatures higher than about 150°F early in the composting cycle to prevent die off of beneficial organisms before adequate stability has been achieved. Managing compost temperatures to the range of 130 to 150°F is desirable while turning and/or aeration are being practiced.

During composting, pathogens are almost completely destroyed through elevated temperatures and competition with thermophilic organisms. The U.S. EPA regards composting temperatures of 104°F for 5 days as a "process to significantly reduce pathogens" in sewage sludge. And, to be classified as a "process to further reduce pathogens", which is considered equivalent to pasteurization, temperatures of 131°F must be attained for 3 days within vessles, bins or aerated static piles or for 15 days within windrows being turned at least 5 times. Most weed seeds are inactivated at 150 to 160°F.

Composting Systems

The two basic steps for successful composting operations are materials preparation and biological stabilization. The preparation stage consists primarily of adjusting moisture content, structure and/or chemical content as necessary. High moisture manure or sludge can be dried to below 60 percent moisture content by blending finished compost or bulking agents (wood chips, cotton gin trash, cornstalks, straw, etc.), or the moisture content of manure or sludge may need to be raised to 40 to 60 percent moisture by adding water. Sorting, removing or grinding very large particles (e.g. slabs of dry feedlot manure) or foreign materials may also be necessary. The organic waste may be "seeded" with microorganisms from commercial sources or using finished compost to possibly help initiate decomposition.

Biological stabilization by composting can be carried out in: (1) windrows, (2) aerated static piles, or (3) aerated bins or vessels. Each method involves various types and levels of mechanization that affect processing time, space allocation, labor requirement, cost and management.

Windrow Operations

The most commonly-used method of composting is the windrow process which involves stacking organic wastes into windrows that are turned periodically. A basic windrow composting operation is relatively simple and requires few control measures other than monitoring of temperature and moisture.

Windrows should be 3 to 5 feet tall and have a base width of about 10 to 15 feet. Air movement through the porous composting material should resemble a chimney effect as internal heating occurs.

Aeration may be accomplished by mechanically turning the windrow. In many cases, the same equipment used for manure collection and loading (wheel loaders, etc.) can be used for windrow composting. Turning requires a tractor front-end loader, a wheel loader or special purpose machinery. Commercially-available composting machines are designed to move a rotating spiked-drum or auger through the compost while travelling the length of the windrow. One type of composter straddles the windrow and turns the compost in place using a rotating spiked drum. Another type uses a cross-auger to lift, mix and redeposit the compost to form a new parallel windrow.

Windrows should be turned frequently at first and then decreased by the end of the first month. A recommended turning frequency is:

1st week -- 3 turnings
2nd week -- 1-3 turnings
3rd week -- 2 turnings
4th and 5th week -- 1 turning
5th and above -- 0 turning

Temperature should be used to determine the need for turning to stimulate or control heat production.

Minimum composting time is one month in the turned windrow followed by at least two months in a curing pile. Afterwards, the compost may be ready to be bagged and marketed.

Aerated Windrow or Static Pile Composting

Composting can also be performed in static windrows or piles in which forced air is provided. The manure or sludge is placed in a windrow or pile over a gallery of perforated pipes beneath the windrows. Air is blown through the pipes and upward into the compost through the perforations. An alternate procedure is to apply suction to the aeration pipes and draw air into the compost windrow or pile. Forced aeration eliminates frequent turning but requires an electric compressor/blower and pipe network to distribute the air. At least 5 to 10 standard cubic feet (SCFM) of air per cubic yard of compost is required initially. This aeration rate may be gradually reduced to 1 scfm of air per cubic yard during the third or fourth week with no aeration after four weeks.

The so-called Beltsville Aerated Pile Method (named after the USDA/ Agricultural Research Service composting research facility at Beltsville, Maryland) is one variation of forced-air windrow composting. Developed specifically for wet sewage sludge, the method involves mixing woodchips or similar bulking agent with the sludge, and then constructing an elongated pile of sludge/woodchip mixture that is placed on a pad of woodchips or unscreened finished compost. The pad contains a loop of perforated pipe that provides forced-aeration. The pile is covered with a blanket of unscreened finished compost which both insulates and serves as an odor barrier. Atmospheric air is drawn into the pile under negative pressure with a blower, and exhaust air is discharged through a small pile of finished screened compost that serves as a partial odor filter. The blower is cycled on and off in 15-minute intervals. The recommended average aeration rate with the blower operating is 8 to 10 scfm per dry ton which usually maintains 5-15% oxygen in the compost pore space and removes moisture. Design of the aeration system is an engineering problem which should take into account air pressures, depth of pile, air flow velocities, friction losses in air distribution pipes, and blower power requirements.

Within three days after composting begins, pile temperatures have generally increased to a range of 140 to 160°F where they remain for most of the 3-week composting period. Afterwards, the composted material is removed and transferred to an unaerated curing pile for 3 to 4 weeks for further composting and drying without mixing. The bulking agent is then separated by screening and is reused by blending with incoming sludge.

Aerated-Bin Composting

Aerated-bin composting systems are either continuous-flow (mechanically stirred) operations or batch-operated systems (un-stirred). Continuous-flow systems are more highly mechanized than batch systems. Following materials preparation (grinding, mixing and moisture adjustment), the mixture is gradually fed into the aerated composting bin via wheel loaders, gravity-fed hoppers, or belts. Environmental conditions in the aerated bin are controlled so that a steady rate of decomposition is maintained by the microorganisms. Aeration within the reactor is done by mechanically turning the composting material, by forced draft compressors/blowers, or a combination of the two. Mechanical mixing or turning is usually performed daily to assure that oxygen reaches all microorganisms. Forced aeration usually exceeds 5 to 10 scfm per cubic yard the first two weeks, 1 to 2 scfm per cubic yard the third week, and 1 cfm per cubic yard or less the fourth week. Temperature probes should be used to determine proper turning frequencies and aeration schedules, which may differ for each composting mixture.

A continuous flow aerated bin often produces well-stabilized end products within one month. Curing in a stockpile for several weeks should follow removal from the continuous-flow aerated bin.

Aerated bin composting can also be carried out in batch mode. Aeration is provided by perforated pipe, with air under either positive or negative pressure or some alternating combination of the two. At intervals of several days, materials are transferred into an adjacent bin. Transfer methods include wheel loaders, flighted lifter-mixers, or conveyors.

The purchase of expensive mechanical equipment is probably not warranted unless stable markets for compost are available. Corrosion of mechanical equipment is sometimes experienced in manure composting.

Summary

Livestock and poultry manure as well as sewage sludge can be composted to provide an improved product for land application or upgraded use such as horticultural planting mixtures. Composting stabilizes organic matter, improves materials handling characteristics, preserves nutrients, and reduces product odors. However, odors may be produced during composting operations.

The objective in composting should be to provide a proper nutrient balance and environment for the reproduction of aerobic thermophilic bacteria. Factors such as temperature, moisture content, structure, carbon-nitrogen ratio, pH, and proper aeration are critical to efficient composting. Operating temperatures of 130 to 160°F are desirable and frequently attained during aerobic composting. These temperatures kill fly larvae, pathogens, and weed seeds. Excessive temperatures over 150 to 160°F are not desirable in the early stages of composting.

Composting can be carried out in windrows or bins with aeration provided by mechanical turning and forced aeration. Aerated bins with mechanical equipment for turning and/or aeration are generally more efficient yet more expensive than windrow composting. Supplies of manure or sludge and bulking agents as well as market demand for the finished compos should be carefully investigated before producers invest heavily in composting equipment.

ANAEROBIC DIGESTION OF POULTRY WASTE AND BY-PRODUCT UTILIZATION

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INTRODUCTION

Anaerobic digestion is a microbiological process through which organic waste is degraded and converted to biogas (methane and carbon dioxide) in the absence of oxygen. The application of this technology to the treatment of sewage and animal wastes has been known for many decades and has been in practice in many parts of the world (Hobson et al., 1981; Stafford et al., 1980; China State Biogas Association, 1985). An anaerobic poultry waste digester system has been developed in our laboratory from a laboratory bench-top experiment to a simple and low-cost digester for 4,000 hens on the NCSU research farm (Shih, 1987a,b). The products from the system were studied for economic utilization and other associated benefits were demonstrated. Based on our digester design and study, anaerobic treatment of poultry manure can be efficient and economical. In this communication, different aspects of poultry waste digestion will be briefly discussed.

CONVENTIONAL ANAEROBIC DIGESTION

Anaerobic treatment of organic waste has several advantages over the aerobic process. It degrades organic matter and at the same time produces biogas energy. The recovery of biogas fuel compensates for the operational cost of energy. Because it operates in an enclosed tank, the process controls odor better than an aerobic system does. The anaerobic condition can reduce the survival rate of many pathogens and conserve nutrients which could otherwise be oxidatively destroyed in an aerobic condition.

However, the anaerobic digestion process, which operates conventionally in a stir-tank at mesophilic (30-35°C) or ambient (15-20°C) temperatures, is known to suffer several critical disadvantages. First, the bio-reaction rate is slow. The treatment requires a long retention time and the volume of the digester is usually very large. Because of the size requirement, the costs of construction, equipment and maintenance are high and make the process economically unattractive (Thornton, 1978). Other disadvantages associated with anaerobic digestion are the high consumption of water and the requirement of treatment of wastewater discharged from the system.

In order to make the process of anaerobic digestion more economical and adaptable to agricultural uses, it was imperative to search for technological improvements to increase the bio-reaction rate and thus shorten retention time and reduce digester volume. It is equally important to develop a simple and low-cost digester system. To enhance the economics of the system, the utilization of products and by-products must be fully developed.

THERMOPHILIC ANAEROBIC DIGESTION

Thermophilic bacteria which grow well at an elevated temperature (45-65°C) usually metabolize substrates at a high rate. A systematic method to select a thermophilic microbial population from the natural environment to degrade poultry manure and produce biogas at a high rate was successfully carried out (Huang and Shih, 1981). It was found that chicken manure is a good substrate which can support a high biogas rate when the digester is operated under selected optimal conditions. It was estimated that the potential of biogas energy which can be derived from 50,000 laying hens by anaerobic digestion is 10 million BTU per day (Shih, 1987b).

The comparison of the performances of thermophilic (50°C) and mesophilic (35°C) digestion of poultry manure is summarized in Table 1. The reaction rate at 50°C is obviously much higher than that at 35°C. The retention time (RT) can be as short as 4 days and the loading rate can be as high as 15 kg VS/m^3/day in the laboratory and 7.5 kg VS/m^3/day in a farm digester (Steinsberger and Shih, 1984). Based on these data, the design of a thermophilic digester can be much smaller than a mesophilic one for the treatment of the same amount of waste. The input of operational energy would be higher, but because of its high output of energy the thermophilic operation has a theoretical energy efficiency of 74%, only 11% less than that (85%) of the mesophilic operation (Shih, 1987b).

LOW-COST DIGESTER

Encouraged by our laboratory findings, a digester was built on the university farm for the treatment of manure from 4,000 hens. The system consisted of a hot-water heater, a plug-flow digester made of a plastic bag, the insulation material, and a gas monitoring system. It was characterized by simplicity, low cost and appropriate technology (Huang et al., 1982; Steinsberger and Shih, 1984). The performance data of the system are presented in Table 1. Compared with the laboratory results, it reached a 50% loading rate, 90% biogas rate and 100% biogas yield. The reduced loading rate was believed to be due to the reduced digester volume by the accumulation of grit or sand. The three year operation of the digester was simple, effective, and without major problems.

The combination of the thermophilic condition and the plug-flow design has made the construction and operation of a waste digester highly efficient and relatively inexpensive. An estimated cost of a digester system for 50,000 hens is approximately $50,000 ($1.00/hen).

BY-PRODUCT UTILIZATION

One of the major by-products of the system is the sludge in the settlement. The sludge can be recovered and dried by the biogas heat to become a solid by-product (SBP). The composition of SBP and its potential use as a feed supplement have been evaluated in our laboratory (Steinsberger et al., 1987). Typically, the SBP has 50% organic and 50% inorganic matter. It has 10% true protein, 3% nitrogen, 4% phosphorus, 3% potassium and 18% calcium. By feeding SBP as the sole source of phosphorus, it was determined that the phosphorus in SBP is 90% bioavailable for growing chicks. No toxicity or adverse affects were detected in chicks when fed a 10% level of SBP in the diet. This demonstrated that SBP can be a useful feed supplement and source of many nutrients. However, the availability of nutrients other than phosphorus has yet to be determined.

The effluent or wastewater from the digester is a liquid by-product which needs to be treated or utilized. Aquacultural use of the effluent has been studied (Shih, 1987a). It was found that the liquid effluent with its nutrient contents put into a fish pond at a proper rate can support the growth of tilapia fish without additional feeding. Fish culture is not only a way to reuse the nutrients in water, but also a means of secondary treatment of wastewater. An integration of fish pond and poultry production can generate additional income, improve landscape and provide recreation.

PATHOGEN CONTROL

The fate of pathogenic microorganisms in poultry waste digesters has been studied (Shih, 1988). When the influent (manure slurry) and effluent samples were compared, it was found that fecal coliforms, including Salmonellas, were completely destroyed in the thermophilic digester in 24 hours. A reduction of fungi was also close to 100% in the digester. The oocysts of pathogenic protozoan Eimeria tenella were inoculated into the digester. After 24 hours they were recollected and tested for sporulation in vitro and infectivity in young chicks. The digester-treated oocysts were found to have lost both their infectivity and ability to sporulate. A DNA-hybridization technique was developed to detect the viral DNA of Marek's disease virus (MDV) (Pyrzak and Shih, 1987). MDV were completely destroyed as their DNA was undetectable after 24 hours in the digester. It was concluded from our studies that a broad spectrum of microbial pathogens can be destroyed by anaerobic digestion, especially at thermophilic temperatures. The benefits of poultry waste digestion in the control of pathogens and protection of human and animal health are significant. It is difficult to assess the value on a monetary basis, but the control of infectious diseases and reduction of medication in the farm environment are obviously advantageous.

CONCLUSION

A poultry waste digester system operated at a thermophilic temperature has been established from the laboratory to farm operation. Benefits of the system have been demonstrated. It has a high bioreaction rate and short retention time, and therefore the digester can be compact. When the digestion is at an elevated temperature, the digester medium has low viscosity and mixing by effervescence is possible. The energy-intensive mixer is not needed. Because of the ease of mass transfer and no need of a mixing mechanism, the digestion process is readily adaptable to a digester with a simple plug-flow design. At the thermophilic temperature the process destroys most, if not all, pathogens and thus protects the health of farm workers and animals and also helps generate pathogen-free by-products. The latter is of particular importance when the by-products are used for feeding animals and fish. The solid settlement in the digester can be collected for feed supplementation and the digester effluent with nutrient content can be used for aquaculture.

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TABLE 1. ANAEROBIC DIGESTION OF POULTRY MANURE

Digester Size	Temp. (°C)	RT (day)	VS%	TS%	Loading (kg VS/m^3/d)	Biogas (v/v/d)	Biogas (m^3/kg VS)	CH_4%	Reference
97 m^3	35°	40	8	11.8	2.0	0.9	0.44	62	Converse *et al.* (1981)
2.8 m^3	35°	15	5	7	3.3	2.0	0.6	60	Morrison *et al.* (1981)
590 m^3	35°	24	5	7	2.1	0.8	0.6	58	Safley *et al.* (1985)
15 l	35°	54	20	35*	3.7	0.3	0.5	60	Jantrania & White (1985)
1 l	50°	4	6	8	15.0	4.5	0.4	70	Huang *et al.* (1982)
8 m^3	50°	4	3	4	7.5	4.0	0.53	55	Steinsberger & Shih (1984)

*Manure and corn stover (2.5:1)

UTILIZING POULTRY WASTES IN RUMINANT FEEDING

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Poultry wastes which may be used for feeding ruminants consist of broiler litter, caged layer waste and turkey litter. These wastes are from birds managed intensively so the wastes have to be handled properly to avoid contamination to water supplies and risk to human health and comfort. The wastes have been recognized as good sources of plant nutrients, and have been used extensively as fertilizer. In research conducted during the past 30 yr it was shown that these materials have substantial nutritional value for ruminants. Since the wastes contain substantial levels of fiber and non-protein nitrogen, they are best suited for use by ruminants.

Nutritional Value

Broiler and turkey litter are composed of bedding material, excreta, feathers and wasted feed. The caged layer waste consists of excreta from hens kept in cages, wasted feed and feathers.

Poultry Litter

Broiler litter is usually high in nitrogen (crude protein), averaging 31% crude protein, dry basis (Bhattacharya and Taylor, 1975), but varies considerably in this component (table 1). Approximately 40 to 50% of the nitrogen in litter is in the form of protein (Bhattacharya and Fontenot, 1965, 1966). The main non-protein constituent in broiler litter, uric acid, is utilized efficiently by rumen microorganisms. Uric acid has been shown to be more efficiently utilized by ruminants than urea (Oltjen et al., 1968).

Broiler litter can be an important source of energy for ruminants. Average digestibility by sheep of energy in broiler litter with peanut hulls and wood shavings as base materials, calculated by difference, was 64% (Bhattacharya and Fontenot, 1966). The litter contained 60% TDN, and 2240 kcal of digestible energy and 2181 kcal of metabolizable energy per kilogram of dry matter for ruminants. These values compare favorably with those of high quality roughage such as alfalfa. Litter is rich in calcium and phosphorus and also contains substantial levels of at least some trace minerals (Bhattacharya and Taylor, 1975).

Limited data are available concerning the nutrient content of turkey litter. Cross and Jenny (1976) reported that turkey litter contained 18.2% crude protein, 34.5% neutral detergent fiber and 36.6% ash, dry basis. Based on the fiber and ash contents the available energy value would likely be lower than for broiler litter.

Performance of animals fed poultry litter has been satisfactory, especially if the level of waste has been limited to that needed for supplementary protein. Rate of gain was similar for fattening steers fed chicken litter as for those fed cottonseed meal, if energy intakes were equalized (Noland et al., 1955). As shown in table 2 rate of gain of steers fed a fattening mixture containing 25% peanut hull or wood-shaving broiler litter plus 1 kg of long hay per day was similar to that of steers fed a control mixture and long hay (Fontenot et al., 1966). Feed efficiency was in favor of the litter-fed cattle. Broiler litter has been used successfully to feed growing cattle and beef cows. Smith and Wheeler (1979) summarized performance data for cattle fed poultry litter. Mean data from 93 control and 179 experimental cattle in which poultry litter comprised an average of 24% of the dietary dry matter were respectively: average daily gain, .99 vs. .94 kg; dry matter intake, 10.0 vs. 10.3 kg; feed to gain ratio, 10.4 vs. 11.4.

Caged Layer Waste

Caged layer waste has been shown to contain an average of 28% crude protein, dry basis (Bhattacharya and Taylor, 1975). Protein nitrogen makes up about 40% of the total nitrogen in the caged layer waste. Nutrient composition of the excreta is variable which may be due to the plane of nutrition of the hens and waste management systems (Evans et al., 1978). Nitrogen and ash in excreta were higher from hens fed high protein and energy diets than for those fed lower protein and energy diets. Also, accumulation of wastes under cages resulted in nitrogen losses.

The TDN content of dried caged layer waste appears to be somewhat lower than for broiler litter (table 1). Digestible energy values were 1875 kcal/kg in sheep and 1911 kcal/kg in cattle, dry basis. The high ash content of caged layer waste will lower the energy value. Evans et al. (1978) reported a 14% decrease in gross energy and a 33% increase in ash content in caged layer waste composted for 252 days.

Calcium and phosphorus are high in caged layer waste, especially calcium, resulting in a high calcium to phosphorus ratio (Bhattacharya and Taylor, 1975). The waste is over three times as high in calcium as broiler litter and a little higher in phosphorus.

Data concerning the performance of cattle fed dehydrated poultry waste (DPW) compared to those fed conventional protein supplements were summarized by Smith and Wheeler (1979). Data from 120 cattle in each group showed that rate of gain of cattle supplemented with DPW was similar to that of cattle fed traditional supplements. Feed intake values were 6.34 vs. 6.61 kg per day and feed to gain ratios were 6.49 vs. 7.25, respectively. From a summary of 100 dairy cows fed DPW as a supplement and 100 cows fed a control supplement the mean milk production of the cows fed diets supplemented with DPW was 40.0, compared to 40.5 kg for control cows (Smith and Wheeler, 1979). Milk fat was not affected.

Processing Poultry Wastes

Processing is important for destruction of pathogens, improvement of storage and handling characteristics and maintenance or improvement of palatability. Research has been conducted with dehydrated poultry litter (Harmon et al., 1975; Cullison et al., 1976) and caged layer waste (Smith and Calvert, 1976; Tinnimit et al., 1972). Harmon et al. (1974) reported that dehydration of broiler litter resulted in a substantial loss in nitrogen which could be reduced by acidifying the litter prior to dehydration. Due to the high cost of fossil fuel considerable interest has developed in methods of processing which require minimal levels of fossil fuel energy.

Ensiling Poultry Litter

Good ensiling occurred with mixtures of broiler litter and whole plant corn silage at levels up to 45% of litter, dry basis, with pH less than 5 and lactic acid levels similar to those in regular corn silage (Harmon et al., 1975a). Protein content of the silage was increased up to 18%, dry basis, by incorporating 45% broiler litter into corn silage. Voluntary intake of silage with 30% litter, dry basis, by sheep was about 75% greater than that of plain corn silage, and nitrogen was efficiently utilized (Harmon et al., 1975b). In a subsequent finishing experiment similar performance was obtained in heifers fed a corn-broiler litter silage containing 30% litter, dry basis, as for heifers fed corn silage supplemented with soybean meal (McClure and Fontenot, 1985). Total concentrate intake was 1% of bodyweight.

Broiler litter can be ensiled alone. However, in order to obtain good fermentation the moisture level should be about 40% (Caswell et al., 1978). Digestibility of proximate components and nitrogen utilization by sheep fed a ration containing litter ensiled with 40% moisture was similar as for sheep fed a soybean meal supplemented ration. Adding whey to increase the moisture content of ensiled litter was beneficial in lowering the pH if the litter had been deep stacked previously, but was of no benefit when the litter was removed from the house and ensiled immediately (Duque et al., 1978). Substituting ensiled broiler litter for corn silage did not lower the performance of steers until the level of litter exceeded 30% of the dry matter (Cross et al., 1978). In fact, rate and efficiency of gain were higher for cattle fed 30% broiler litter silage than for those fed no litter. Finishing cattle fed corn silage supplemented with ensiled broiler litter at a level of 30% of the dry matter performed similarly to those supplemented with soybean meal (Chester-Jones et al., 1981). In cattle fed hay-concentrate rations performance was not lowered by substituting up to 40% of the ration, dry basis, with ensiled broiler litter. There was a dramatic depression in performance, when the level of litter was increased to 60%, dry basis. Cross and Jenny (1976) reported that substitution of 15 or 30% turkey litter silage for corn silage increased rate of gain in growing dairy heifers. Increasing the level of silage to 45% resulted in similar performance as for those fed the basal ration.

Deep Stacking Poultry Litter

Deep stacking of broiler litter produces considerable heat and has been shown to destroy coliforms (Hovatter et al., 1979). Maximum temperature was reached at 4 to 8 d, then the temperature plateaued and tended to equilibrate with atmospheric temperature. Litter ensiled at 40% moisture or deep stacked produced similar performance in cattle, when incorporated at levels up to 60% of the dry matter of the ration (Hovatter et al., 1979; Chester-Jones et al., 1980). Feeding corn silage supplemented with deepstacked broiler litter, resulted in similar performance in fattening cattle as feeding silage in which litter was mixed with corn forage at ensiling time (McClure and Fontenot, 1985). For both rations the proportions were 70% corn forage and 30% litter, dry basis. Deep stacking should be in a covered shed with ample air circulation to avoid spontaneous combustion. This type of processing can be used only with waste which has a low-moisture level.

Ensiling Caged Layer Waste

Saylor and Long (1974) reported maximum acidity, lactic acid concentration, crude protein and in vitro dry matter digestibility with an ensiled mixture of 60 parts of caged layer waste and 40 parts of hay. Caged layer waste and sugarcane bagasse were ensiled in different proportions by Samuels et al. (1980). The pH of the ensiled mixtures, generally below 6, and lactic acid levels (4 to 8%, dry basis) indicated good ensiling had occurred. In metabolism trials with ensiled mixtures containing 40, 50 and 60% caged layer waste, dry basis, it was found that apparent digestbility of dry matter, organic matter and crude protein were highest for sheep fed the diet containing 60% caged waste. Dry matter digestibility of the waste, calculated by difference, averaged 65%. Among the waste-containing silages, dry matter intake tended to be highest for the 60:40 silage. Caged layer waste and corn stover in proportions of 60:40 and 40:60 were ensiled alone and with 10% dry molasses (Moriba et al., 1982). The pH and lactic acid levels generally indicated good ensiling for all mixtures. Addition of molasses resulted in dramatic increases in lactic acid. Dry matter digestibility of the caged layer waste in the ensiled mixtures, calculated by difference, averaged 77%. Undoubtedly, this is higher than actual, due to the low digestibility of corn stover ensiled alone.

Canadian workers ensiled a mixture of caged layer waste, chopped alfalfa hay, corn, molasses, minerals and vitamins alone and with tannic acid or paraformaldehyde in small glass jars equipped with a gas release valve (Flipot et al., 1975). After a

42-day fermentation period the pH was 5 and lactic acid was over 6% for the control mixture. The pH values for the tannic acid- and paraformaldehyde-treated silages were 4.9 and 5.4, respectively. There was a decrease in lactic acid for these two silages. Goering and Smith (1977) ensiled corn forage alone or with the addition of dehydrated poultry excreta or liquid from cattle excreta. The pH was 4.26 and 3.83, respectively, for the silages treated with dry poultry excreta and liquid from cattle manure. Lactic acid levels also indicated good ensiling had occurred with the addition of excreta to the silage.

Caged layer waste was ensiled with whole plant corn and sorghum forages by Richter and Kalmbacher (1980). The waste comprised 33 and 42% of the dry matter for the corn- and sorghum-waste silages, respectively. The pH varied between 3.60 and 4.85 and lactic acid was about 4%, dry basis, for the silages. Addition of caged layer waste did not affect digestibility but resulted in a lower dry matter intake.

Quality of Animal Products

Feeding animal waste has not affected taste of the meat, milk or eggs (Fontenot and Jurubescu, 1980).

Safety Considerations

The only disease problem which has been shown to be caused by feeding animal waste has been copper toxicity in sheep fed broiler litter with high copper levels (Fontenot and Webb, 1975). The problem would not be severe in cattle since they are not as sensitive to high dietary copper. Beef females have been fed diets containing high levels of broiler litter with high copper levels, alone and in combination with supplementary copper to add the equivalent of 200 ppm to the litter during the winter period for 7 yr with no deleterious effects (Webb et al., 1979).

Pathogenic Bacteria and Parasites

Heat processing destroys potential pathogens (Fontenot and Webb, 1975). Proper ensiling of animal wastes also appears to be effective in destroying pathogens (McCaskey and Anthony, 1979). It appears that a pH of 4 to 4.5 and a temperature of over 25° C are important for destruction of salmonella. Ensiling feedlot cattle manure and grass hay was effective in eliminating parasites (McCaskey and Anthony, 1979). Apparently, due to the ammonia and minerals in poultry waste it is rather difficult to reach a pH of less than 5 without additional materials such as whole plant corn forage. However, ensiling of broiler litter with added water has been shown to destroy coliforms even when the pH did not go below 5.4 (Caswell et al., 1978). The potential risks of clostridia in ensiled waste containing rations was suggested by the alleged botulism outbreak in cattle fed poultry waste in Israel (Egyed et al., 1978). The botulism organism (Type D) appears to be endemic in Israel as outbreaks have been reported in animals fed other types of feeds (Tagari, 1978; Gordin, 1978). No butulism has been reported in animals fed waste containing rations in the U.S.A. The survival of Clostridium sporagens as a model for C. botulinum was studied by innoculating in a bovine waste-blended ration and in corn forage which were ensiled for 60 days (McCaskey and Anthony, 1979). A decline in numbers of organisms occurred in both silages.

Residues in Animal Products

Indications are that the mycotoxin problem is no greater in poultry litter than in feed (Lovett, 1972). No evidence of pesticide accumulation in waste or in animal tissue from animals fed waste has been reported (Fontenot and Webb, 1975).

Three heavy metals, arsenic, copper and selenium, are added to livestock and poultry rations and three, cadium, lead and mercury, are not added but occur in feedstuffs. Feeding of arsenicals has been shown to result in increased liver arsenic in cattle after a 5-day withdrawal but the levels were much lower than the accepted safe levels (Webb and Fontenot, 1975). The other heavy metals have not been found to be sufficiently high to present a problem in cattle waste and poultry litter (Westing et al., 1980). Liver copper is increased by feeding waste with high copper levels (Webb and Fontenot, 1975).

Medicinal drug residues were present in broiler litter in variable amounts if the drugs had been included in the broiler diet, but the levels were quite variable (Webb and Fontenot, 1975). However, residues of the three drugs that were in litter, chloratetracycline, nicarbazin and amprolium, did not accumulate in animal tissue of finishing beef cattle after a 5-d withdrawal. Thus, it appears that with a modest withdrawal period there is no serious tissue residue problem from feeding broiler litter. However, it should not be fed to cows producing milk or hens producing eggs for human consumption since insufficient data are available on these aspects.

Regulation of Feeding Animal Waste in the U.S.A.

The Food and Drug Administration (FDA) published a policy (21 CFR 500.4) in the September 2, 1967 Federal Register not sanctioning the use of poultry litter as animal feed (Kirk, 1967). Broad interpretation subsequently extended this policy to include all animal wastes used as ingredients in animal feeds. Food and Drug Admininstration took this position because the amount of information then available was not believed adequate to conclude that animal waste was safe when used as a feed ingredient. FDA (1980) revoked 21 CFR 500.4 on the use of poultry litter as an animal feed ingredient on December 30, 1980 (45 FR 86272) and is leaving the regulation of animal waste to the individual states. In many states regulation is through an officially adopted model regulation for processed animal waste (AAFCO, 1982).

The salient points of the AAFCO regulation are: 1) the waste must be processed so it will be free of pathogenic organisms, 2) if it can be documented by records that animals producing the waste have not been fed drugs no withdrawal period is required and the waste can be fed to any class of animal, 3) if it cannot be documented by records that the animals producing the waste were not fed drugs a 15-d withdrawal is required prior to slaughtering animals or prior to using milk or eggs for human consumption. Some of the individual states also have regulations.

Value of Animal Wastes

Although it has been shown that non-ruminants can utilize certain wastes, the high fiber and frequently high non-protein nitrogen in animal wastes indicate that ruminants are best suited for utilization of wastes. Possibly, wastes could be used to replace part of the diet of swine which do not have a high energy requirement, such as gestating sows. Smith and Wheeler (1979) estimated the monetary value of different kinds of animal wastes. These values were compared to the value of wastes for alternate uses (Fontenot et al., 1983). Values given in table 3 show that the wastes have considerable monetary value and are much more valuable as sources of feed than for fertilizer or methane generation.

Practical Feeding

Beef cow wintering rations probably offer the greatest potential for the use of broiler litter. Cows may be wintered on a mixture of 80% broiler litter and 20% ground corn or other palatable concentrate. The reason for mixing grain with the litter is to insure adequate consumption since litter alone would meet the protein and energy needs of pregnant beef cows if they ate enough of it. A small amount of hay or other forage should also be fed for normal digestion and health.

Pregnant cows should be fed 6 to 7 kg of the litter mixture per head per day along with 1 kg of hay or equivalent forage. For cows nursing calves, the amount of the litter mixture needs to be increased to 8 to 9 kg per head daily while continuing to feed a small amount of hay or other roughage.

Calves may be successfully wintered on a ration of 50% broiler litter and 50% ground corn along with hay fed free choice. Feeding 3 kg of the mixture per day to 180 to 225 kg calves being wintered should produce gains of .5 kg per day. The mixture could also be fed with as little as 2 to 4 kg of silage per head daily. The amount of the mixture will need to be adjusted depending on the amount of hay or silage fed.

Up to 20 to 25% of the dry matter in beef cattle finishing rations can be broiler litter. It can be fed either as litter ensiled with corn silage or by mixing deep stacked litter with silage or other ration ingredients at feeding time. When fed with corn silage plus concentrates such as ground corn at 1%

of body weight, 20% broiler litter in the ration on an "as fed" basis will provide all the protein needed to balance the ration.

The beef cattle producer needs to know the amount of litter available in order to plan his feeding program. About .9 kg of dry broiler litter is produced per bird during a production cycle (Van Dyne and Gilbertson, 1978). Thus 900 kg of broiler litter dry matter is produced per 1000 chicks during a production cycle. Assuming that the litter will contain 80% dry matter as it is taken from the house, the numbers of cattle which could be fed would be as shown in table 4 from each 100,000 broilers (single cycle). In the calculations it was assumed that the wet spots would amount to about 10% of the litter and would not be used as feed.

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TABLE 1. NUTRITIONAL VALUE[a] OF POULTRY WASTES

Item	Kind of waste	
	Broiler litter[b]	Dehydrated caged layer waste[b]
Crude protein, %	31.3	28
True protein, %	16.7	11.3
Digestible protein, %	23.3	14.4
Crude fiber, %	16.8	12.7
Ether extract, %	3.3	2
NFE, %	29.5	28.7
Dig. energy[d], kcal/g	2440	1884
Metab. energy[d], kcal/g	2181	
TDN[d], %	59.8	52.3
Ash, %	15.0	28
Calcium, %	2.4	8.8
Phosphorus, %	1.8	2.5
Magnesium, %	0.44	0.67
Sodium, %	0.54	0.94
Potassium, %	1.78	2.33
Iron, ppm	451	0.2
Copper, ppm	98	150
Manganese, ppm	225	406
Zinc, ppm	235	463

[a]Dry basis.
[b]Adapted from Bhattacharya and Taylor (1975).

TABLE 2. FEEDLOT PERFORMANCE AND CARCASS QUALITY OF STEERS FED BROILER LITTER (123 DAYS)[a]

	Broiler litter rations		
	Wood shav. litter[b]	Peanut hull litter[b]	Control ration
	kg	kg	kg
Initial wt.	379	376	391
Final wt.	536	524	551
Gain	157	148	160
Daily gain	1.28	1.20	1.30
Daily feed[c]			
mixture	11.9	11.9	13.5
long hay	1.0	1.0	1.0
Feed/gain			
mixture	9.34	9.91	10.40
long hay	0.79	0.84	0.78
total	10.13	10.75	11.18

[a]Adapted from Fontenot et al. (1966).
[b]25% litter in fattening mixture.
[c]Salt and a mineral mixture of 3 parts defluorinated phosphate, 1 part limestone and 1 part salt were provided, in addition.

TABLE 3. RELATIVE VALUE OF ANIMAL WASTES UTILIZED FOR DIFFERENT PURPOSES[a]

	U.S. dollars per ton		
Kinds of wastes	Fertilizer	Feed	Methane
Beef cattle	25.06	118.14	13.73
Dairy cattle	17.00	118.14	12.74
Swine	18.61	136.57	17.17
Caged layer	36.45	155.14	17.93
Broiler litter	26.54	159.57	16.29

[a]Adapted from Fontenot et al. (1983).

TABLE 4. ESTIMATED NUMBER OF CATTLE WHICH COULD BE FED WITH BROILER LITTER FROM 100,000 BROILERS[a,b]

Class of animals	Ration	No. of days	No. of cattle
Pregnant beef cows	80% litter & 20% ground corn[c]	140	134
Lactating beef cows	80% litter & 20% ground corn[c]	140	101
Growing calves	50% litter & 50% ground corn plus hay (free choice)	140	459
Growing calves	11 kg corn silage & 2 kg litter	140	321
Finishing cattle	Corn-litter silage (30% litter, dry basis), corn grain at 1% of bodyweight	200	189

[a]Single cycle.
[b]It was assumed that 10% of the litter would be in wet spots and would not be fed.
[c]Plus a limited amount of hay or other roughage.

Preliminary Investigations of Composting as a Method of Dead Bird Disposal

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INTRODUCTION: Broiler producers are facing increasingly difficult problems in managing the waste products of their industry. Disposing of normal mortality, followed by responsible management and use of manure, are the principle concerns of Delmarva broiler producers at the present time.

Three dead-bird disposal methods are currently available:

1. Burial, in pits, or in containments. Law requires that burial depth should be at least six feet above seasonal high water tables. For most of the Delmarva peninsula, birds would have to be "buried" on 3'-6' raised platforms (Plains Indian style) to comply with this minimum.
2. Incineration is recognized as the (biologically) safest method of disposal. However, it is slow, expensive (capital expense, labor and fuel) and, interestingly, generates more pollution control complaints than any other method, even when approved incinerators are operated properly.
3. Rendering Mortality into byproduct meal is possible, and is practiced in small, concentrated, production areas where plant capacity, transportation, and material quality can be controlled. Major objections to large-scale collection, transport and processing of normal mortality arise from disease control, ingredient purchasing and nutritional personnel.

The development, or adaptation, of non-polluting, legal, safe and practical means of dead bird disposal has been identified as Delmarva's highest research priority. The continued growth and competitiveness of the industry depends, in large measure, upon the success of these research efforts.

New dead bird disposal methods must satisfy the following criteria:

a. The method(s) must not significantly increase the costs of production. Major costs include capital expenditures and depreciation, labor, utilities, materials and the value or expense of disposing of the end product.
b. The method must be legal and safe. Disposal methods must conform to existing soil, water and air pollution standards, and must be biologically secure.
c. The method must be appropriate for continuous use, at the farm, and must be flexible enough to accomodate farms of various sizes.

OBJECTIVES:

Preliminary composting studies were designed to:

a. Test composting as a method for on-farm, continuous disposal of normal (i.e. 200# per day) broiler mortality,
b. Evaluate composting methods and ingredients to determine optimal rates and applications.
c. Test design, operation, pest control and pathogen survival characteristics of dead bird composts.
d. Determine material (physical, chemical and biological) properties of dead-bird compost, and develop recommendations for its' value and uses.

METHODS:

Ingredients and Composition: Experimental dead-bird composts consist of broiler manure ("cake"), dead birds, water, and one of several alternative carbon sources. A typical mixture is composed of, by weight, 4:2:3:1 parts of manure, dead birds, water and straw, respectively (Table 1).

Table 1. A Compostible Mixture

Ingredient	Moisture(%)	Parts	C:N	% of Total
Broiler Carcass	60	2	5	15.4
Straw	10	1	90	7.7
Broiler Cake	30	4	15	30.8
Water	100	6	--	46.2
Totals	65.4	13.0	22.9	100.0

This mixture has a Carbon:Nitrogen ratio of approximately 22:1, and a moisture content of approximately 65%, providing a balance of nutrients to sustain a high rate of microbiological activity. Material selection and blending satisfy the biological requirements of composting, and also use materials readily available to the average broiler producer. Corn stover, soybean crop residue, newsprint, etc. can be substituted for straw, with appropriate adjustments for their varying Carbon:Nitrogen ratios.

The Composter: Figures 1-4 show the design of several composters. They are, respectively, the University of Maryland prototype composter, a working commercial adaptation of the University of Maryland composter, an improved University of Delaware adaptation of the University of Maryland composter, and a University of Maryland plan for an improved 3-stage composter. The basic compost cell is simply a scaled-up version of a home gardener's composter. The dimensions of the University of Maryland boxes are 5' x 5' x 5', or 125 $ft.^3$. Boxes are constructed of pressure-treated lumber and posts, with removable drop-boards between boxes (indicated by dashed lines).

Operation: Whole ground, or intact, carcasses are added to the composter with manure, straw and water, in the proportions indicated above. As mortality accumulates, successive layers of material are added until boxes are filled.

Pile temperatures are monitored daily. After an initial lag phase of two to five days, temperatures increase rapidly and peak at between 145°F and 165°F. Between 7 and 14 days, temperatures begin to decline; at this point piles are turned. Following a second (seven-day) stage of heating and reduction, compost is removed from the composter, and is stockpiled on the ground, where it undergoes a third cycle of heating and reduction, and stabilization.

RESULTS:

Heat Generation and Carcass Reduction: Figures 5-8 show illustrate heat generation, over time, in four typical dead-bird composts. Composts A and B were built with successive layers of ground carcass and other ingredients, unmixed and unturned until 69 and 54 days, respectively. In both of these composts, turning, which achieved aeration and mixing, regenerated the piles and rapidly accelerated the decomposition of soft tissue. Composts C and D show improved performance with mixed, frequently turned, composts. Temperatures peaked within two to four days, and turning maintained high temperatures and rapid tissue reduction. In all composts, two cycles of heating were sufficient to completely reduce carcass to hard-tissue residues (bone and feathers), and to yield an odorless, spongy, compost material.

Chemical Composition of Compost: Table 2 summarizes preliminary analyses of dead-bird compost, and broiler manure. On a dry-matter basis, compost and manure have similar N, P and K values. These results do not distinguish inorganic N from organic N. Composting normally transforms inorganic N to organic N. Plant trials, comparing applications of manure and compost, are now being conducted to determine the nitrogen release characteristics of compost, as compared to manure.

Table 2. Nutrients: Manure vs. Compost

	H_2O%	N%	P_2O_5%	K_2O%
Cake	44.40	2.50	3.57	2.27
Compost	60.40	2.12	2.33	1.46
Compost	44.40	2.97	3.27	2.05

(44.4% H_2O)

Microbiology of Dead-Bird Compost: Table 3 summarizes preliminary microbiological testing of fresh broiler litter, whole broiler carcass, stored broiler manure, and dead-bird compost. Fresh litter and whole carcasses have high total aerobic bacteria counts, with variable occurrence of lactose-negative, Brilliant Green positive forms. Stable dead-bird compost has significant aerobic and anaerobic bacterial populations, the majority of which are Gram-positive, spore-forming Bacillus like organisms.

Table 3. Microbiology of Compost

	Total Aerobes	Coliforms	Brilliant Green	Anaerobes (RCM)
Litter (fresh)	8.0	5.3	-/+	---
Whole Carcass	6.0	3.0	-/+	6.0
Cake (stored)	3.0	3.0	-	3.0
Compost	4.0	3.0	-	4.0

[1]Log Base 10/gram

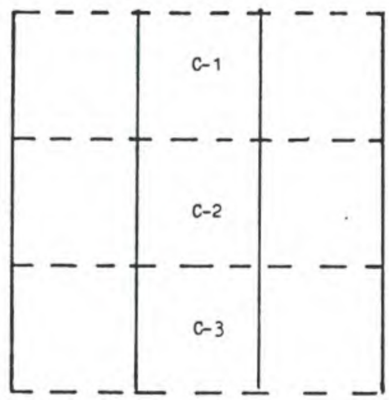
SUMMARY

Preliminary studies of composting as a method of on-farm dead bird disposal are encouraging. Use of simple structures, easy-to obtain ingredients, and basic compost management techniques, reduce broiler carcasses to an odorless, friable compost, rapidly. The method satisfies the requirements for economy, simplicity, pollution control, on-farm disposal, and can be scaled to farms of varying capacity. Best results have been obtained with a two-staged process, utilizing either whole or ground carcasses.

Fly breeding has been a problem in winter (February) operation, and needs to be addressed with design, and operation changes, or fly control additives. Studies of pathogen survival, and of the nutrient and soil amendment properties of compost, are continuinig.

FIGURE 1

U. Md. RESEARCH COMPOSTER (DEAD BIRD DISPOSAL)



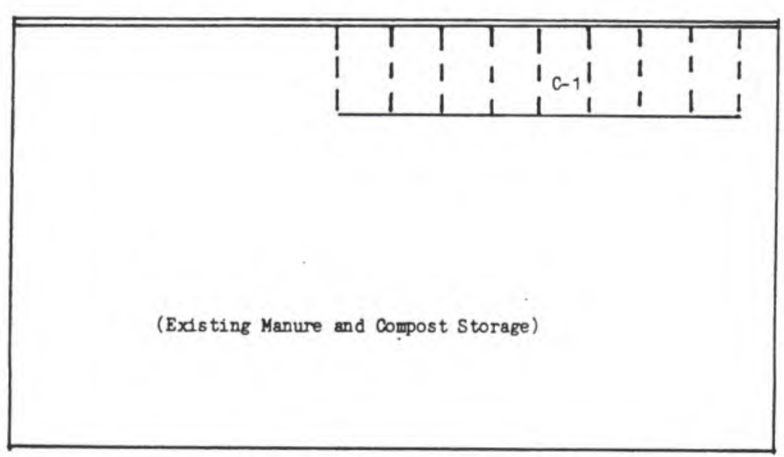
SCALE: 1" = 5'

DISPOSAL CAPACITY: 340 lbs. Carcass per day

C-1 (primary composting); C-2 (secondary composting); C-3 (tertiary composting)

FIGURE 2

COMMERCIAL SINGLE-STAGE COMPOSTER



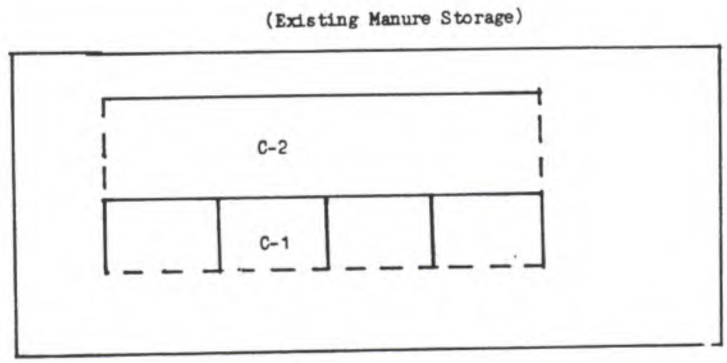
SCALE: 1" = 10'

DISPOSAL CAPACITY: 400 lbs. Carcass per day

C-1 (primary composting)

FIGURE 3

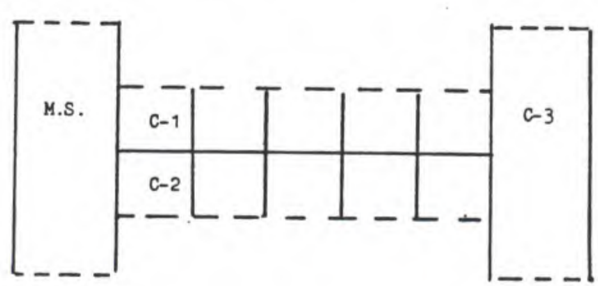
UNIV. DEL. DEMONSTRATION COMPOSTER



Scale: 1"= 10 feet
DISPOSAL CAPACITY = 440 lbs. Carcass per day
C-1 (primary composting); C-2 (secondary composting)

FIGURE 4

IMPROVED U. MD. 3-STAGE COMPOSTER



1" = 10 feet
DISPOSAL CAPACITY = 525 lbs. Carcass per day
M.S. (manure storage); C-1 (primary composting); C-2 (secondary composting); C-3 (tertiary composting and compost storage)

FIGURE 5.

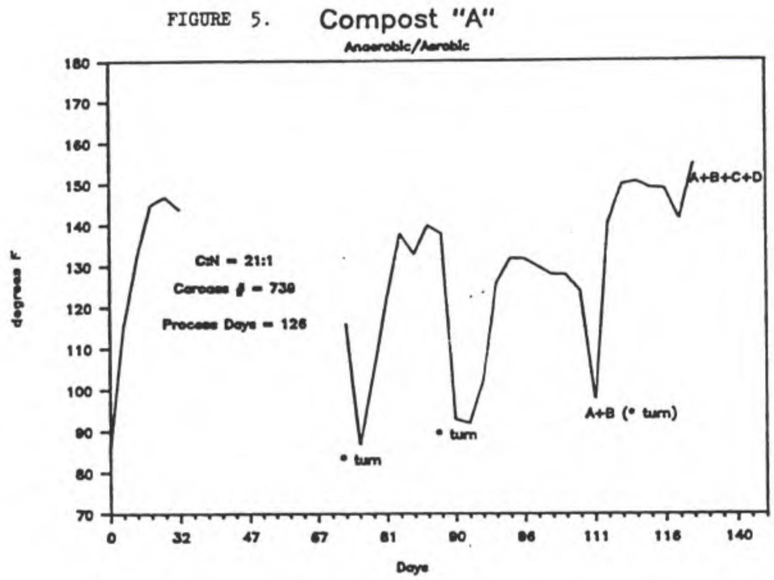


FIGURE 6.

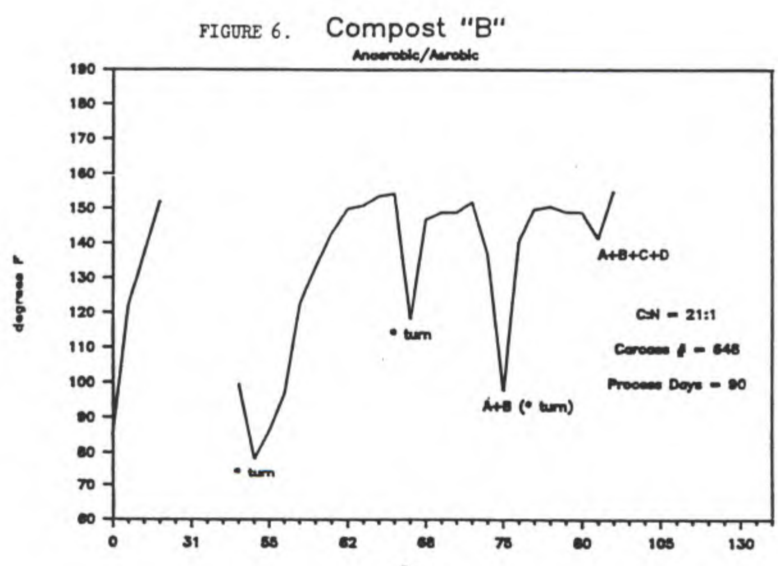


FIGURE 7. Compost "C"

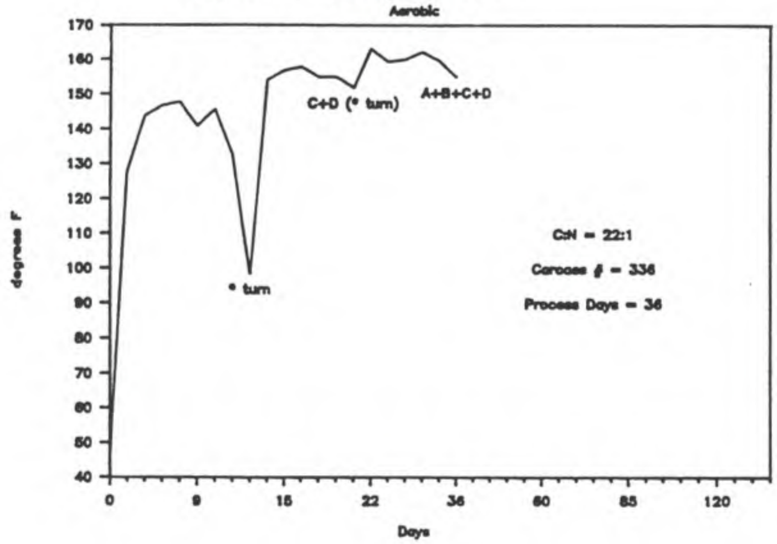
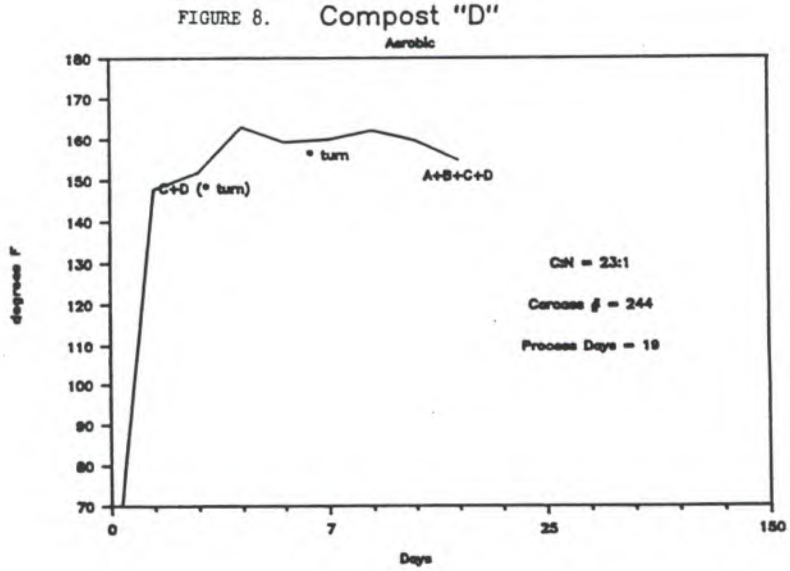


FIGURE 8. Compost "D"



DEAD BIRD AND HATCHERY WASTE DISPOSAL AND UTILIZATION

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Closed Tank Digestion Systems for Dead Bird Disposal

Inefficient methods of conventional dead bird disposal and increasing concerns with environmental regulations necessitate the need for practical, economical, efficient, biosecure and environmentally sound means of carcass "disposal." Mortality losses from U.S. broiler production alone are estimated at 160,000 tons of carcasses annually. Burial pits with open bottoms have been the most common method of disposal. However, increased production capacity per farm, high mortality rates and increasing market weights of broilers have resulted in slow decomposition rates and failures with this type of disposal. Of increasing concern is the possible contamination of groundwater for those open bottom pits placed on certain soil types which are in areas having high groundwater tables.

In an effort to enhance carcass decomposition and contain the decomposed mass within a sealed unit, various types of tank digestion systems were evaluated at Delaware. Of the factors known to increase decomposition (oxygen, carbon to nitrogen ratio, moisture, temperature, pH, bacteria and insects), only oxygen and temperature were selected in our initial study. The closed tank digestion systems studied were a control (bottomless tank simulating a commercial open bottom pit), modified control (solid bottom tank), heated modified control and an aerated heated modified control. Temperatures in these buried 50 gal. tanks were 72° and 93° F for the unheated and heated treatments, respectively. Whole carcasses were added twice weekly to two replicate tanks/treatment and at rates simulating normal mortality over two consecutive flocks (July-Nov.).

Compared to the control, total accumulated decomposed mass at the end of the 18 week test period was 40% and 12% greater for the unheated and heated modified control, respectively. The aerated heated modified control had 76% less mass than the control. If these tank digestion systems were designed to be reusable, odors associated with the clean-out and disposal of the decomposed residue would be a major concern with all systems except the aerated heated. Secondly, hydrogen sulfide concentrations in the non-aerated tanks often exceeded safe levels for human exposure. Although the aerated heated system was very efficient in decomposing carcasses and had less offensive odors, there are other practical and economical considerations requiring further study.

Acid Preservation and Utilization of Dead Birds

Reducing tissue pH to inhibit the microbial decomposition process is a widely used food preservation technique that appears to be applicable to recovering poultry mortality losses. Current research at Delaware is devoted to establishing the most efficient acid type and concentration and the optimum environmental conditions for preserving poultry carcasses.

This information will be used to determine the potential feasibility and design of the following concept. An acid resistant tank(s) will be placed on each farm. A company will fill the tank with a specific amount, type and concentration of weak acid solution. The poultry grower will drop his mortality into the tank and will never have any contact with the acid solution. At the end of the flock, the solids will be removed and the tank refilled with solution or the entire tank replaced (portable units). Nutrients in the preserved carcasses will be recovered by conventional rendering methods or by acid hydrolysis procedures. Compared to disposal pits, the acid preservation concept may offer an efficient and biosecure means of recovering a protein source at a time when alternative animal protein sources are needed. Unlike routine pickup of "fresh" carcasses that is in use in parts of the U.S., this method could greatly reduce transportation cost and the potential for farm-to-farm disease transmission. The frequency of farm visits with the acid preservation process may be reduced by 95%; and the acid may reduce, if not eliminate, most pathogens in the carcasses before they leave the farm. In addition, final product quality may be improved, particularly during hot weather since the low pH rapidly inhibits the spoilage process.

Research to date suggest a 3.4% solution of sulfuric acid (v/v) will preserve three times more ground carcass by weight than either a 3.4% solution of phosphoric or 1.7% propionic acid. The pH of tissue preserved by sulfuric, phosphoric and propionic was 3.1, 2.3 and 4.9, respectively. A preliminary estimate of acid cost to preserve the ground tissue is 0.10, 0.75 and 1.30¢/lb. of carcass for sulfuric, propionic and phosphoric acid, respectively. Caution is needed on selecting the most desirable preservation acid based solely on these costs since there are many long-range considerations that may alter the overall economics. Since whole mature broiler carcasses were not preserved in a 3.4% sulfuric acid solution, various optimum particle sizes were studied. Rather than grind broilers, placing multiple punctures in the body cavity appeared to be the most acceptable. Equipment to puncture carcasses should be less expensive than grinding units and "pickling" intact birds would be more cost effective than hydrolyzing the carcasses at the farm level. Additional studies on optimization of acid solution concentration, time and temperature response on the preservation process and pathogen survival in acid preserved carcasses are planned. If these studies suggest the concept may be feasible, the following areas need to be addressed; acid handling and safety procedures, design of an on-farm container and puncturing mechanism, method and equipment for transportation of the acid to and material off the farm, processing/rendering technology, nutritional properties of the finished product and an economic analysis of the entire system.

Hatchery Waste Disposal and Utilization

From the 6.7 billion eggs set in broiler hatcheries last year, an estimated 107,000 tons of waste was generated. This waste consists primarily of egg shells, non-fertile eggs, dead embryos and dead/cull chicks. The composition of hatchery by-product meal processed through a triple pass dehydrator has been reported as follows:

	Hatchery By-Product Meals	
Component (%)	Broiler	Egg Type Chick
Moisture*	65.00	71.00
Protein	22.20	32.30
Fat	9.90	18.00
Calcium	24.60	17.20
Phosphorus	0.33	0.60

*Raw, before dehydration

Vandepopuliere, et. al, 1977.
Poultry Sci. 56:1140-1144.

Primary methods of hatchery waste disposal include landfill, land application, rendering and egg wringing. On Delmarva, the following are considered the advantages and disadvantages of each of these disposal methods. Although a major portion of Delmarva's 210 tons of hatchery waste/week is currently being landfilled, there are concerns with cost (tipping fees $10-30/ton + trucking cost) and odors from this material at the landfill. One of two local companies that has been applying the waste to land has discontinued this practice due to problems with odors from an inability to routinely incorporate (disc) the material into soil. Based on guidelines for poultry manure, the rate of hatchery waste application is adjusted on soil nutrient requirements. The cost of labor and equipment for land application may not offset the value of the product as a fertilizer, but it is an alternative to landfill fees. Research indicates hatchery waste has some value as a feedstuff (Vandepopuliere, et. al, 1977). Due to the problems associated with landfilling, one Delmarva company is currently rendering its hatchery waste. Since many rendering plants are not designed for handling this type of product, processing this type of waste can pose major difficulties in the system. The most promising alternative to hatchery waste disposal for Delmarva is the construction of an egg wringing facility. All local hatcheries will discontinue current disposal methods and support this method. Waste picked up from each hatchery will be delivered to a central facility where the liquid fraction is separated, dehydrated and converted into a feedstuff. Although this process recovers 40% of the total waste, the remaining solid fraction still requires disposal/utilization. There are seven egg wringing plants planned or in operation in six different broiler producing states.

LACTOBACILLUS FERMENTATION
A METHOD OF DISPOSAL/UTILIZATION OF CARCASSES CONTAMINATED BY PATHOGENIC ORGANISMS OR TOXIC CHEMICALS

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The disposal/utilization of carcasses, food waste, manure and other animal products contaminated by pathogenic organisms or toxic chemicals provide major problems; especially for regulatory agencies. In the past, burning, deep burying, composting and perhaps rendering offered the best means of disposal.

Today, with EPA requirements concerning burning and burial, other alternatives must be explored. Controlled lactobacillus fermentation offers a partial answer. Coupled with rendering, fermentation offers an excellent method of disposing of contaminated carcasses as well as retaining some useful purpose from these carcasses.

Laboratory work at the University of Georgia over the past several years, supports the principle of fermentation as an initial step in the destruction of pathogenic organisms. Our work has dealt with representatives of various bacterial and viral groups. The work was done in a tightly controlled environment in which individual organisms were introduced separately into the food waste substrate. Through periodic sampling, the approximate time of pathogen destruction was determined.

The adenovirus group represented by infectious canine hepatitis was the most difficult to destroy. However, at a temperature of 30 C and 40 C. this representative of the group was destroyed within five days. Of the myxo virus group, represented by newcastle disease virus and the measles virus, the organisms were destroyed within two days at 30 C and 40 C and within three days at 20 C.

Of the bacterial groups, the gram negative bacteria were destroyed within the first day at 20 C and 30 C. Gram positive bacteria were destroyed within two days except group E *streptococcus*. Since this organism is so similar to *lactobacillus* this is not surprising.

To determine the effect of whole carcass contamination, newcastle disease virus was introduced into live chickens. When the disease reached its peak, the birds were euthanized and their carcasses were included in a 20% and 40% level in relation to the carbohydrate source. In both cases, the newcastle disease virus was destroyed within five days at 20 C, two days at 30 C and within one day at 40 C.

The same situation was developed with an infection of *Salmonella typhimurium* in rats. At the 20% carcass level as well as the 40% carcass level, *Salmonella typhimurium* was destroyed within the first day at 30 C and 40 C.

The effect of fermentation on toxic chemicals has not been determined. Dilution may be the final answer to carcasses contaminated with toxic chemicals. Fermentation would allow contaminated carcasses to be held for long periods of time, inexpensively. The contaminated product could be mixed in small amounts with normal rendering to finally utilize the product.

What we are hoping to provide is a means of handling carcassses on a small or large scale without the use of burying or burning. Fermentation is not the final answer in carcass disposal but it does provide a method of destroying pathogenic viruses and bacteria in preparation for rendering. Stabilizing carcasses contaminated with toxic chemicals would allow renderers to gradually utilize this contaminated material by diluting it in normal rendering operations and over a period of time, safely utilizing chemically contaminated carcasses.

Myxo Virus Group
Measles Virus
pH 4

	Days					
	1	2	3	4	5	6
20°						
30°						
40°						

Myxo Virus Group
Newcastle Disease
pH 4

	Days					
	1	2	3	4	5	6
20°						
30°			solid			
		liquid				
40°		solid				
	liquid					

Myxo Virus Group
Newcastle Disease
Measles Virus
Renderpest
Canine Distemper
Avian Influenza

Adeno Virus Group
Infectious Canine Hepatitis
pH 4

	Days					
	1	2	3	4	5	6
20°						
30°						
40°						

Adeno Virus Group
Infectious Canine Hepatitis
Quail Bronchitis
Egg Drop

Corona Virus Group
Infectious Bronchitis
pH 4

	Days					
	1	2	3	4	5	6
20°						
30°						
40°						

Corona Virus Group
Infectious Bronchitis
Transmissible Gastroenteritis (TGE)
Bluecomb

Herpes Virus Group
Porcine Pseudorabies Virus
pH 4

	Days					
	1	2	3	4	5	6
20°						
30°						
40°						

Herpes Virus Group
Pseudorabies
Infectious Bovine Rhinotracheitis (IBR)
Malignant Catarrhal Fever
Equine Viral Rhinopneumonitis
Laryngotracheitis
Mareks Disease
Duck Plague

Irido Virus Group
Frog Virus 3
pH 4

	Days					
	1	2	3	4	5	6
20°		solid				
			liquid			
30°						
40°						

Rhabdo Virus Group
Vesicular Stomatitis

	Days					
	1	2	3	4	5	6
20°						
30°						
40°						

Irido Virus Group
Frog Virus 3
African Swine Fever

Rhabdo Virus Group
Vesicular Stomatitis

Picorna Virus Group
Porcine Picorna Virus
pH 4

	Days					
	1	2	3	4	5	6
20°		liquid				
30°				solid		
		liquid				
40°			solid			
		liquid				

Toga Virus Group
Bovine Virus Diarrhea
pH 4

	Days					
	1	2	3	4	5	6
20°						
30°						
40°						

Picorna Virus Group
Porcine Picornavirus
Foot & Mouth Disease
Epidemic Tremor
Duck Hepatitis
Teschen Disease

Toga Virus Group
Bovine Virus Diarrhea (BVD)
Louping Ill
Rift Valley Fever
Hog Cholera
Equine Encephalitis

Gram Negative Bacteria
pH 4

	Days					
	1	2	3	4	5	6
20°						
30°						
40°						

Gram Negative Bacteria
Salmonella typhimurium
Salmonella anatum
Salmonella cholera - suis
Yersinia Pseudotuberculosis
Yersinia enterocolitica
Pasteurella Multocida

Gram Positive Bacteria
pH 4

	Days					
	1	2	3	4	5	6
20°						
30°		Except Streptococcus E				
40°						

Gram Positive Bacteria
Listeria monocytogenes
Erysipelothrix rhusiopathiae
Corynebacterium pseudotuberculosis
Clostridium perfringes
Group E Streptococcus

Salmonella typhimurium
RATS
20% Level

	Days					
	1	2	3	4	5	6
20°						
30°						
40°						

Salmonella tryphomurium
RATS
40% Level

	Days					
	1	2	3	4	5	6
20°						
30°						
40°						

Newcastle Disease
CHICKS
20% Level

	Days					
	1	2	3	4	5	6
20°						
30°						
40°						

Newcastle Disease
pH 4 CHICKS
40% Level

	Days					
	1	2	3	4	5	6
20°						
30°						
40°						

Case Histories of Nitrogen Removal Upgrade, Mechanical Dewatering Systems, and Overland Flow

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Poultry processing has undergone truly explosive growth over the last 20 years. Plants that were producing less than 400,000 birds per week are now producing almost 900,000 birds per week--inside the same building with the same number of evisceration line. This tremendous growth, coupled with a strong national mandate for insuring a clean environment, has challenged the industry to find cost-effective, innovative solutions for treating its process wastewaters.

This paper will address solutions to a few of the problems our growth and prosperity has caused. First, the paper will review how Gold Kist upgraded an activated sludge plant to achieve nitrification limits imposed on the facility after 20 years of operation. Next, the paper will discuss various mechanical means that have been used successfully to dewater ever-increasing quantities of float fat that are being produced as a result of stricter pretreatment regulations. Finally, the paper will review the land-based treatment system Gold Kist will use at its new processing plant to be built near Sanford, North Carolina.

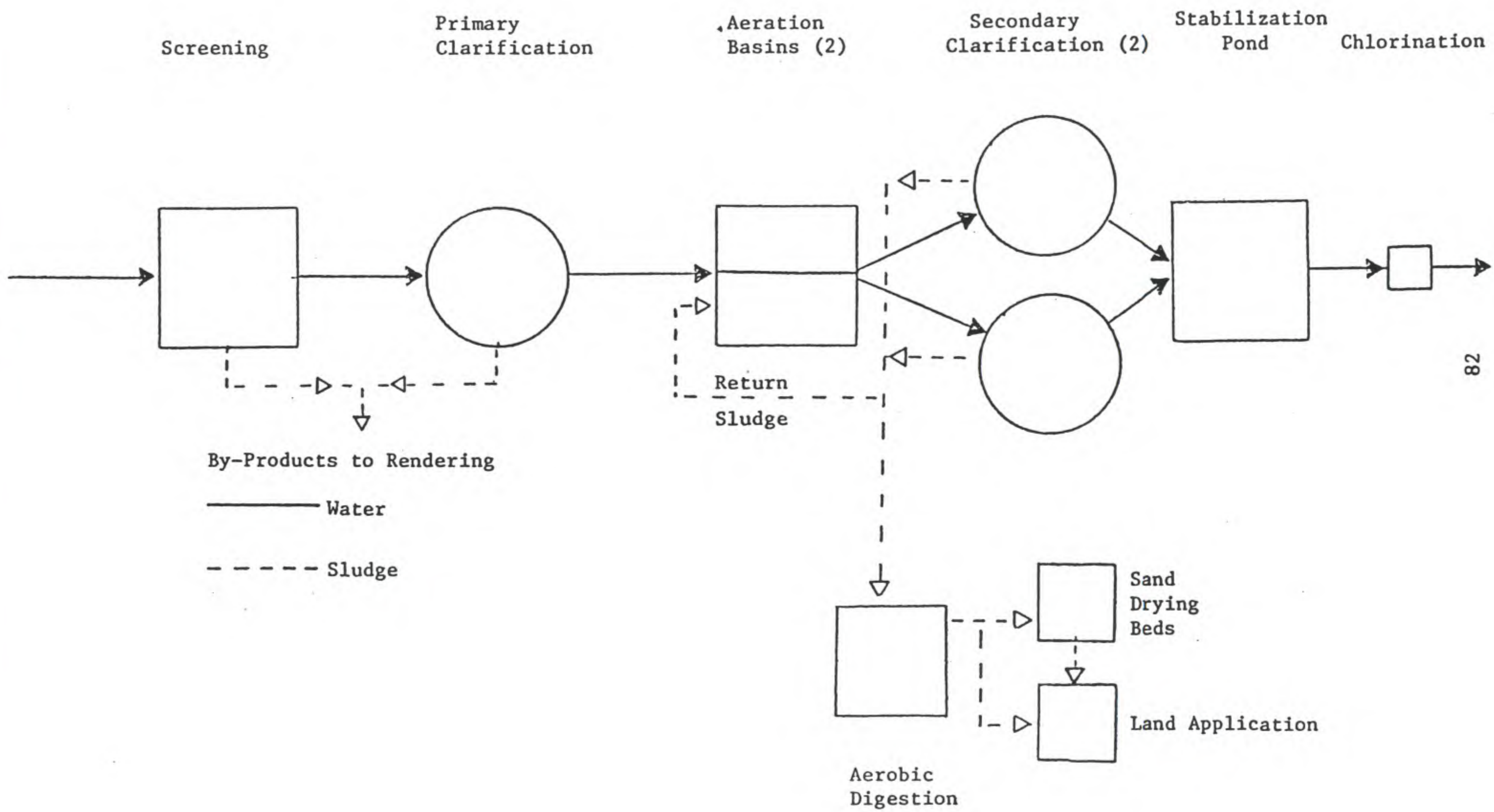
Plant Upgrade to Achieve Nitrification

Prior to 1984, treatment at our Live Oak, Florida plant consisted of screening, primary clarification, aeration basins (two basins, 0-5 MG each), two final clarifiers (1200 and 1600 ft^2), a 4 MG final pond, chlorination and discharge into the Suwannee River (see Figure 1). Aeration is provided by five 75 HP Spencer blowers utilizing both Norton Dome diffusers and Walker Process spargers. Primary sludge and activated sludge were wasted to a 0.4 MG aerobic digester, thence to six sand drying beds.

The plant had an excellent compliance record with respect to BOD and TSS, and has only had a handful of exceedanes of these parameters in its 20-year history.

In 1980, the Florida Department of Environmental Regulation and USEPA Region IV imposed a discharge limit of 10 mg/l Total Kjeldahl Nitrogen with a 15 mg/l maximum. The plant, quite frankly, was simply not designed to achieve consistent, year-round nitrogen removal. Consequently, we began formulating plans to upgrade. Two areas for improvement were targeted--increased biological treatment to allow for removal of nitrogen and improvement of sludge handling facilities.

Schematic For Wastewater Treatment at Gold Kist
Live Oak Poultry Processing Plant



A number of different alternatives for increased biological treatment capacity were considered, including additional aeration basins, RBC, trickling filter, facultative lagoons, etc. A detailed cost analysis on each option was prepared, and we ultimately selected a combination of increased aeration basin capacity and installing a trickling filter (see Figure 2). The filter was designed as a roughing unit to be placed between the primary clarifier and the aeration basin. Its purpose was to "knock down" the high BOD in the primary effluent, thereby allowing more of the capacity of the aeration basin to be utilized for nitrification. Additionally, the old aerobic digester, which shared a common wall with the aeration basin, was converted to another basin, increasing total basin capacity from 1 MG to 1.4 MG. A new, lined earthen basin was constructed.

As is indicated in Table 1 below, the performance of the filter has matched--even exceeded--our expectations. The filter is achieving almost 60% BOD reduction, and over 60% FOG reduction. As an added bonus, TKN is reduced an average of 17%.

Table 1. Trickling Filter Performance

	Influent (ppm)	Effluent (ppm)	% Removal
BOD	1,000	410	59
TSS	393	237	39
FOG	210	78	63
TKN	96	79	17

As stated above, another facet of the upgrade was improved sludge handling facilities. A new 0.9 MG digester was constructed. Parshall flumes were installed on the return sludge lines and the waste sludge line, allowing the operator exact control over two of his most important operating variables. Finally, we cleared 30 acres of land to allow for direct land application of digested sludge. A travelling irrigator is utilized for this purpose.

The result of the improvements has been not one single permit limit violation at the plant since 1984.

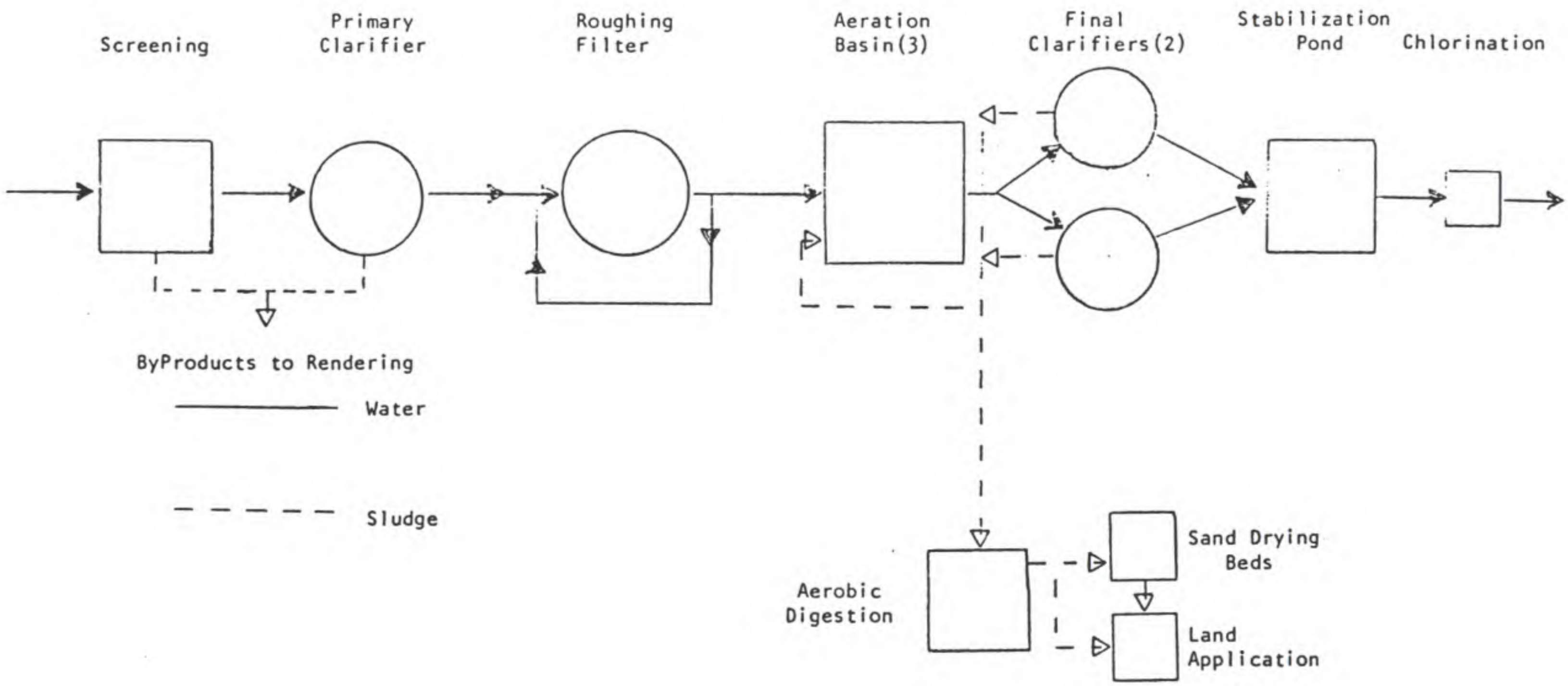
Mechanical Sludge Dewatering Systems

As pretreatment regulations have been put into effect, more and more of us in the industry have gone to utilizing chemical flocculants to improve the efficiency of our DAF units. Doing so has caused a question that has been heard now for several years--what do we do with the float fat?

Schematic for Wastewater Treatment at Gold Kist

Live Oak, FL Poultry Processing Plant

NPDES #FL0001465



This paper will review two commercially available mechanical dewatering systems: the belt press and the centrifuge.

Gold Kist has recently installed a 1-1/2 meter belt at its plant in Douglas, GA. Treatment at the two evisceration line NELS plant consists of screening followed by dissolved air flotation in a rectangular tank (65'x10'x6') with chemical addition. Discharge quality to the city sewer must be better than 300 mg/l BOD and TSS, and 100 mg/l FOG.

The dissolved air flotation system produces 6,000-10,000 gallons per day of float fat. This material is augered to a hold tank; then, each day on the afternoon shift, the belt press is started up to dewatering both shifts' fat.

The float fat is pumped from the hold tank to the belt press. In this line, both cationic and anionic polymers are injected. After going through a conditioning tank, the fat is distributed into the presses feed box. The upper belt passing through the feed box carries the fat through the gravity dewatering zone. Here, a series of plastic plows aid in releasing free water from the coagulated fat. This free water is collected in a catch pan and returned to the wet well for process wastewater. At the end of the gravity section, the fat drops off the upper belt onto the lower belt. The two belts then wedge together and roll over a series of eight drums of gradually decreasing diameter. This design allows a gradual pressure build-up on the float fat, to keep from shearing the fat, or causing extrusion or migration on the belt. After the last roller, the two belts separate and the fat removed from the belts by a plastic doctor blade. The dewatered fat is then pumped using a piston pump to the offal trailer.

The following table summarizes the performance of the belt press.

Table 2. Belt Press Performance

	Float Fat (%)	Product % Avg.	Range
Total Solids	8-12	32.3	27.25-41.01
FOG	5	18.05	16.16-22.64
Protein	2	8.66	8.38- 9.12
Flow Rate	32-38 GPM		

Another approach which several processors have chosen is the three-split centrifuge. In this process, float fat from the DAF unit is preheated with live steam to a temperature of 180-200°. It is then sent to the centrifuge, which is turning at 4,000-5,000 rpm. The heated mixture separates under these conditions to three distinct phases--solid, water and oil. A scroll augers the solid out of the centrifuge. The two liquids are collected by different ports and discharged from the machine.

The water phase is returned to the wet well for process wastewater. The solid and oil are collected for reclamation as by-products.

Table 3 lists the performance of centrifuge at two plants.

Table 3. Centrifuge Products

	Solid		Oil	
	Athens AL	Gainesville GA	Athens AL	Gainesville GA
Total Solids	38.55	37.65	99.64	99.54
FOG	11.79	10.46	99.39	98.73
Protein	16.89	17.00	0.21	0.83
Ash	3.73	3.61	0.04	0.04

Overland Flow System

The final system discussed in this paper is the overland flow treatment system. Golden Poultry Company, a partially owned subsidiary of Gold Kist, is in the process of building a new plant outside of Sanford, North Carolina. That plant will have two evisceration lines capable of NELS speed.

Treated water from the plant will be discharged to the Deep River. This river has extremely low summertime flow, making very stringent permit limits necessary. The treatment system will consist of screening, dissolved air flotation with chemical addition, overland flow system, collection, disinfection and discharge.

In overland flow, one creates a series of terraces approximately 200 feet long, at whatever width local contours easily provide.

These terraces are sloped at 2% to 8% along the 200-foot length. Pretreated wastewater is applied to the terrace via spray nozzles, normally situated about one-third of the distance down the slope. A limited quantity of wastewater will percolate into the soil; a limited quantity will evapotranspirate. The bulk of the water is treated by predominantly biological removal methods. At the soil/water/air interface, conditions are obviously favorable to stimulate bacterial growth. These bacteria remove the pollutants from the water. The grass cover, in addition to preventing erosion, also aids int he sedimentation of solids. These settled solids are then digested on the soil surface.

At the bottom of each terrace is a runoff collection channel. These channels ultimately combine to pass through the metering and disinfection systems. An extremely high quality product can be produced by the overland flow system. In Table 4 are listed results from an overland flow system in use by one processor.

Table 4. Overland Flow Performance

	Applied Quality (mg/l)	Treated Effluent (mg/l)	Removal Efficiency (%)
BOD	450	15	95
TSS	470	20	95
FOG	200	10	95
TKN	45	8	80
Phosphorus	9	5	40

Summary

As these above examples illustrate, the technology of treating poultry wastewater is far from stagnant. As long as our industry grows there will continue to be ample opportunity to improve management of the wastewater we generate.

ANAEROBIC PACKED-BED PRETREATMENT OF POULTRY PROCESSING WASTEWATER

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Poultry processors are facing increasing regulatory and economic incentives to treat or pretreat their plant's wastewaters. Recent developments in anaerobic treatment technologies make it a viable option for meeting pretreatment requirements at poultry processing plants, ie., treatment to meet surcharge limits for disposal to publicly owned treatment works (POTW). If complete treatment is desired, anaerobic treatment can be easily coupled with aerobic biological treatment processes to meet this treatment objective. The anaerobic process has the distinct advantage of producing biogas (methane and carbon dioxide) as its main byproduct in the conversion of organic matter. In comparison to the more traditional treatment processes (dissolved air flotation and activated sludge), an anaerobic process produces relatively small amounts of sludge which requires disposal at considerable costs.

The anaerobic packed-bed process has not been previously applied to the treatment of poultry processing wastewater. This paper will summarize some of the major finding of the laboratory and pilot-scale research conducted with poultry processing wastewater.

To evaluate the treatability of poultry processing wastewater, laboratory tests were conducted on three types of anaerobic packed-bed reactors; upflow, downflow and downflow with recycle. The reactors were identical being constructed from 4.0 inch (ID) acrylic tube having an empty-bed volume of 5.6 liters. The reactors were packed with one inch ceramic saddles with a porosity of 72%, giving an actual bed volume of 4.0 liters. These tests were conducted using wastewater obtained from weekly grab sampling from a local broiler processing plant. Table 1 shows the average composition of wastewater used in this study. The wastewater was supplemented with 0.4 to 0.8 g/L of sodium bicarbonate to maintain the effluent pH of each reactor near neutral.

TABLE 1. Poultry Processing Wastewater Characteristics

PARAMETER	CONCENTRATION (mg/l)
Total COD	1900-2900
Total BOD_5	1250-1750
Total Suspended Solids	800_1500
Total Volatile Suspended Solids	700-1400
Fats, oil and Grease	100- 400
NH_4 - N	20- 40
Alkalinity, as $CaCO_3$	80- 550
pH (standard units)	6.7- 7.3

The results of the laboratory phase indicate that the anaerobic packed-bed process could meet pretreatment requirements with as short as a 10 hour hydraulic retention time. Organic loading rates of up to 6 kg TCOD/m^3 day were possible with resultant effluent levels of BOD_5, TSS, and FOG below 190, 250, and 70 mg/l, respectively.

A major advantage of this treatment process is the consistent pollutant removal without the production of large quantities of sludge associated with conventional wastewater treatment systems. These reactors were operated for 285 days without solids wasting while maintaining effluent suspended solids levels below typical discharge requirements.

The laboratory treatability results are very promising but because of the small scale its usefulness in design of a full scale system are limited. To obtain a more accurate representation of a full scale system, a pilot scale system was constructed and installed at a poultry process plant in September of 1987. Monitoring and data collection are presently in progress and a detailed analysis will be published upon completion. Some of the preliminary results from the pilot system merit discussion.

The reactor is a 1,000 gallon HPDE tank filled with a commercial 6 inch plastic random packing media. The reactor contents are maintained at 35° C with heat being provided by a propane water heater through an immersion plate heat exchanger. An influent/effluent heat exchanger recovers some of the heat from the effluent to preheat the influent. Thermocouples are used to monitor temperature throughout the system. A wet test gas meter is used to monitor biogas production and gas composition is checked with a gas chromatograph. Influent and effluent wastewater samples are routinely analyzed for parameters of interest.

Wastewater is pumped to the unit during the processing shifts, 16 hours per day, 5 days per week. During the off periods the contents of the reactor are recycled through the primary heat exchanger to maintain the temperature. A small amount of sodium bicarbonate is added to the influent to buffer the system. Preliminary results indicate that the removal efficiencies are significantly less than those obtained in the lab study. Pilot and lab scale results for COD and TSS are compared in Table 2.

TABLE 2. Comparison of Lab and Pilot Reactors

PARAMETER	LAB-SCALE	PILOT-SCALE
COD Removal %	81	55
TSS Removal %	79	74
COD Loading kg/m^3/d	4.9	5.0
COD Removed kg/m^3/d	4.5	2.6

While these efficiencies are less than those for the lab study it still indicates that pretreatment levels could be obtained with a hydraulic retention time of about 20 hours. The pilot system has also demonstrated that the process is very stable. It has performed consistantly despite periods of high flow, no flow, low temperatures, high temperatures, no buffer addition and the pumping of air into the reactor. Start-up presented no problems and appeared to be acclimated in about 30 days.

Increasing the DAF Efficiency of Poultry Processing Wastewater Treatment

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The most frequently used method of pretreating poultry processing wastewater, prior to discharge into a municipal sewer system, is a combination of physical and chemical treatment. This consist of screening and sedimentation followed by chemically flocculating with trivalent metal ions and/or polymers prior to floc removal by dissolved air flotation (DAF). Flocculant (sludge) is either recovered for rendering or land disposal.

Poultry processing wastewater is generally a high strength waste consisting of large amounts of organic material (feed, meat particles, blood, grease, etc.). Although effective in reducing organic loads, DAF's generate large volumes of sludge, up to several thousands of gallons per day.

Because of deficiencies inherent in the original design of the pretreatment system (high sludge volumes, expensive sludge disposal, low DAF efficiencies), a number of modifications have been developed. These modifications include physical treatment as well as chemical feed location alternatives.

Basic wastewater technology was utilized to improve the physical removal of solids. In September, 1985, a grit chamber was installed between the primary and secondary screens to remove solids. The solids collected are mechanically removed and loaded into an offal trailer thereby reducing the load to the secondary screens and DAF unit. Since the installation of the grit chamber, the efficiency of the DAF has improved. The amount of solids that once passed through the screens, then settled to the bottom of the DAF, has been reduced. Prior to installation of the grit chamber, removing solids from the DAF would take 2-2.5 hours per week. At present it takes .75-1.0 to remove solids. Reducing the amount of solids entering the DAF has had the following benefits:

1. Improved quality of effluent.

2. Reduced chemical requirements. Polymer dosage of 4-5 ppm, reduced 2-3 ppm.

3. Sludge volume was reduced.

Having noted the increased efficiency of the DAF, methods to further improve the grit chamber's efficiency were investigated. I felt upstream flocculation would increase the yield of the grit chamber. In the spring of 1986, ferric sulfate was added into the feather flume along with the conventional point at the wet well. The idea was if flocculation was started prior to screening, the efficiency of primary and secondary screens would be improved. Sixty to 80 ppm of ferric sulfate added into the feather flume formed a floc. The flocced particles attached to the feathers and were carried into the offal trailer. In this way the feather acted as a filter. The water draining out of the offal trailers turned from the normal blood red to clear. An increase in the amount of solids captured by the grit chamber and secondary screens was observed. Sludge volumes generated by the DAF were reduced. With the conventional system, 14,500 gallons per day were produced. The modified method produced 9,200 gallons of sludge per day.

This system, however, had disadvantages. Changes in organic loading in the feather flume due to breaks and change of shifts caused overdosages of ferric sulfate to occur. The overdose would cause a low pH influent to the DAF, poor flocculation and a poor quality effluent to be discharged. To solve this problem, sodium hydroxide was added into the feather flume along with ferric sulfate. This balanced the pH and allowed for good flocculation. Controlling the two chemicals was often difficult. The conventional and new feed points were a hundred yards apart. Adjustments were time-consuming and frustrating. To solve this problem, an alternate feed point for sodium hydroxide was determined. Sodium hydroxide was added into the wet well rather than the feather flume. This change solved the problems of control of feed rate and upstream overdosing of ferric sulfate. If at break, the upstream addition becomes excessive, increasing the sodium hydroxide at the wet well increased the pH to the proper level. During processing it allowed the DAF to run 0.5-1.0 pH units higher than with ferric sulfate alone. Advantages to the ferric sulfate upstream, sodium hydroxide and ferric sulfate addition in the wet well are:

1. Better quality effluent.

2. Reduced cost of dewatering sludge.

3. A more compact, sturdier floc formed in DAF (sludge volume reduced).

4. Less polymer required. Polymer more effective at higher pH.

5. Reduced solids entering DAF.

6. Less corrosive water entering DAF.

Summary

DAF efficiency was improved over the past three years by modifying the traditional design of the pretreatment system.

1. Installed grit chamber

2. Ferric sulfate addition in feather flume

3. Ferric sulfate addition in feather flume, sodium hydroxide and ferric sulfate in wet well

Chemical cost savings, as well as improved quality effluent, were realized.

	Chemical (Daily)	Surcharge (Daily)	Total (Daily)	Annual
Traditional	556	40	596	154,960
Modification 1	458	40	498	129,480
Modification 2	431	16	447	115,220

TREATMENT OF WASTEWATER FROM RENDERING PLANTS

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Wastewaters generated by rendering plants are treated by a combination of wastewater pretreatment and final treatment processes prior to ultimate disposal by discharge to a stream or by discharge to a land application site. Various pretreatment processes typically used on rendering plant wastewater such as screening systems, dissolved air floatation (DAF) systems, and, anaerobic and facultative lagoon systems will be presented emphasizing methods successfully used to upgrade the treatment efficiency or expand the treatment capacity of these types of pretreatment systems. Plate pack DAF cells, pipeline flocculation units, conventional DAF cells and flow equalization basin designs are presented to improve rendering and wastewater pretreatment. Final treatment processes used on rendering plant wastewater such as aerated lagoons, complete mix activated sludge systems, total barrier oxidation ditch systems, sequence batch reactor systems and cyclical complete mix activated sludge systems with special emphasis on operation of these systems to reduce wastewater nitrogen concentration prior to discharge into a stream or prior to discharge onto land application sites.

Process control parameters for operation of activated sludge nitrogen removal systems such as aerobic and anoxic biomass volume and dissolved oxygen concentration control, pH control, inhibitory substances and basin temperature control will be reviewed.

Performance data on BOD, Ammonia, and Nitrogen removal at one Total Barrier Oxidation Ditch (TBOD) system in Pennsylvania and one TBOD system in Arkansas used prior to final wastewater disposal by stream discharge will be reviewed.

Phased construction of an aerated lagoon final treatment system designed to be upgraded in the future by conversion to activated sludge nitrogen removal system is presented as a cost effective method to expand rendering plant production capacity without requiring an expansion of land area for ultimate disposal of treated wastewater by spray irrigation. Land area requirements for spray irrigation of wastewater with and without upstream nitrogen removal treatment area compared. Alternate land application methods of pretreated wastewater are presented.

LAND APPLICATION OF DAF SLUDGE

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Licht and Revel (1981) reported that waste products generated from food processing, if properly utilized, have environmental and economic benefits. Maphis (1981) suggested that a need exists for the development of economically and environmentally safe procedures for handling packinghouse (red meat) sludges in many operations across the U.S. Land application seems to be a feasible solution to this industry's sludge disposal problem. Nitrogen in the flocculated protein can be an effective plant nutrient source if applied in proper amounts and conditions.

Broiler processors use relatively large volumes of water for sanitation, heat transfer and transport. As water is used it becomes contaminated with blood, fat, viscera, tissue particles, feathers, manure, etc., and can not be discharged into a water course.

The feathers, viscera and other heavy solids are screened from the waste water (primary treatment) and processed into feed ingredients by rendering. After this primary treatment, the wastewater is still heavily contaminated with fat, blood and minute particles of meat and feathers, which must undergo extensive physical and biological treatment before being suitable for stream discharge. Chemical flocculation followed by dissolved air flotation (DAF) has been found to be an effective method of reducing the contaminant concentrations of broiler processing wastewater to approximately that of domestic sewage.

In reducing the contaminant concentrations, DAF produces large volumes of skimmings. The skimmings are 5-15% solids, making them expensive to haul and render. Some nutritionists prohibit rendered DAF skimmings from poultry by-product meal. Therefore, many buyers of rendered products will not accept by-product meal containing DAF.

As a result, the Universities of Delaware and Maryland conducted studies on land disposal of DAF sludge from poultry processing. A summary of the studies and their application to this problem will be presented herein.

COMMON PROCEDURE

There were some procedural practices common to both studies. They were:

1. Monitoring wells (5.0 cm diameter) were installed before application of the DAF sludge.

2. The sludge was applied directly from the poultry processing plant as it was generated.

3. The sludge was applied to the test plots by use of a liquid manure spreader and incorporated into the soil by disking for odor control and nutrient preservation.

4. Sludge properties were determined.

5. Water from the monitoring wells were tested for nitrate nitrogen.

DELAWARE STUDY

Figure 1 shows the plot layout (Ritter, 1981). Plot identification, size, DAF load rates and well location and identification are shown on the layout.

The plots were located on a Sassafras Sandy loam and a Woodstown Sandy loam soil. Soybeans were planted following wheat the first year of the study. In Plot 5 the soybeans had emerged before DAF application, which killed the soybeans. Soybeans were planted in Plots 1-4 in the second year of the study but no yield data were available.

Nitrate nitrogen in the groundwater was below 10 mg/L (EPA standard for drinking water) in Wells 1 and 3, but exceed 10 mg/L in Well 2. The elevated concentration in Well 2 (19 mg/L) was probably caused by the high application rate of DAF sludge in Plot 5. Also, no crop was grown in the plot to utilize the nitrogen. No total or fecal coliform bacteria were detected in the wells.

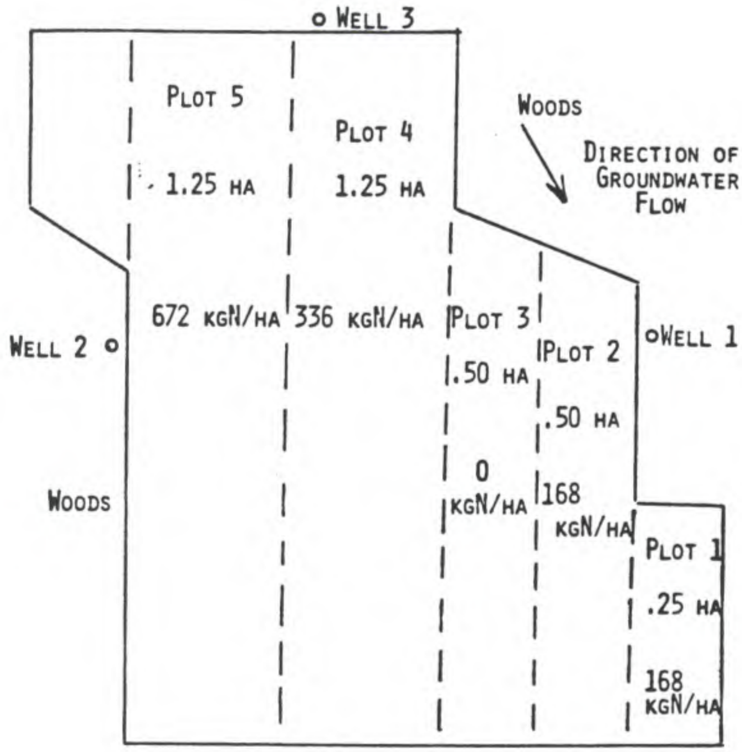

Figure 1. Delaware plot layout.

Hydraulic conductivity tests were conducted. Approximately 3500 kg/ha of grease was applied to the high rate plots. Soil permeability was not decreased by this loading of grease. Visual observation showed more earth worms in the DAF plots which could assist with maintaining good soil permeability. There was no change in soil moisture retention between the various application rates of DAF sludge.

MARYLAND STUDY

A plot layout for the Maryland study is shown in Figure 2 (Carr, et. al. 1988). A 1.7 ha field was divided into equal plots (Plots 1-9).

Duplicate plots were applied with nitrogen from DAF sludge at the rate of 67 kg/ha and 135 kg/ha for corn production. Table 1 shows an analysis of the poultry processing plant sludge used in the Maryland study.

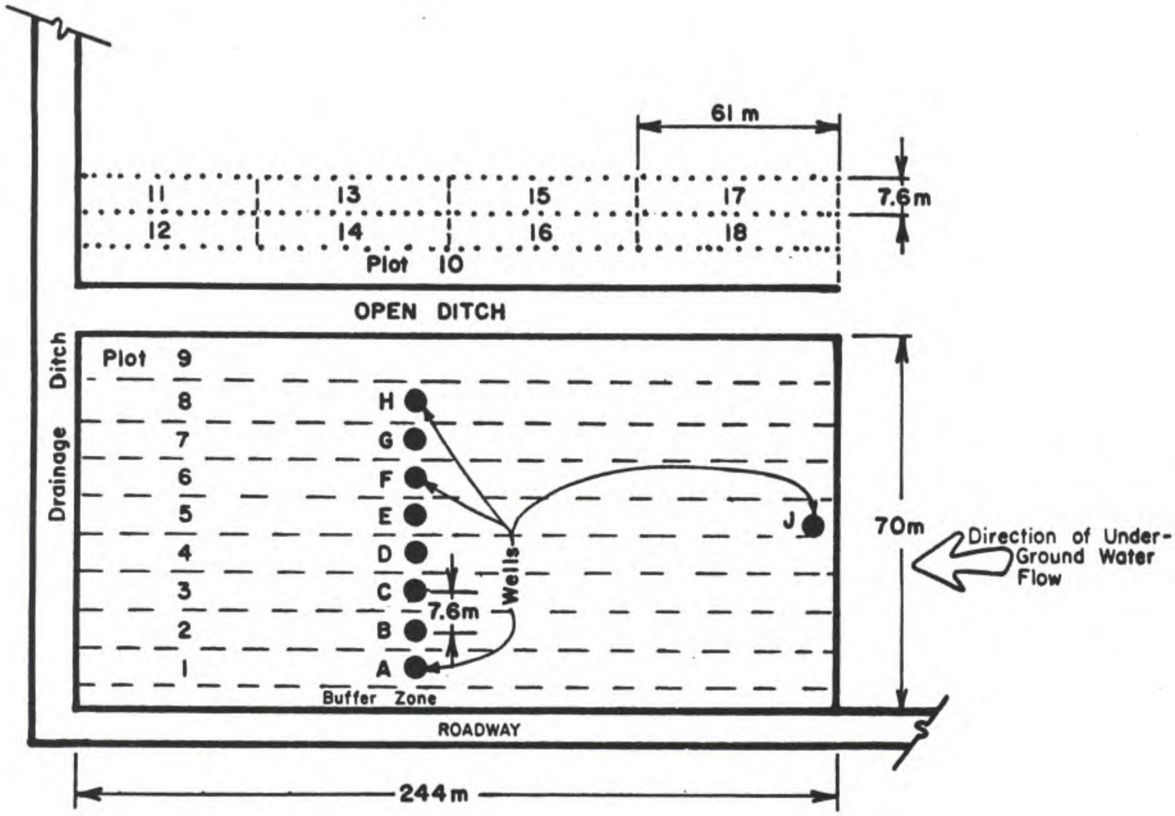

Figure 2. Maryland plot layout.

Table 1. DAF sludge analysis.

Item	Concentration (Typical)	
	Wet basis	Dry basis, mg/L
Solids	15.0%	0.0
Nitrogen, total	0.8%	55,000
Phosphorus, As P_2O_5	0.223%	15,410
Potassium, As K_2O	0.080%	5,520
Copper	0.0008%	53
Cadmium	0.00001%	1.2
Lead	0.00007%	5.2
Zinc	0.004%	280
Aluminum	0.08%	5,500
Oil and Grease	6.6%	453,500
pH	5.5	----
COD	287,000 mg/L	----

To obtain the desired nitrogen rates, sludge was applied at 6.3 t/ha and 12.6 t/ha, respectively. The nitrogen rates were determined based on corn yield goals and not maximum soil load rates. A 20% minerilization rate was assumed for the year applied (Loehr, 1979).

For the first two years of this study, fall and spring applications were made. The fall applied plots did not receive a spring application. The purpose of the seasonal application was to determine if there were visual germination and plant toxicity problems with corn. None were found. Therefore, DAF sludge was applied to all plots within one week of planting in the two final years of this study.

No increase in the levels of nitrate nitrogen occurred in the water table for the four years DAF sludge was applied to the plots. At no time did the nitrate nitrogen exceed the EPA safe drinking water standards of 10 mg/L

An increase in earth worm population was noted in the DAF sludge plots. The higher rate of DAF application resulted in greater corn yields regardless of the season applied (Table 2).

Table 2. 1980-83 Corn yield form DAF applied plots.

Application Date/ Rate N Eqv.	Plot No.	Grain yield t/ha @ 15.5% Moisture			
		1980	1981	1982	1983
Sludge applied in the Fall of 1979 and 1980 to the plots specified, respectively.					
135 kg/ha	1 & 5	6.2 [ab] [1]	10.2 [a]		
67 kg/ha	3 & 7	4.6 [b]	7.3 [ab]		
Sludge applied in the Spring of 1980 and 1981 to the plots specified, respectively.					
135 kg/ha	4 & 8	7.7 [a]	10.5 [a]		
67 kg/ha	2 & 6	5.2 [b]	5.8 [b]		
Sludge applied in the Spring of 1982 and 1983 to all plots, respectively.					
135 kg/ha	1,4,5,8			8.1 [a]	5.5 [a]
	12,14,15,17			9.5 [a]	
67 kg/ha	2,3,6,7			5.2 [b]	4.6 [a]
Commercial N Control					
157 kg/ha	10	5.7 [ab]			
143 kg/ha	10		7.7 [ab]		
135 kg/ha (NH_4NO_3)	11,13,16,18			8.4 [a]	
Control no N added	9	2.4 [c]	1.3 [c]	2.3 [c]	0.4 [b]

[1] Different superscripts note significant differences at P<0.05 within a column.

However, spring application generally produced the highest yield. Yield data comparing DAF sludge plots to ammonium nitrate plots (Plots 11-18) in 1982 showed no significant difference at $P < 0.05$. Corn yields from the high poultry DAF applications were comparable to those produced by commercial fertilizers at similar nitrogen application rates. Corn yields in 1983 were lower than in prior years because of a very dry summer.

Plant and grain samples were collected at harvest in 1981 for heavy metal analyses in the high DAF plots and commercial fertilizer plots. Results of these analyses may be seen in Table 3. Quantities of the various metals found in the grain were equal to or less in the DAF treatment. Both treatments did not exceed standards established by EPA (1976) nor the maximum dietary tolerance levels for sheep (NRC, 1980). Sheep were the least tolerant to the heavy metals in question.

Table 3 - 1981 Analysis for heavy metals in corn

Plant Tissue	Heavy Metals, µg/g				
	Pb	Cu	Cd	Hg	Fe
DAF-High rate:					
Leaves & stalks	1.00	6.40	0.08	0.27	14.0
Kernels	<0.05	0.98	<0.02	<0.03	13.7
Commercial fertilizer:					
Leaves & stalks	0.10	3.10	0.10	0.27	9.30
Kernels	<0.05	1.30	<0.02	<0.03	17.90
Maximum tolerable dietary levels for sheep 1/	30.00	25.00	0.50	30.00	500.00

1/ NRC, 1980

Application Of The Research

As a result of the research efforts by the Universities of Delaware and Maryland, both States have issued permits for land disposal of undigested DAF sludge from poultry processing. The permits are site specific and will specify the application rate. The sludge is trucked to the land application site as it is produced at the processing plant and soil injected. If soil conditions do not permit injection, the sludge is stored in holding tanks (short term) or holding ponds (long term) until conditions are suitable.

Summary

DAF sludge from poultry processing is high in water content and will require large energy expenditures to dewater. Its use in by-product meal is not received favorably by nutritionists. As an alternative, land application has been received favorably by regulatory agencies in Delaware and Maryland who have issued permits for land application.

High applications of DAF sludge from poultry processing will not decrease soil permeability or have other adverse effects on soil properties when incorporated into the soil. It should be soil injected to prevent odor problems. Ground water nitrate nitrogen pollution was insignificant, but the nitrogen load rate should not exceed 300 kg/ha on coastal plain soils. The sludge can be used effectively in corn production as a plant nutrient.

DAF sludge use from poultry processing should be tied into an overall nutrient program through soil testing, DAF sludge analysis and plant nutrient requirements for a yield goal. Contact your local Cooperative Extension office if you need assistance in planning your plant nutrient program. Working together, we can protect our environment and utilize DAF sludge from poultry processing effectively.

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RUNOFF POTENTIAL FROM POULTRY MANURE APPLICATIONS

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The Ohio State University
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Introduction

The relationship between animal waste management and environmental quality has been of interest to agricultural engineers and scientists for at least 25 years; some would argue the period has been much longer. When the American Society of Agricultural Engineers (ASAE) sponsored the National Symposium on Animal Wastes in 1966, the focus was on defining a variety of problems involving waste management, but few environmental considerations. In 1971, when ASAE sponsored the 1st International Symposium on Livestock Wastes, more attention was devoted to the impacts of runoff quality from areas treated with animal manures. When the Water Pollution Control Act Amendments of 1972 (P.L. 92-500) were passed by Congress, even more interest was drawn to animal waste management, but generally in terms of large feedlots, since the emphasis in P.L. 92-500 was on point sources of pollution. Except where specific water quality problems were linked to animal waste application areas, the use of animal wastes on cropland was generally accepted as a routine agricultural practice of little consequence environmentally.

In the eastern U.S., runoff quality from both pasture and cropland came under close scrutiny in 1983 when the EPA Chesapeake Bay Study identified nonpoint source contributions of pollutants as one reason for the general decline in water quality bay-wide. In this region, much attention is now devoted to minimizing the losses of nutrients to both surface and ground waters from agricultural production systems. This is likely to become a national priority since passage by Congress of the Water Quality Act of 1987, which emphasizes controlling nonpoint sources of pollutants.

Factors Affecting Runoff Characteristics

The quality of runoff from a given area is influenced by the quantity of runoff, and thus by those factors that determine runoff generation. These include soil characteristics (structure, texture, organic matter content, etc.), topographic features (e.g. slope, drainage density), soil cover, surface micro- (and macro-) features (i.e., soil roughness), precipitation type, rate and duration, antecedent soil moisture content, and in some cases, location of the water table below the soil surface. Man has varying degrees of control over these factors ranging from no control to total control. Numerous texts discuss these factors in detail.

Runoff quality is influenced also by the characteristics of the media (soil/plant ecosystem) with which the runoff comes in contact. These include the physical, chemical and biological properties of the soil/plant system, which are in turn influenced by the characteristics of any amendments that may be added to the system. Further, the rate at which amendments are applied and how they are applied affects runoff quality. Researchers at North Carolina State University observed that in a grassed poultry manure application area, the amount of nutrients on the grass influenced runoff quality more than the amount of nutrients on the soil surface.

Two other influences may be less obvious; these are time between manure application and runoff, and environmental conditions. Animal manures are unstable, biological products, the characteristics of which are changed by a variety of physical, chemical and biological processes. All of these are influenced by the environment in which they occur, as defined by such parameters as temperature, relative humidity, and wind velocity. These processes are also a function of time, which determines the rate and extent to which reactions proceed.

The preceding discussion illustrates the complexity of natural factors affecting nonpoint source pollution, and highlights the futility of trying to precisely characterize runoff leaving areas receiving animal waste. Unlike effluent quality from wastewater treatment plants, runoff from land application areas defies precise definition.

"Worst Case" Runoff Quality From Poultry Manure Application Sites

To determine the effects of poultry manure applications on runoff under "worst case" conditions, The University of Maryland Agricultural Engineering Department conducted a study on Woodstown sandy loam soils using runoff plots and a rainfall simulator. Each plot had a fallow "source" area to which nutrients were applied. Some plots had grassed filter strips of Ky-31 fescue below the source areas. Source areas were 22 m (72.6 ft) long by 5.5 m (18 ft) wide. Filters were 4.6 m (15 ft) and 9.2 m (30 ft) long. Source areas were purposely kept fallow to attain a "worst case" situation for nutrient loss, i.e. the occurrence of precipitation soon after nutrient application but before a crop has had time to begin significant nutrient uptake.

Commercially supplied liquid nitrogen, UAN (a 30% N urea-ammonium-nitrate solution), was used exclusively in the first series of tests (i.e. Runs 1 - 6). Poultry (broiler) litter was used exclusively in Runs 7 - 12. Liquid nitrogen was applied before Run 1 at a rate of 112 kg N/ha (100 lb N/ac). Broiler litter was applied before Run 7, which was approximately 1 month after Run 1, at 8.9 wet metric tons/ha (4 wet tons/ac), the lowest rate farmers can apply with conventional spreading equipment. Approximately 287 kg N/ha (256 lb N/ac) were applied in manure; however, using currently accepted values for nitrogen availability from this waste, only 57 kg N/ha (51 lb/ac) would be expected to be available for crops during the first year.

Artificial rainfall was used to generate runoff from the plots according to the following schedule:

Run 1 - "Dry soil test", 1-hour duration; 48.25 mm (1.9 in) rain applied
Run 2 - "Wet soil test", conducted 24 hours after Run 1; 1/2-hour duration; 24.13 mm (0.95 in) rain applied
Run 3 - "Very wet soil test", conducted 1 hour after Run 2; 1/2-hour duration; 24.13 mm (0.95 in) rain applied
Runs 4, 5 & 6 - Identical to Runs 1, 2, & 3, respectively; conducted 1 week after Runs 1 - 3
Runs 7 - 12 identical to Runs 1-6, respectively, but conducted approximately 1 month after Runs 1 - 6

Runoff from each plot was collected in a gutter at the base of each plot and routed through flumes for measurement. Individual runoff samples were hand-collected throughout each runoff and frozen for subsequent analysis.

Results and Discussion

Hydrology. Lag time during runs using broiler litter increased in all categories over that experienced using liquid N. (Lag time was defined as the time between initiation of rainfall and the appearance of runoff.) This was likely due to the mulching effect of the litter, and to the "damming" of flow channels through the filters by wood chips contained in the litter. (Obviously the latter effect was not important in the plots with no filters.) The fact that all plots were recultivated before tests involving broiler litter probably also contributed to the increased lag times. The same trends were demonstrated in duration times (length of time runoff occurred) and the amount of runoff that occurred in these tests. In all cases the amount of runoff generated during tests with poultry manure was less than that during testing with UAN. The effect was especially noticeable on areas that had no vegetated filter below them; differences in runoff ranged from 10% to 30% less runoff from broiler litter tests. As filter length increased, the difference in runoff during poultry manure testing vs. UAN testing decreased, yet there was always at least 10% less runoff during poultry manure tests.

Runoff water quality. Samples of runoff were analyzed that were collected early and late in the runoff event, and at marked changes in runoff rate at intermediate times. As would be expected, pollutant concentrations varied widely between each runoff event, as well as within each event. During the first 1-hour event with broiler litter, concentrations of TKN, TP and TSS in runoff from bare areas averaged 34.5, 14.6 and 4178 mg/1, respectively. During the second 1-hour test approximately 1 week later, TKN, TP and TSS concentrations averaged 11.6, 8.8, and 2987 mg/1, respectively. TKN concentrations resulting from the first two, half-hour events were 19.2 and 29.0 mg/1, respectively. These compared to average TKN concentrations of 12.4 and 10.1 mg/1, respectively, for the second two, half-hour events. TP and TSS concentrations from all half-hour events were approximately the same.

Surface losses of nutrients. Table 1 contains an abbreviated summary of data for nutrient and suspended solids losses in runoff.

Losses of phosphorus were higher from the initial 1-hour and first 0.5-hour tests involving UAN, than they were for the corresponding tests involving broiler litter (except for the 4.6 m plots). Total P losses for the second 0.5-hour runs were somewhat comparable for both UAN and broiler litter tests, with those from the litter tests being slightly greater. Suspended solids losses were not as different in tests with the two nutrient sources during these runs as during the previous two sets of runs, a fact that may have influenced the relationship between P losses.

Table 1. Surface Runoff Losses of Nutrients and Solids (Totals)[1]

Ave. Ppt[2], mm	Filter Width, m	N Source>>	Total P[3], gms UAN	Total P[3], gms BL	Total N[4], gms UAN	Total N[4], gms BL	TSS[5], gms UAN	TSS[5], gms BL
+++++ Initial 1-Hour Runs +++++								
42.79	9.2		20.23	18.73	16.38	32.64	5431	1870
43.64	4.6		28.50	19.88	57.89	30.23	12243	3639
43.74	0.0		44.01	29.00	42.80	32.91	70827	9454
+++++ 1st 0.5-Hour Runs +++++								
24.63	9.2		14.10	13.85	12.30	20.63	3157	1919
24.97	4.6		14.74	20.17	21.97	30.37	4966	4195
23.89	0.0		22.35	22.50	30.69	28.35	16220	6623
+++++ 2nd 0.5-Hour Runs +++++								
23.08	9.2		11.29	12.94	11.22	21.79	5214	2676
24.47	4.6		12.46	18.12	13.80	39.41	13143	4652
24.42	0.0		20.03	24.52	21.14	40.27	13654	8318

[1] Except for 1-hr and 1st 0.5-hr tests using BL on bare plots, values represent average of 6 plot-tests, i.e. 2 tests on each of 3 plots
[2] Ave. Ppt - average amount of simulated rain
[3] Total P - total phosphorus in runoff
[4] Total N - total nitrogen in runoff
[5] TSS - total suspended solids in runoff
UAN - urea-ammonium-nitrate (liquid nitrogen)
BL - broiler litter

As with total P, total N losses during UAN tests generally decreased as the number of tests performed increased, indicating probably that less material was available for transport. Losses of total nitrogen during tests with broiler litter did not show dramatic reductions over time, and were sometimes 1.5 to 3 times greater than those during UAN testing, especially as testing proceeded and greater volumes of precipitation were applied. This seems to indicate that nitrogen continually leached from the manure and was transported by the runoff. However, despite much larger N application rates in tests with broiler litter as opposed to liquid N, the average total mass losses of N were approximately the same for the two treatments. Dramatic differences were evident in suspended solids losses during UAN and poultry manure tests. This would indicate that the waste provided a good mulch for the soil surface and shielded soil particles from detachment and transport by the rainfall and runoff.

For the experimental design used in this study, a mass loss of 10 gms represented an areal loss of 0.84 kg/ha (0.75 lb/ac). Thus total P losses from bare plots from all runs involving UAN amounted to 7.3 kg/ha (6.5 lb/ac);

total N losses were 7.9 kg/ha (7 lb/ac). For the entire testing period (losses from UAN plus broiler litter), total P losses for bare plots equalled 13.7 kg/ha (12.2 lb/ac) and total N losses equalled 16.4 kg/ha (14.6 lb/ac). By comparison, total P losses from plots with 9.2 m (15 ft) filter strips amounted to 7.7 kg/ha (6.8 lb/ac) and total N losses were 9.7 kg/ha (8.6 lb/ac). These losses were produced by simulated rainfall that amounted to approximately 1/4 of the total annual precipitation expected at the research site.

Conclusions

Conclusions must be kept within the context under which this study was conducted, i.e. a "worst case" scanario. Results would be expected to vary under different experimental conditions.

The results do suggest, however, that lower mass losses of N and P in runoff from agricultural cropland may be possible by substituting broiler litter for liquid N as a partial or total source of nitrogen. (This would be predicated on the use of the litter according to agronomic guidelines that strive to match application rates to realistic yield goals.) The results also incidate that poultry litter can be effective in reducing losses of suspended solids (eroded soil) from fallow areas.

Not addressed by these results is the contribution of nutrients to ground water. Such contributions should be evaluated before the total environmental consequences of poultry litter applications can be assessed. Further research should also be conducted to determine runoff and ground water quality from field-sized areas.

Acknowledgements

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Ground Water Contamination from Poultry Manure

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Introduction

Arkansas, Georgia, Alabama, North Carolina and Mississippi are the largest broiler producing states in the U.S. (Arkansas Ag Statistic Service, 1986). One of the most concentrated areas of broiler production is on the Delmarva Peninsula. In 1985, Arkansas produced 760 million birds and Georgia produced 677 million birds.

California, Georgia and Pennsylvania are the states with the largest number of laying hens. California has 39.4 million laying hens while Georgia and Pennsylvania have 23.7 and 30.9 million, respectively (USDC, 1984).

The largest turkey producing states are North Carolina, Minnesota and California. Turkey sales in 1982 for North Carolina were $30.8 million while sales in Minnesota and California were $27.5 and $21.6 million, respectively.

The value of poultry manure as a nutrient source for corn, small grains, fruits and vegetables has been recognized for a long time (Perkins et al., 1964; Liebhardt, 1976; Albregts and Howard, 1981). If poultry manure is applied at excessive rates to cropland, it may cause high nitrate levels in the ground water. High nitrate concentrations in drinking water are detrimental to infants during the first six months of life. Infants given breast-fed milk of mothers who drank high nitrate water may develop methemoglobinemia. The U.S. Environmental Protection Agency has set 10 mg/L N as the nitrate drinking water standard as a safeguard against methemoglobinemia from developing in infants.

Manure Characteristics

When poultry manure is applied to land, the amount of nitrogen in the manure will depend upon how the manure was handled and stored. If manure is not incorporated when it is applied to land, 60 percent available nitrogen in poultry manure may be lost after 7 days (Graves, 1986). The nutrient content of poultry manure is given in Table 1. The values presented in Table 1 account for storage losses (Isaacs and Harris, 1987; Midwest Plan Service, 1985).

Table 1. **Nutrient Content of Poultry Manure**[a]

Type	Total N	Available N (kg/mt)	P_2O_5	K_2O
Broiler Total Cleanout	40	25	40	22
Broiler Crust	22	12	18	12
Layers	20	12	10	5

[a] Values given in terms of wet weight of manure as applied to land.

Ground Water Contamination

Potential ground-water contamination from poultry manure may occur from storage of poultry manure or from land application sites. The major ground-water contaminant is nitrates. Excess rates of application of poultry manure may also cause high salt concentrations in the soil profile or ground water.

There have been a number of studies reported in the literature that have shown poultry manure to cause high nitrate concentrations in the ground water. Liebhardt et al. (1979) applied poultry manure to corn plots on an Evesboro loamy sand soil in Delaware at rates of 0, 13, 27, 54 and 179 mt/ha. At the highest rate of application nitrate concentrations in the ground water ranged from 65 to 174 mg/L N at the 3 m depth. On plots where no manure was applied, the nitrate concentration in the ground water ranged from 7 to 15 mg/L N. They found that as the rate of poultry manure applications increased, so did the concentration of nitrates in the ground water.

In southern Delaware, Robinson (1977) found nitrate concentrations above 10 mg/L N in 41 of 95 wells sampled, and that higher nitrate levels were commonly detected in areas with poultry operations. Ritter and Chirnside (1984) found that 32% of the wells sampled in coastal Sussex County in an intensive ground-water study had average nitrate concentrations above 10 mg/L N. The highest nitrate concentrations occurred in areas with intensive broiler production or intensive crop production with excessively drained soils. They found in several areas that nitrate concentrations in the ground water decreased as the distance from poultry houses increased.

Bachman (1984) analyzed nitrate data from 604 wells tapping the Columbia aquifer on the Delmarva Peninsula in eastern Maryland. Higher nitrate concentrations were found at sites with urban and agricultural land uses and moderately drained soils. Water from wells near poultry houses had the highest median nitrate concentrations, 9.7 mg/L N.

Nitrate Mineralization

In recent years there have been a number of studies to determine nitrogen mineralization rates in poultry manure. Bitzer and Sims (1988) proposed using the following formula for predicting the amount of available nitrogen in poultry manure:

$$PAN = 0.80\ N_i + 0.60\ N_o$$

where: PAN = available nitrogen - kg/mt
N_i = inorganic nitrogen - kg/mt
N_o = organic nitrogen - kg/mt

Bitzer and Sims (1988) found the average amount of organic nitrogen mineralized in 20 poultry manures was 66%. Mineralization of organic nitrogen in poultry manure was found to be a rapid process, that when combined with the amount of inorganic nitrogen in the manure, resulted in large amounts of available nitrogen within 2 weeks after incorporating the manure. In an earlier study Sims (1986) found most of the net nitrogen mineralization in poultry manure occurred in the first 90 days.

Westerman et al. (1987) found that 40-50% of the organic nitrogen in broiler and turkey litter was available within a few weeks of application and potentially 50-70% was available within 8-10 months.

Best Management Practices

Best management practices (BMPs) should be used for both poultry manure storage and manure application. If broiler manure is to be stockpiled for long periods of time, a polyethylene liner should be installed on top of the pile to prevent leaching and downward movement of nitrogen from the pile. Care should be taken to remove all manure from the stockpiled site when the manure is applied to land. A small layer of manure left on the site could result in downward movement of nitrogen. An alternative to a polyethylene liner is to construct a permanent manure storage structure. Several State Cooperative Extension Services have published fact sheets outlining the different types of manure storage that can be used and the proper method to cover a manure pile with a liner (Brodie et al., 1986, Isaacs and Harris, 1987).

In applying poultry manure to cropland the key to reducing ground-water contamination is nutrient management. The following BMPs emphasize nutrient management:

1. applying only enough manure to be removed by the crop,

2. manure nutrient analysis,

3. soil testing,

4. calibration of manure spreader,

5. timing of application, and

6. liming.

Only enough nitrogen to supply crop requirements should be applied. In order to determine the correct amount of manure to apply, it is important to have the soil tested, manure analyzed and to know the rate at which a particular manure spreader will apply manure at different tractor speeds.

Broiler management and manure cleanout practices in the broiler industry have changed significantly in the past 15 years. This has caused a change in the nutrient content of the manure being applied to cropland. In some cases, growers are only removing the cake, which would have a different nitrogen content than from a complete cleanout. A farmer can have his manure analyzed by a commercial laboratory at a cost of $20-30/sample.

When precise amounts of nitrogen are being applied to cropland, it is important to have the manure spreader calibrated. There are a number of extension fact sheets that have been published that outline manure spreader calibration procedures (Isaacs and Harris, 1987; Brodie and Smith, 1986).

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MANURE MANAGEMENT ON FROZEN SOIL

Stewart E. Ackerman

There has been a concerted effort by many researchers to anticipate and design against pollution problems when manure and other agricultural wastes are applied to frozen soils.

Dr. Flannery and John Bezpa at Rutgers prepared an excellent guide entitled "The Use of Poultry Manure in Crop Production." They advise against the application of manure on ground that is frozen or snow-covered. S. Klausner, Zwerman and Ellis at Cornell Department of Agronomy, however, demonstrated management techniques that were effective in minimizing nutrient losses when manure is applied to frozen soil. Naylor, Guest et al., Department of Agricultural Engineering also at Cornell, demonstrated a technique for the control of the loss of nutrients from liquid sludge when applied to frozen ground. It is the work of these two research teams which I would like to report to you.

The ideal management strategy for livestock and poultry manures, of course, is to apply them to land that is dry enough to be plowed or tilled immediately after application. The reality of operation limitations of large poultry farms with many poultry houses, however, is that some manure applications will be made when the ground is frozen. This is a fact of life for modern animal agriculture, at least in the northeast. It is realistic, therefore, to develop methods of managing these applications to prevent or limit the movement of manures off of the site of application.

In a survey of New York poultry farms with a half million or more birds in 1988, I found that all the farmers found it essential to apply some manure on frozen ground. The reason is simply that there is not enough good manure-spreading conditions between crop harvest and freeze up and between spring thaw and planting. Further, those farms with high rise poultry houses usually try to clean out the manure two times a year. This is done for fly control. Farms with manure handling systems that require more frequent cleaning have much less opportunity to avoid winter spreading. To wait for early spring before spreading, in the case of these large farms, is courting disaster. Wet conditions, as often occur in the northeast in the spring, make manure spreading impossible for several days at a time.

The objective of poultrymen is to move manure onto crop land when it is open, to get it done before crop planting time and to avoid spreading when odors will create complaints from neighbors. For most large farms, this means some spreading in the winter months. While the time required to clean out a six-month accumulation of manure from an 80,000 bird high rise house is only three or four days, a farm with ten or more such houses will run out of time if they don't spread during the winter months. Consequently, the technology of animal agriculture is severely taxing the resources on many farms for manure management.

Restrictive policies by State Agencies regarding manure applications to frozen ground are pushing this search for better answers. Legislation is not the answer. A few years ago New York State's Department of Environmental Conservation attempted to restrict the application of manures on frozen soil. This effort was not successful. The Department's current stated policy is to exempt all of animal agriculture from restrictions on waste management for non-point sources except as complaints may arise from pollution. However, the Department has not given up on control. In a recent instance, the Department required a poultry firm that planned a major expansion to use a system of soil birms on the contour on all land on which manure would be applied while frozen. This exception was made on the grounds that "the farm was not a family farm."

No exemptions in New York State are provided for waste disposal by the processors of agricultural products. The permit process for the food processing industries is extremely difficult and uncertain. It was in an effort to secure a permit for a poultry processor that L. Naylor did his work on the application of sludge to frozen ground. Based on the success of this project, New York State's Department of Environmental Conservation stipulated that the poultry farm mentioned above would have to use soil birms on all frozen land on which manure is applied.

The system designed by Naylor has merit. It is simple and inexpensive. It requires only a moldboard plow. This system of controlling the movement of manure applied to frozen ground consists of establishing birms of soil on the contour using a moldboard plow. In Lewis Naylor's work, birms were spaced 50 ft. apart on plots with slopes of 3 to 8%. These birms, which were 5" to 8" high, were designed to contain three times the highest daily application rate of liquid sludge. The spacing used between birms may be increased substantially where non-liquid manures are used, and on fields of less slope.

The system of birms effectively controlled all surface runoff as none of the birms were breached. Snow cover effectively absorbed all of the sludge applied. Average snow cover was three inches, but varied from 0 to 12 inches. Total precipitation on the application site was 6 inches in the 6 weeks period of the study. At the end of the trial, there was no evidence of solids movement between the application sites, although some soil infiltration during three thawing periods in the study time were probable. Nitrogen application rates from the sludge were 0, 6, 13, 26, and 47 pounds per acre equivalent. The sludge contained 3 lbs. of nitrogen per 10,000 gallons. The highest application rate of sludge was 58,000 gallons per acre equivalent. Treatment differences were observable in hay quality and yields.

This work of Mr. Naylor was designed to solve a specific problem--the disposal of sludge from waste water processing on agricultural lands in a manner that would prevent its' movement off the application site and to benefit crops grown on the land. The system did demonstrate a method of controlling the movement of waste products when applied to frozen soils.

An obvious limitation of a series of birms established with a moldboard plow is that the land in hay and other non-cultivated crops could not be treated in this manner. However if a site were to be used for several consecutive winters for waste disposal, a series of permanent terraces would serve equally well and would not interfere with forage harvest.

The second study on which I would like to report is that conducted by Klausner, Zwerman and Ellis in the Department of Agronomy, also at Cornell University. In their work, a series of weirs were used to collect all the water flowing off the plots where manure was applied. The work was conducted over three winters. Water passing through the weirs was collected, measured, and analyzed for nutrient content. This work clearly demonstrated several management strategies for reducing nutrient losses from fields where manure is applied during the winter months.

The following are the recommendations based on Klausner's work:

1. Stay off the land all together during thawing weather. Vehicle tire tracks can cause a lot of damage by channeling runoff.

2. Apply manures to frozen soils as early in the winter as possible. The runoff potential is far less if ice sheating forms on top of manure rather than under it.

3. Reserve the least erosive fields for winter manure applications.

4. Spread manure on fields with the great vegetation residues. Grass, hay, and fields with small grain stubble are best.

5. Spread as far away from drainage ditches, water ways, and ponds as possible.

6. Plant grass strips along draining ditches and water courses.

7. Base manure application rates on the fertilizer requirements of the crops to be grown.

STORAGE OF POULTRY MANURE IN SOLID FORM

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Common procedures for managing poultry manure after removal from the poultry house result in losses of valuable fertilizer nutrients that have the potential of contaminating ground and surface waters. The methods of applying manure to cropland when crops are dormant or stockpiling manure uncovered on the soil for the winter season before application on cropland can result in a severe reduction of nitrogen in the manure through volatilization and leaching. The nitrogen lost can represent a decline of farm income because the manure nitrogen could have been used to replace purchased fertilizer nitrogen.

Solid poultry manures have a nitrogen content of from slightly less than 7 percent to under 1 percent by wet weight. This range represents the change in nitrogen content between well maintained poultry house conditions and poorly managed manure stored outside in uncovered piles.

Potassium, phosphorous and other elements do not escape from manure to the environment as readily as nitrogen. The nitrogen loss leaves a manure product that when applied to crops in amounts necessary to meet crop nitrogen needs over a number of years results in an increase in the concentrations of the other manure elements in the soil. In some instances the increase can result in reduced crop yield potential. Also, soils with high levels of phosphorous can contribute greater amounts of total phosphorous to surface water systems than soils with moderate phosphorous concentrations and equal soil erosion.

Poultry manure storage allows for the optimum use of labor and equipment and provides a means of nutrient retention and environmental protection. Combined with effective nutrient use as fertilizer based on the most abundant nutrient in the manure with other nutrients supplemented by commercial fertilizers, storage can represent considerable long term economic gain for the farm enterprise. However, depending on the type of storage method or structure selected, the capital cost can overwhelm any economic gain.

Storage Starts In The Poultry House

Manure storage occurs within the poultry house in both floor litter and cage type systems. Deep pit houses for caged layers allow accumulation of manure beneath the cages in pits that can be entered with cleaning vehicles from the outside of the structure. With floor litter systems manure is mixed with the litter by the birds and storage occurs on the floors through a continued build-up of a dry litter manure mixture.

The cleaning frequency of either system is determined by the quality of the manure or manure litter in the house and the amount of remaining storage space available. Wet manures will require more frequent removal than dry manures. Typically, deep houses are expected to be cleaned one or two times per year. Whereas, floor systems might be partially cleaned of wet manure "cake" after every flock but not totally cleaned for a number of years.

Poultry manure should be maintained in a dry state so that nutrients are conserved, insects and odors are controlled and handling and storage costs are minimized. A primary management objective should be to select and operate bird watering systems to minimize water spillage on the manure. For example, a trough type watering system used with floor birds on litter can allow production of 20 to 30 cubic feet of wet manure cake per 1,000 bird flock. Closed-system drinkers allow less than 1 cubic foot of cake per 1,000 bird flock.

In deep pit layer houses water spillage can turn solid manure into a slurry capable of breaching the containment doors and moving outside to cause possible environmental damage and costly cleanup. The pit should be inspected daily for signs of water spillage and leaks repaired immediately. Often, with large operations, this task cannot be accomplished in a timely manner. Under such conditions consideration should be given to installing a water collection gutter below the drinkers so that spilled water can be transported for disposal outside of the manure storage pit.

Reduced water spillage will:

1) save water
2) improve production environment and resulting product quality
3) reduce ammonia release from the manure
4) reduce the volume of manure to be stored
5) extend the time between clean-out

Additional drying is provided by properly functioning ventilation systems. Reduced fan rates during winter contribute to wet manure production. In deep pits air circulation fans within the pit will help remove moisture from the manure.

There is a fine balance of heat and moisture with winter ventilation. Too much air exchange increases the heat requirements. However, too little air flow increases manure moisture and the subsequent release of ammonia. Ammonia release reduces bird performance and requires removal by increased ventilation rates which causes an increased heat demand. It would appear that paying for additional heating energy to maintain dry manure and prevent ammonia release might be better than paying for the extra heat required of ventilation to remove ammonia from the building. Dollars spent on moisture management provide economic and environmental returns to all phases of bird and manure management.

Outside Manure Storage

Storage outside of the house is required only when manure must be removed from inside storage during times when land is not available for immediate manure application. Usually, deep pit clean-out can be scheduled to apply manure when needed without additional storage. However, floor litter might be partially cleaned between flocks and as determined by litter management schedules of poultry integrators. Clean-out does not necessarily occur at optimum land application periods making storage necessary.

General Considerations For All Storage Systems

The storage method must protect the manure from prolonged contact with rainwater. This requires a surface that sheds water. A deep , well-rounded stockpile of compacted manure litter will shed water. However, the edges of the pile at the ground surface may become saturated. Cage layer manure will readily soak up moisture and should be stored only under cover with confining walls.

All storage systems should be separated from seasonal high ground water by a minimum of 4 feet of well-drained soil or a water resistant liner of compact clay, plastic or concrete. Locate the storage to avoid normally wet areas, run-off or drainage pathways, and other areas of running or standing water.

Careful storage site location must consider insects, birds and rodents that can transmit or transfer avian diseases. Storage receiving manure from many different sites should not be located near a poultry production facility.

Floor manure litter contains both wet and dry organic materials that produce heat when stored in confined piles. Storage structures and compact piles may be subject to spontaneous combustion. Limit manure contact with wood or provide for concrete wall construction.

Open Stockpile

Uncovered stockpiles of floor manure litter can be improved with proper construction. Choose a high, well-drained location away from waterways. Construct by dumping manure to form a narrow pile. Drive over the pile with a tractor, truck or other heavy wheeled vehicle to provide compaction. Drive over and dump additional manure on top of the compacted pile and compact again. Widen the pile on each side as it is made deeper. Continue this procedure until the stockpile has a deep, well-rounded top surface with sloping sides of compact manure. Because slightly wet manure will compact better than dry manure, the wetter material should be applied to the pile last to provide a compact surface crust.

Covered stockpile

Stockpiles of manure can be protected by covering with plastic sheeting anchored with earth and used auto tires. Select the site as indicated for improved stockpiles. Locate near natural windbreaks. The manure need not be compacted. Make a deep pile with a wide top that is flat or slightly dished. When possible, segregate wet and dry manure to avoid conditions leading to spontaneous combustion. Take care while covering with plastic to avoid tearing. Anchor the ground edges by laying the sheeting edges across a small trench approximately 12 inches deep and backfilling with soil. Small pools of rainwater will collect on the top and help hold the plastic in place. Lay auto tires on the top and tie tires in chain fashion with rope to hang down the sideslopes. Improperly anchored plastic will become loosened and tear or blow off the pile. Heavy gauge (6 mil) can last one or two seasons. Lighter gauge material is not recommended.

Stockpiles With Temporary Ground Liners

Where stockpiles must be located on high water table soils, a ground liner is recommended to prevent nitrogen leaching to ground water. A liner must be accompanied by a cover. The liner is a sheet of 6 mil plastic laid on the soil surface on which the stockpile is formed. Prepare the soil surface by removing any debris that might puncture the plastic. If the soil is loose, provide some compaction with a wheeled vehicle before laying out the plastic.

Apply a 12 inch layer of manure over the plastic before forming the pile to minimize the possibility of tearing by the equipment tires. A compact pile can be formed. Fold the edges of the liner 1 to 2 feet up the sides of the pile and anchor in the manure. Apply the surface cover as described for a covered stockpile. The ground liner will be torn during unloading of the pile and new plastic will be required each year. The torn plastic liner can cause difficulties with manure spreading equipment.

Stockpiles With Permanent Ground Liners

If you desire a permanent location for manure storage, a concrete slab can be constructed on which to place a covered stockpile. Using concrete removes the problems associated with a plastic liner. The concrete should be 6 inches thick, reinforced with wire mesh and placed on 6 inches of compact gravel. To prevent concrete failure, thicken the perimeter of the concrete to form a footer where traffic enters and exits. Grade the site to achieve maximum underdrainage. An improved gravel roadway will allow stockpile construction during poor soil conditions. Construct a covered compacted stockpile. Anchor the cover sheet edges with wood poles, concrete blocks or other heavy objects on the concrete slab.

Bunker Type Storage Structures

Bunkers are permanent aboveground concrete slabs with two parallel walls of concrete identical to those used for storing silage on livestock farms. A bunker allows deeper piling and compaction of manure to reduce the total area required of the manure storage. An end wall can be constructed to slightly increase the storage capacity, However, loading the structure is more easily accomplished without an end wall. A cover of plastic can be attached to the walls with batten strips and anchored with tires. Also, a more permanent cover of reinforced fabric with edge anchorage eyelets and roll out crank similar to that used for truck covers can be used. With careful use, storage and repair the reinforced fabric cover will last for many years.

Storage Structures With Permanent Roofs

Concrete slabs, bunkers or other structures with permanent roofs can be constructed to eliminate the need for plastic covers. The roof structure must be a clear span supported by the outside walls or perimeter posts. Interior posts will obstruct loading and unloading and might be ignited if spontaneous combustion conditions exist. Roof structures must be of sufficient height to allow manure piling. Compaction loading will be difficult under roof. Roofs 12 feet or higher may require wall panels to protect the stored manure from blowing rain. Some ammonium nitrogen release will continue to occur from a stockpile under roof unless the pile is covered tightly with plastic.

Permanent Structures vs. Temporary Covering

An improved stockpile covered with plastic sheeting provides the best combination of nutrient retention and environmental protection at least cost. This combination of versatility, simplicity, economy and effectiveness is rarely found in waste management.

Manure litter clean-out under an unsure schedule makes planning a manure storage structure also unsure. With small amounts of manure removed regularly and a large amount removed once in, perhaps, 3 years, a structure capable of holding the entire amount remains empty most of the time. A smaller storage would be insufficient during the major clean-out. The cost of a large permanent structure is unjustified with this frequency of need. However, a single structure can be effectively utilized for multiple houses if clean-out periods are scheduled to disperse the waste load.

Many roofed structures for poultry manure storage have been selected because of alternative utility for machine storage. The cost of the structure exceeds the economic return from the increased fertilizer value of the manure. Selection is based on the perceived value of the alternate utility. When these structures are cost shared with public funds for water quality protection, use as a garage causes agency concerns. However, as long as manure is stored in the structure when necessary the intended environmental protection is achieved.

Summary

Improved storage for poultry solid manure is required to allow the most effective use of the manure nutrients. Storage can take many forms with a great range of investment costs. However, inexpensive plastic sheeting can perform well with very low cost. All available storage techniques and structures must be managed carefully to fully realize their potential for nutrient retention and environmental protection.

Fertilizer Value of Poultry Manure and Commercial Fertilizers

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In general the goals for fertilizer nutrient management on a farm are to achieve maximum economic benefits from the nutrients and at the same time have minimum impact on the environment. Managing nutrients goes well beyond just buying fertilizer. It is extremely important to consider all of the nutrient sources on a farm. Probably the most important of these non-fertilizer nutrient sources is manure on farms with livestock or poultry. There are three factors about manure that must be considered in order to develop and adequate nutrient management plan: 1) Manure produced; 2) Nutrient content; and 3) Nutrient Behavior.

Manure Produced An important starting point in developing a nutrient management plan is to determine the amount of manure that is available for utilization on cropland. This can be best estimated directly by measuring the volume of manure in a storage or collected in a house. If direct estimation is not possible the amount of manure can be estimated from animal numbers and size. Poultry will produce around 60 pounds of fresh manure per 1000 pounds of liveweight per day.

Manure Nutrient Content Knowing the amount of manure available is an important practical consideration, but to properly utilize it, it's nutrient content must be known. Many textbooks and other publications contain tables of "typical" nutrient contents for different kinds of manure. These figures are usually good average values for nutrient content but because manure nutrient contents vary drastically, these book values are of very questionable value to the individual farmer. Analysis of manure samples in Pennsylvania over the last several years indicate an average analysis for fresh poultry manure of 66 lbs. of nitrogen, 54 lbs. of phosphate, and 31 lbs. of potash per ton of manure which agrees very well with the "book" values of 60 lbs. of nitrogen, 55 lbs. of phosphate, and 30 lbs. of potash per ton of manure. However, the nitrogen analysis of these "similar" poultry manure samples showed a four fold difference between the lowest and the highest samples analyzed. Similar variation is found in the phosphate and potash values. Fortunately, manure can be readily analyzed at a reasonable cost to determine the actual nutrient content of an individual manure source. Representative samples should be taken for analysis as the manure is used so that storage losses will be taken into account in the analysis.

Manure Nutrient Behavior Finally the behavior of the nutrients in manure in terms of how they can contribute to the nutrition of a crop must be known if the true fertilizer value of the manure is to be determined. You cannot determine the fertilizer value of manure simply by multiplying the nutrient content by the current fertilizer nutrient price. Such a calculation will give an indication of the potential value of the nutrients in the manure but the actual fertilizer value realized will depend on how the manure is handled and used.

The behavior of manure nitrogen is especially dependent on handling. The nitrogen in poultry manure is essentially 75% soluble uric acid or urea nitrogen and 25% organic nitrogen. Like fertilizer urea the urea in poultry manure is readily available to a crop. The organic nitrogen in manure is very slowly available over time as the organic matter decays in the soil and releases the nitrogen in mineral form. The first assumption about the availability of nitrogen from poultry manure is that 75% of the nitrogen is potentially available to crops immediately. However as with urea fertilizer, there is a significant potential for volatilization loss of nitrogen from manure. Urea is rapidly converted to ammonia in the soil. If this reaction occurs on the soil surface, and thus the ammonia is free to go off into the atmosphere, very large losses of nitrogen can occur by this mechanism. If, however, the manure is incorporated, so that the ammonia that is produced is trapped in the soil, this loss will not occur. Consequently the availability of manure nitrogen will depend strongly on whether it is incorporated and how soon the incorporation follows application. The table below gives the nitrogen availability factors used in Pennsylvania to estimate the amount of nitrogen that will be available to a crop in the year that the manure is spread.

Nitrogen availability factors for poultry manure

Incorporation	% N Available
< 3 Days	75
3 to 4 Days	45
5 to 7 Days	30
> 7 Days or None	15
Fall Applied (regardless of incorporation)	15

As was noted above the remaining nitrogen that is in organic form will become available over a period of time. Thus the amount of this residual nitrogen that will be available in a given year will depend on the history of manure applications on a field. The more frequent the applications the more residual nitrogen that will be released. Because this decay and release is a very variable process only a rather crude estimate of residual nitrogen availability is possible. The table below gives the factors used in Pennsylvania to estimate this residual nitrogen from previous poultry manure applications.

Residual nitrogen availability factors for poultry manure.

History	% N Available
Rare or Never	0
Frequent*	7
Continuous**	12

* Frequent = 5 to 7 out of 10 years
** Continuous = 8 to 10 out of 10 years

Once the nitrogen in the poultry manure is in the soil it is not automatically taken up by the crop. The nitrogen transformations that can occur in the soil are many and complex and can often have negative impact on the nitrogen availability. The two most important such processes are leaching in well drained soils and denitrification in poorly drained soils. Both process can occur in most soils and can result in significant losses of available nitrogen. Leaching is of particular concern because of the potential for the nitrate to contaminate the groundwater. The best management approach to avoiding these losses is timing the manure application as near to the time of crop need as possible. This will generally help to avoid the wetter times of the year when the potential for loss is highest and it will improve the probability that the nitrogen will be rapidly taken up by the growing crop before it can be lost. For fall applied nitrogen it has been our experience that a large proportion of the nitrogen is lost regardless of incorporation. This is mainly due to the extended time period and climatic conditions between application and need by the crop. Applying manure in the fall, incorporating it, and establishing a cover crop should significantly improve the retention of this nitrogen for the following year's crop.

Thus the nitrogen available from poultry manure is a combination of that available from the current application, which is highly dependent on handling and incorporation, plus a residual from previous applications and is sensitive to transformations once in the soil. Unfortunately there currently is no reliable soil test for available nitrogen in regions of the country where precipitation exceeds evapotranspiration.

Phosphorus in manure is mainly in the organic fraction of the manure and is thus only slowly available to a crop. However, unlike soluble phosphorus sources, phosphorus in this form is less subject to soil fixation. The net result appears to be that the phosphorus in manure is about as effective as fertilizer phosphorus in building and maintaining soil phosphorus levels. Because of it's low solubility, manure phosphorus can not be substituted for starter fertilizer where starter is needed. Once in the soil phosphorus is not very mobile and thus will accumulate in the soil. The major loss pathways for phosphorus are physical, primarily by runoff of the manure and by erosion of the soil. Phosphorus soil tests are very useful for managing manure phosphorus.

Potassium in manure is primarily in the soluble fraction of the manure and is thus readily available to crops like fertilizer potassium. Potassium is relatively immobile in the soil and thus like phosphorus it will accumulate in the soil. The major loss pathways for potassium are also physical, primarily by runoff of the manure and by erosion of the soil. Soil tests are effective tools for managing manure potassium.

Manure Nutrient Management Understanding farm nutrient flow can be very useful in developing a farm nutrient management plan. On a cash grain farm the nutrient flow is a fairly simple straight through flow: Fertilizer nutrients are brought on the farm and the crop produced leaves the farm.

On a primarily feed-self-sufficient livestock farm nutrients are harvested off of the farm fields in the crops, the crops are then used as feed in the animal enterprise

resulting in some nutrients (usually less than 25%) leaving the farm in the animal products and the rest of the nutrients being returned to the farm fields in the manure. Nutrients maybe added to this cycle as fertilizer on the farm fields and as nutrients contained in feed purchased for the livestock operation but the primary nutrient flow is from the farm field to the barn and back. The most important consideration in managing nutrients on this type of farm is accounting for all sources of nutrients and effectively recycling them in the cropping program. This type of system is the common one on dairy farms.
On poultry farms there is often a third system which is a combination of the first two where the connection between the cropping program and the livestock operation is short circuited. In this case, the animal enterprise is not linked to the cropping program by the necessity that the crops support the animals. Often the crop acreage is very limited and thus most if not, all of the feed and the large quantities of nutrients contained in it, are purchased into the animal enterprise. Like in the livestock system discussed above, only a small proportion of this large quantity of nutrients leaves the farm in the animal products the rest is now in the manure and is applied to the cropland. However in this case the amount of nutrients in the manure is in no way related to what was harvested in the crops grown on the soil where the manure is being spread. Because of this short circuiting there is the potential for major nutrient imbalances to occur. Attempts should be made to try to bring the nutrients into balance by removing some of the manure from the farm.

Another consideration in managing manure nutrients is the effect of crop rotation. Different crops have very different nutrient requirements. For example a corn crop requires a large amount of nitrogen, a smaller amount of phosphate and potash. An alfalfa crop however requires no nitrogen, some phosphate, and a large amount of potash. Therefore a rotation of these crops will have a very different nutrient requirement than either one of the individual crops grown in a field in a given year. This becomes very important when manure is used to meet some of the crop nutrient needs. For example when poultry manure is applied to continuous corn at a rate to meet the nitrogen needs of the corn crop a large excess of phosphate and potash will be applied. When the manure is incorporated to maximize the efficiency of the nitrogen this excess is approximately 3 times the phosphate requirement and 2 times the potash requirement of the corn. When the manure is not incorporated thus requiring higher rates to meet the nitrogen needs of the corn crop these excesses are 16 and 12 times the crop requirement for phosphate and potash respectively. In a rotation of 4 years of corn and 2 years of alfalfa when poultry manure is applied efficiently the phosphate excess is reduced to 2 times the crop requirement and there is only about one-half as much potash applied as is need in the rotation.

Manure applications should be planned based on the known need of the crop and soil as determined by a soil test and on the available nutrient content of the manure. The soil test should be used to prioritize the fields on a farm on the basis of the nitrogen requirement of the crop and on the test levels for phosphorus and potassium. High nitrogen requirements should be given priority as should low soil test levels. The lower the soil test level the greater the probability that adding more of that nutrient will result in a profitable response. Also, remember that the nutrients in manure only have value if they replace fertilizer nutrients. Once the fields have been prioritized the manure available should be allocated based on meeting the nitrogen needs of the current crop while not exceeding the phosphorus and potassium needs of the crop rotation. Fertilizer should only be used to supplement nutrients required by the current crop which are not being met by the manure application. Excess manure should be moved off of the farm to areas where the nutrients can be used effectively with minimum environmental hazard.

APPLICATION OF POULTRY MANURE -- LOGISTICS AND ECONOMICS

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Introduction

Farmers have traditionally been considered caretakers of the land. Manure and litter were handled by spreading for fertilizer, a practice as old as agriculture itself. However, increasing industrialization and concentration of farming operations, especially poultry operations, has made application of production by-products difficult. In a great many cases, suitable land resources are not available, and sufficient land is not under the control of poultry operators for waste spreading.

Increasing scrutiny of waste application practices by environmental regulatory agencies will force poultry growers to find ways of effectively utilizing manure and litter if they are to continue in business. The future is not bright for those industries which cannot effectively dispose of their wastes without adversely impacting surface and ground water resources, or creating nuisance conditions for their neighbors.

A major challenge in recent years has been to find ways of making manure and litter attractive as a substitute for commercial feeds and fertilizer. Most of the problems in doing this involve economics, and the development of an integrated manure/litter handling industry to serve growers in moving the waste from the point of production to where it can be utilized in an environmentally safe manner, in place of commercial fertilizer or cattle feed. This paper will review major considerations and problems and experience we have had in Virginia attempting to find effective and economical uses for poultry manure and litter.

Socioeconomic and Environmental Considerations

Poultry manure and litter are generally conceded to be valuable as soil amendments, especially when compared to other types of farm manure. But, like other organic fertilizers, it is subject to great variation in levels of nutrients important to crop fertilization. Management factors such as the type of bedding used, the frequency of litter change, moisture management, handling, and the degree of storage used prior to field application all contribute to the variability of manure and litter as a fertilizer. And, while manure analyses can help determine an effective utilization plan, the inconsistent nature of poultry wastes complicates the development of an attractive marketing plan.

Detailed study is needed before determining what farmers in a given area can afford to pay for manure or litter, and how much they can effectively use. An economic evaluation of poultry wastes must include the labor and machinery resources available to the user as well as a relative comparison of those required for commercial fertilizer and poultry waste application. Realistic allowances for nutrients actually supplied by the waste must be used, giving credit only for those actually required by the plant ----- not the value of total nutrients contained in the wastes. And, although the organic content of poultry wastes may cause their nutrients to be more stable in the soil as well as to improve soil physical properties, it is difficult to place a quantitative value on these advantages.

One method of dealing with the large quantities of litter generated in the poultry industry is to develop markets or disposal areas some distance from the point of production, which can be economically reached by transport. It has been suggested that many farmers outside intensive poultry areas could effectively substitute poultry wastes for commercial fertilizers if programs could be developed to enable them to economically make such a substitution.

Since virtually all farmers use some type of fertilizer, it is often assumed that poultry manure should be readily accepted as a substitute for commercial fertilizers. This has apparently not been the case up to now for several reasons. A great amount of poultry production is centered in regions which are predominantly agricultural, and which have considerable other livestock manure competing for disposal on surrounding cropland and pasture. In addition, many poultry operations generate far more wastes than can be safely and effectively utilized on their property.

The uncertain nutrient content of poultry wastes in general has made some farmers, especially those who are not accustomed to utilizing livestock manures, reluctant to accept it as a substitute for commercial fertilizers. These same farmers often do not have access to manure spreading equipment, so some alternative must be found for applying manure and litter hauled to the farm. Rented equipment often is expensive, and the likelihood of damage when spreading wastes is great; stones, rocks, and boards easily damage spreading equipment creating additional expenses for repair and downtime, and a general reluctance on the part of farmers who are used to the convenience of commercial fertilizer to substitute manures and litter. Concerns also have surfaced about herbicide resistant weed seeds being brought into an area in manure and litter, but limited testing to date has not revealed this to be a problem. Certain crops may also be vulnerable to fungi produced in manures and litter.

Regulatory considerations also must be considered in planning to transport wastes off-farm for uses elsewhere. If the material is marketed as a fertilizer, state regulatory agencies which oversee fertilizer sales may require "label" certification as to the content of a truckload of litter. Because of the variable nature of litter, such certification would obviously be difficult, and would not be valid from truckload to truckload, or pile to pile of wastes.

In Virginia, we have even had concerns about trucking manure significant distances off the farm where it was produced. There has been little concern about transport within a county, or to the farm next door. However, where longer haul distances are involved, the Virginia State Water Control Board has raised questions about who assumes responsibility in case of waste spillage during transport, or after delivery to another user. We have seen instances where farmers received litter or manure, and left it improperly stacked for long periods of time, generating nuisance complaints from neighbors. The complaints most often were directed at the generator of the waste rather than at the receiving farmer who did not provide proper storage or utilization of the manure.

A major concern in utilizing litter or manure off the farm where it was produced is the possibility that diseases will be transmitted from farm to farm. This might occur either through the waste itself, or through equipment or workers used to handle the wastes. So far, there has been no strong proof that such transmission is not possible, but litter and manure transfer is taking place. Certainly disease transmission is possible; however, it is not considered a major concern so long as manure is not spread adjacent to poultry facilities.

Handling Costs

A common reaction of growers to a program of off-farm utilization of manure is "how much can I earn from this?" There are obvious costs of waste management in any operation. The removal of litter or manure from housing is an expense in any operation. Perhaps this cost can be passed on to the user of the litter/manure.

It is well established that ammonia nitrogen can be conserved if applied manure or litter is disked in, plowed down, or injected during or soon after application. The economic advantages of this extra effort may not be attractive, especially with poultry litter because of the relatively low fraction of total N in the ammonia form. This conclusion is based on the assumption that an acre can be disk harrowed (12 ft disk harrow @ $0.90 per hr.) with a 90 hp tractor in .22 hours (tractor cost, @ $6.85 per hr.). Assuming labor at $5.00 per hour, total cost of disking applied waste would be $2.81 per acre, regardless of the amount applied. Typically this operation would reduce ammonia loss from litter from about 25% to only 5%. Average ammonia content of broiler litter in Virginia, based on laboratory tests, is about 14 lbs. per ton. By disking litter in following application, ammonia loss can be reduced from 3.5 lbs to 0.7 lbs per ton, or a savings of about $0.59 per ton of litter applied. At least 4.75 tons of litter of similar analysis would have to be applied before disking would begin to pay.

In order to provide better environmental protection, and to preserve the nutrient content of wastes, various types of storage have been promoted in Virginia and many other states. The most prominent type of storage to date in Virginia has been a high-roofed post-frame shed, typically 40-42 ft wide with length to suit the size operation and length of storage time desired. Many of these structures were constructed for turkey and broiler litter storage using cost-sharing funds provided by the Virginia Department of Soil and Water Conservation and the U. S. Agricultural Stabilization and Conservation Service. Though it is doubtful that these structures pay their way in nutrients conserved, the cost-sharing funds off-set these disadvantages to the producer, and provide added advantages of protection from surface and groundwater pollution. It is hoped that increased use of storage structures will make litter more attractive to potential brokers, and to the ultimate users who would substitute poultry waste for commercial fertilizers.

Tax Advantages

Recent new tax codes have altered many of the economic advantages formerly available for waste storage structures. However, there still appear to be three types of tax writeoffs for which a poultry grower can qualify. The first type allows the grower to amortize the cost of a certified pollution control facility over 60 months *if* the poultry business was in operation prior to 1976. Amortization begins the month following the month the facility was acquired; obviously, this is the most favorable type of writeoff.

A second option allows the grower to depreciate the cost of the pollution control facility over a period of seven years. This method uses a 200 percent declining balance, switching to straight-line with a half-year convention (that is, writeoff begins halfway through the first year and ends halfway through the eighth).

The third plan is simply a 15-year straight-line writeoff using a half-year convention. This would represent the minimum writeoff a grower would qualify for if he built the pollution control facility.

The following example will illustrate. Assume a grower incurs an initial expense of $27,500 for a litter storage facility. If he is awarded $11,000 under cost sharing programs, his cost is reduced to $16,500. If he was in operation prior to 1976, he can write off 10% of the cost the first year, 20% of the next four years, and 10% in the final year of amortization. This essentially translates to additional tax deductions of $1,650 the first and last years, and $3,300 the four years between. Assuming the grower is in the 28% federal tax bracket, his tax savings are equal to the deduction times 28% federal taxes + 5.75% state taxes (for Virginia) + 13% social security, or 46% of the annual deduction. This totals approximately $7,713 over the life of the facility. Calculating net present value using an interest rate of 12% results in present value savings of about $5,894 ($4,161 if the grower is in the 15% federal tax bracket).

Although total writeoff amounts for the other strategies are identical, shorter writeoff periods result in higher present values. Net present values of tax writeoffs of the seven year declining balance and the 15 year straight-line method range between $2,620 and $5,883, depending on the tax bracket assumed. All strategies assume that the grower will stay in the same tax bracket over the relevant periods, and that the opportunity cost of the grower's capital is the same as the interest rate at which he borrowed capital to construct the facility. All facilities begin amortization or depreciation midway through the first year of facility installation, either by tax restriction or by assumption. It is interesting to note that the cost of the facility does not affect the writeoff plan.

Further information on these tax plans may be found in U. S. Internal Revenue Service Publications 535 and 225.

Case Examples

Case 1:

A major egg producer located in a mountainous area of Virginia suffered complaints for many years from state regulatory agencies and local residents about their manure handling practices. The company did not control sufficient crop land for manure disposal, but depended on local farmers to take their manure for use on crops and pastures. Manure was hauled to the individual (usually small) farms and dumped in piles for the owners to spread. Often the manure lay in piles for long periods of time, generating complaints from neighbors and regulatory agencies. The egg producer bore responsibility for the complaints, not the end users. These complaints focused attention of environmental agencies on problems at both production and manure disposal sites.

Finally, in an effort to make significant corrections, the company hired a supervisor to oversee management of the manure disposal program. A major component of the program has been education of the various farmers who use the manure to assure that the manure is applied in a timely and efficient manner. As a result, most complaints have subsided, and demand for manure has increased as local farmers began to recognize the value and, in many cases, advantages of organic fertilizer over the commercial fertilizers used previously.

Some of the viewpoints of this company based on their experience follow:

* Wet litter/manure creates special problems with truckers. When trucks were hired for hauling by the day, drivers often returned "empty" with material still stuck to truck beds thereby reducing the amount of material that could be hauled on subsequent trips. The problem was alleviated by hiring independent trucks on a tonnage basis; drivers were paid $5.00 per ton hauled, with a minimum of 4 trips required in a 7 hour day. A private trucker who could broker his own load of manure was paid $7.00 per ton.

* Physical size of trucks is not as important as the moisture content of the waste. Very wet litter or manure often supplies the maximum load weight of the truck before it is actually "brimming" full. Axle loads based on bridge formulas, especially on secondary roads, present special problems. This fact complicates transportation economics.

* The maximum feasible one-way haul distance for this operation was approximately 35 miles.

* At present day values of N, P, and K, the maximum value a farmer can justify for layer manure is between $7 and $9 per ton. This takes into account the extra labor and bother associated with receiving and spreading manure as compared with ordering commercial fertilizer applied by the dealer.

* The increase in minimum wage from $3.75 to $4.65 will adversely affect the attractiveness of poultry litter/manure for use as a fertilizer substitute.

<u>Case 2:</u>

Specialists and Extension Agents at Virginia Tech have undertaken a demonstration to explore feasibility of moving litter from the intensive poultry production area of the Shenandoah Valley to the grain producing area of eastern Virginia, a distance of about 100-160 miles. We are examining the possibility of using the backhaul capabilities of grain trucks delivering to the Valley from the grain producing areas. The idea would be to promote sale of litter to a broker, or trucker, who in turn would haul and sell litter to grain farmers in litter deficit areas of the state. Some observations so far:

* Sale of the litter at the poultry farm is typically $4-5 per ton. If the buyer loads the litter, a cost of $4 is normal, but if the grower loads the litter, a cost of $5 per ton is more typical.

* Most growers will only have access to a farm tractor loader. The trailer-type trucks used for large-scale transport will require a larger rubber-tired loader. In our area, these rent for about $40.00 per hour. Since it takes about 1/2 hour to load the 20-ton trailers, loading cost typically runs $1.00 per ton including labor. We are also considering the use of a transportable belt elevator for loading. This would make possible the use of a typical 70 hp farm tractor equipped with a front end loader, or a skid-steer loader. Allowing $5.00 per hour for labor, this loader will cost about $0.30 per ton <u>excluding</u> cost of ownership.

* Hauling costs have been $1.00 per loaded mile on grain trucks which would otherwise be returning empty from deliveries to the Shenandoah Valley area. For the 100-160 mile return trip, this will add a hauling cost of about $5.25 to $8.40 per ton to the litter.

* Manure spreading equipment is not typically available on farms in the litter deficit areas of Virginia. Spreading is being tried using lime spreader trucks, and costs about $5.00 per ton. If a manure spreader is available, along with a 90 hp tractor, and assuming $5.00 per hour for labor and a spreading rate of six 5-ton loads per hour, spreading would cost about $0.50 per ton.

* A typical litter broker in our area expects to clear $1.00 per ton of litter sold.

* Based on the above data, total cost for the litter hauled to the grain production area of Virginia will be $16.00-$19.00 per ton.

* The local broker mentioned above can sell litter for $8.00 per ton when hauled to an adjacent farm, but has trouble finding buyers when the price is set at $10.00 per ton.

* Typical analyses of broiler litter in Virginia indicate average values of 37 percent moisture, and 62, 14, 64, and 37 pounds per ton for total N, ammonia, P_2O_5, and K_2O, respectively. At a current market price of $0.21 per lb. for N, $0.25 per lb. for P_2O5, and $0.15 per lb. for K_2O, litter should have a total gross value of $24.21 per ton based on nutrient value alone.

* However, all the N contained in the litter application will not be available to the crop. Furthermore, if litter is applied to supply all required N for the crop, P_2O_5 and K_2O will be over-applied, and value cannot be credited for the extra P and K applied. Assuming litter is being broadcast each year on a continuing basis, credit can be allowed for accumulated residual N, so that the litter will supply about 43.4 lbs, or $9.11 worth of N per ton (versus $12.95 per ton for the total N contained in the litter as hauled). Additional value for P and K should only be assigned for that portion needed for plant nutrition. For example, if crop requirements are 150 lbs per acre for N, 75 lbs per acre for P_2O_5, and 60 lbs per acre for K_2O (<u>and</u> assuming there is insufficient soil-stored P and K to meet these needs), one could only allow an additional $5.43 for P_2O_5, and $2.60 for K_2O. Total value for the litter would then be $17.14 per ton. Note that many soils are already high, and will remain high in P and K when a continuous litter application program is practiced. So, it often may not be possible to allocate any credit for P and K in pricing litter.

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UTILIZATION OF POULTRY SOLID WASTE ON CROPS

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Poultry manure in solid form can be used as a nutrient source for many crops. The rate of application is very important to use it effectively. Manure and soil analysis as well as plant nutrient requirements are very important in determining how much to apply.

Manure and commercial fertilizer programs should be integrated into one nutrient management package. Over fertilizing may reduce crop yield and degrade the environment. Some examples of poultry manure utilization on crops will be presented herein.

VEGETABLE CROPS

Bandel et. al. (1972) recommend applying 3 tons of poultry manure per acre during the winter to cover crops or just before or after plowing in the spring. If applied after plowing poultry manure should be incorporated into the soil. Poultry manure is caustic to young plants and should be used with caution shortly before or at planting time. There are many vegetable crops that can use poultry manure efficiently. Some are: cantaloupes; cucumbers; egg plants; leafy greens; peppers; pumpkins; sweet corn; squash; tomatoes and watermelons. In order to use poultry manure effectively, in vegetable production, you must have a manure and soil analysis and apply it according to the nutrient requirements.

FIELD CROPS

Small Grains - Poultry manure can be used effectively in the production of small grains such as wheat and barley. Application rate and time of application are very important to prevent lodging. Bandel et. al. (1972) recommend applying poultry manure by broadcasting followed by plowing down or disking in before seeding. Poultry manure can be used to topdress small grain in February or March. Do not apply more than 3 tons per acre when topdressing.

To demonstrate the use of poultry manure in small grains, results from Saluda wheat trials in 1987 will be presented (Mulford et. al., 1987). The poultry manure used in these plots was from a five flock built up broiler litter base used in floor bird production. An analysis of the broiler litter showed it contained: N = 3.9%; P_2O_5 = 3.0% and; K_2O = 1.9%. Table 1 shows yield results of the Saluda wheat trials using Cerone growth regulator.

Table 1. Poultry Manure Application on Saluda Wheat, 1987

Treatment	Yield - bu / A	
	No growth regulator	Cerone growth regulator
Control (No N, just P and K)	54.8	57.4
3T/A poultry manure disc preplant + 60 lbs N/A @ growth stage 6[1]	88.6	92.9
6T/A poultry manure disc preplant	75.8	79.3
6T/A poultry manure broadcast latefall (12/20/86)	84.1	85.8
4T/A poultry manure broadcast Spring greenup (02/20/87)	87.5	85.5
60 lbs. N/A @ greenup (02/20/87) + 60 lbs N/A @ growth stage 6	89.2	92.6

[1] Growth Stage 6 is where the first node on the stem is visible.

The data in Table 1 shows it is possible to produce 80+ bushels of wheat per acre with poultry manure or a combination of poultry manure and nitrogen fertilizer. However, timing and application rates are very important.

Corn - In the late 1970's and early 1980's ferrous sulfate was being used to control ammonia release in poultry housing. The product was applied to broiler built-up litter at the rate of

.15 - .30 lb/sq. ft. of litter surface area. Since most broiler litter in the Eastern Shore area was land applied for field crop production, a question arose as to, what affect would the ferrous sulfate added to poultry litter have on crop production? To answer this question, a three year plot study was conducted at the University of Maryland by Carr (1983). Figure 1 shows the plot layout. Each plot was six rows wide and 50 feet long. The broiler litter was applied at a rate to provide 160 lbs N/A. A mineralization rate of 50% was assumed for the year applied. No irrigation was used in these studies. Yield results for this three year study were adjusted to 15.5 percent moisture.

II A 4	I A 3	II B 5	I B 1	I C 3	II C 4	II D 3	I D 1
II A 5	I A 1	II B 4	I B 2	I C 2	II C 5	II D 1	I D 2
II A 3	I A 2	II B 2	I B 5	I C 4	II C 1	II D 2	I D 3
II A 2	I A 4	II B 3	I B 3	I C 1	II C 3	II D 4	I D 5
II A 1	I A 5	II B 1	I B 4	I C 5	II C 2	II D 5	I D 4

1. Control
2. Ammonium Nitrate 80lbs/A
3. Ammonium Nitrate 160lbs/A
4. Untreated Litter
5. Treated Litter

I. No-Till
II. Conventional Till

A-D Replications

Figure 1. Corn Plot Design

Table 2 shows a three year yield summary of the treatments ranked without regard to tillage practices. Ranking of the nitrogen sources showed (greatest yield to least yield): ammonium nitrate at 160 lb/A; treated litter at 160 lb N Eqv't/A; untreated litter at 160 lb N Eqv't/A; ammonium nitrate at 80 lb/A; and the control. This pattern was consistent for all three years. No significant yield differences were found between the high nitrogen rate of ammonium nitrate and the treated litter at $P \leq 0.05$. However, there was a significant yield difference between the high nitrogen rate of ammonium nitrate and the untreated litter at $P < 0.05$ except in 1981. These data indicate that the ferrous sulfate treatment had an influence in stablizing the litter ammonia nitrogen.

Table 2. Three Year Yield Summary of Treatments Ranked
Bushels/Acre

Treatment	N Eqv't Lbs/A	Year 1980	1981	1982	Three Year Average
Ammonium Nitrate	160	139.49[a1]	163.62[a]	173.53[a]	158.88[a]
Treated Litter	160	136.14[ab]	162.65[a]	172.56[a]	157.12[a]
Untreated Litter	160	124.85[b]	152.75[a]	138.60[c]	138.73[b]
Ammonium Nitrate	80	123.70[b]	148.72[a]	126.50[c]	132.97[b]
Control	None	64.25[c]	69.61[b]	45.54[d]	59.80[c]

[1] Different superscripts note a significant difference at $P < 0.05$.

The three year tillage X treatment data can be seen in Table 3. Treatment rankings were the same as shown in Table 2. These data show no significant differences at $P \leq 0.05$ between corn yield when using the high rate of ammonium nitrate and the treated litter in each of the tillage practices. There was a significant yield difference at $P < 0.05$ between the no-till and conventional tillage practices in favor of no-till for the high ammonium nitrate. A significant yield difference at $P < 0.05$ was determined between the treated and untreated litter. This indicates the ferrous sulfate treated litter was more stable than the untreated litter from nitrogen leaching and volitization. The yield response shown for the low rate of ammonium nitrate and the control was typical, (Mulford, 1983).

Table 3. Three Year Summary of Tillage X Treatment - Bushels/Acre

Treatment	N Eqv't Lbs/A	Tillage: No-till	Tillage: Conventional
Ammonium Nitrate	160	168.62 [a] [1]	149.14 [cd]
Treated Litter	160	161.54 [ab]	152.69 [bc]
Untreated Litter	160	139.35 [d]	138.13 [d]
Ammonia Nitrate	80	124.78 [e]	141.18 [cd]
Control	None	53.28 [g]	66.33 [f]

[1] Different superscripts note significant differences at $P < 0.05$.

Conclusions from this three year study were:

1. The high fertilization rates produced the most corn regardless of the nitrogen source.

2. The three year average shows no significant difference at $P \leq 0.05$ between ammonium nitrate at 160 lbs/A vs treated litter at 160 lb/A N equivalent in no-till nor in conventional.

3. There was a significant difference at $P < 0.05$ between the treated and untreated litter for both tillage practices. The <u>treated litter</u> produced the <u>greater yield</u>.

4. With good growing conditions, the performance of broiler litter and ammonium nitrate at 160 lbs N equivalent/A resulted in similar high yields for the two tillage practices.

Corn Field Study - To take the small plot work a step further, demonstration plots were grown by a corn producer under irrigation. Irrigation eliminated water stress problems. The plots were 6 rows wide (30-inch rows) and 150 feet long. These plots were part of a 175 acre field. Poultry litter was common to all plots. Three fertility treatments were used. They were: poultry litter; poultry litter plus starter fertilizer and poultry litter with starter fertilizer and anhydrous ammonia knifed in when the corn was 15-inches high. The application rates and cost assumptions for the commercial fertilizer (grower cost) were as follows: starter fertilizer 250 lbs/A @ $15.00; anhydrous ammonia 100 lbs/A @ $19.49; and broadcast 0-0-33 150 lbs/A @ $9.85. Corn price received by the grower was $2.37 per bushel. One hundred feet of a interior row was hand harvested for yield determination. Table 4 shows yield results from these plots.

Table 4. Poultry Litter Utilization in Irrigated Corn Production

Year Applied	Rate	Treatment Yield - Bu/A		
	Tons/A	Litter	Litter + Starter	Litter+Starter Anhy. NH_3
Spring 84	3	183^{b} [1]	157^{a}	196^{b}
Fall 84	5	169^{a}	195^{b}	194^{b}
Spring 85	5	183^{a}	195^{ab}	202^{b}

[1] Different superscripts within a row were significant at $P < 0.05$.

From the yield data in Table 4 and the cost assumptions, a summary of gross income minus commercial fertilizer cost can be made. Since poultry litter was common to all plots, it will be used as a base to determine the increase or decrease in gross income per acre by using commercial fertilizer in conjunction with poultry litter. For the 1984 fall application of poultry litter there was a $46.62 increase in gross income by using a starter fertilizer over the poultry litter base; for the 1985 spring application of poultry litter there was a $13.44 increase over base. This demonstrates that the closer to planting time the poultry litter was applied, less nitrogen was lost. In the treatment where starter and anhydrous ammonia were used, the gross income summary for the 1984 fall application was a $24.76 increase over base and $10.54 increase over base for the 1985 Spring application. This demonstrates that the time of poultry litter application is very critical to maximize profit. Also, attention has been given to integration of the manure and commercial fertilizer program into one fertility package to maximize profits.

Another corn grower (a cooperator in field demonstrations) who produces 700 acres of non irrigated corn saved $50 per acre in commercial fertilizer cost (1987) by integration of his poultry manure program and commercial fertility program into one fertility package. He plans to save more in 1988 by reducing the amount of starter fertilizer used at planting.

LAND APPLICATION

The land application of poultry manure in small quantities is difficult. In small plots it has to be hand applied. Application on a large scale is less difficult if you have the proper spreading equipment. There are spinner spreaders that can be adjusted to 1-2 tons/acre. With a typical box spreader, the application rate may be 6-10 tons/acre. In many instances the application rates for nitrogen are excessive because of the equipment design. Nitrogen may not be the limiting nutrient in land application. Phosporus may be the limiting nutrient because of soil build-up from long term application of poultry manure. Therefore, the application of less poultry manure per acre may become more critical with time. This will require better design in spreader equipment for the future. One grower on Delmarva expressed the operation of his box manure spreader this way, "It throws it in the air and I drive from under it". With the box spreader, there is little lateral distribution of poultry manure to either side of the spreader.

Under the direction of Mr. Gary Smith, Department of Agricultural Engineering, University of Maryland (UM), a prototype box spreader beater (UM Rotabeater) has been designed for poultry manure. Initial tests have shown a spread width up to 50 feet. When the research and development of the UM Rotabeater is completed, plans for retrofitting existing box spreaders will be made available.

Summary

Poultry manure can be used to supply nutrients to many crops. Manure and soil testing are very important in determining fertility requirements of a particular crop. Apply only the amounts of manure needed; over application may decrease crop yields and pollute the environment.

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UTILIZATION OF LIQUID POULTRY WASTES ON CROPS

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Two major sources of liquid poultry wastes are discharged from either lagoons of cage layer operations or from poultry slaughtering plants. Water is used in caged layer houses to flush the manure from beneath the birds into lagoons where natural biological processes degrade the manure, however, this process is not complete. Sludge, nitrogenous material and salts accumulate and must be removed periodically. Poultry slaughtering plants use large quantities of water. It is estimated that poultry processors in the United States are enough water to fill a 6,000 acre lake and discharge the Biochemical Oxygen Demand (BOD_5) equivalent to 4.25 million people.

In the past these wastewaters were further tested and discharged into a stream. Meeting stream discharge standards is increasingly difficult, therefore, land application has become the disposal system of choice.

Design criteria for land application systems are based on nutrient mass and hydraulic volume being discharged. The amount of wastewater that can be applied to a site depends on either the amount of nutrients that a cropping system or the volume of water that the site can safely assimilate through evaporation, plant transpiration or by downward movement of the applied wastewater. Design criteria is based either on nutrient loading or hydraulic loading, with either one or the other the limiting factor.

Hydraulic Loading

Wastewater discharged by a poultry processing plant is high volume low strength wastewater. Systems designed for land application of this wastewater should have the design for maximum water removal through evaporation, plant transpiration and nutrient utilization.

The amount of water than can be applied to the land depends on: 1. soil type; 2. rainfall; 3. vegetation; 4. slope; 5. climate; 6. groundwater table; and 7. season.

Wastewater is commonly applied to either cropland or forest land. Both have their advantages. Cropland application advantages include:

1. Crops of economic value can be harvested continually.
2. Mechanized equipment can be utilized.
3. Greater nutrient removal.

Forest application advantages include:

1. Greater evapotranspiration rates.
2. Better soil permeability.
3. Steeper slopes can be utilized.

Nutrient Loading

The other design criteria for land application of poultry wastewater is that of nutrient loading. The goal of a successful wastewater application based on nutrient loading is that the vegetation or biota will remove nutrients at a rate equal to or greater than their application rate.

When designing wastewater land application systems of poultry wastes where nutrient removal is a primary criteria, crop systems rather than forests are preferred. Forage crops can remove greater amounts of nutrients than can forests. As agronomic crop are harvested at least annually the nutrient utilized are removed at least annually.

Table 1 gives the nitrogen uptake of common crops and forest trees.

Table 1. Expected Nutrient Removal by Forage and Field Crops, and Forest Trees

Vegetative Cover (Yield Goals)	Nitrogen Uptake (ka/ha/yr)
Forage and Field Crops	
Coastal Bermudagrass with rye overseed	570 + 205 = 775
Coastal Bermudagrass	480 to 600
Reed canary grass	226 to 359
Fescue	275
Johnson Grass, 27 metric ton/ha	890
Corn (7.6-12.9 m/ha)	155
Milo maize	81
Wheat	50 to 76
Barley	63
Oats	53
Forest Trees	
Mixed hardwoods	200
Red pine	160
White spruce (old field vegetation)	250
Pioneer succession vegetation	250

Overcash and Pal (1979)

Land Application of Layer Lagoon Waste

The producer who uses liquid manure from caged layer flush systems should use the following criteria in application:

1. Know the concentration of nutrients in the wastewater. This material is a fertilizer just as if it were purchased from a fertilizer dealer. Have the material analyzed prior to applying.

2. Select proper equipment. Due to high solids content, use of small nozzles should be discouraged. They will plug and make even distribution of the material a frustrating job. Nozzle openings of at least ½ inch should be used.

3. Clean the system after use. Solids and precipitates will build up in lines and plug the nozzles. The system should be flushed-out after each use.

Land Application of Processing Plant Wastewater

Wastewater from processing plants is high volume low strength waste. Raw poultry processing wastewater is not directly applied to land due to grease and the potential of flies and odors. Some types of pretreatment systems consisting of anerobic and/or treated lagoons and oxidation ponds are used to reduce the organic and nitrogen load discharged. Those treatment systems reduce BOD concentration by 95 percent and nitrogen loads by 40-50 percent.

This wastewater is then applied to either pastures, crop or forests. Acreage and application schemes are dependent on the previously mentioned factors.

Poultry processing wastewater is low in solids and can be sprayed through irrigation systems that work well with water. Common systems are risers and spray heads, center pivot systems and traveling guns.

Nitrate Analysis

Proper disposal of wastewater from poultry operations is becoming increasingly important. The trend of greater concentrations of poultry in smaller areas can lead to excessive application of poultry wastes. One problem of excessive application is nitrate concentration. These extremely soluble nitrates can move into the ground water. Forages removed from field that have received excessive nitrogen can become toxic. Both water and forages are analyzed for nitrates, however, laboratories report the nitrate concentrations using two different notations. One way is as nitrate-nitrogen (NO_3-N) and the other is as nitrate (NO_3). The reporting notation can make a considerable difference in interpreting nitrate concentration.

For example, the human drinking water standard for nitrate is 10 ppm nitrate-nitrogen (NO_3-N) or 45 ppm nitrate (NO_3). Even though the reported value NO_3 is 4.5 times the NO_3-N, the concentration is the same. The difference is only in the reporting notation (Table 2).

Table 2. Nitrate Ion (NO_3-)					
Element	Atomic Weight x	Number of atoms in compound	=	% by Weight	
Nitrogen (N)	14	1	14	$\frac{14}{62}$	= 22%
Oxygen (O)	16	3	48	$\frac{48}{62}$	= 78%
		Molecular Weight	= 62		100%

The nitrate ion (NO_3-) is 22 percent nitrogen by weight. The notation (NO_3-N) reports the concentration of nitrogen from the nitrate ion. The notation (NO_3) reports the concentration of the entire nitrate ion. Therefore, 45 ppm (NO_3) = 10 ppm (NO_3-N). 45 ppm NO_3 x 22 percent nitrogen = 10 ppm (NO_3-N). Incorrect use of this small difference in notation can cause one to make a 4.5 fold error. These two reporting notations are frequently interchanged. Be sure to check the notation on your laboratory reports.

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Water Quality Criteria For Recycling In Poultry Processing Plants

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Today, I will briefly summarize the FSIS requirements for maintaining the integrity of the potable water supply in federally inspected meat and poultry establishments and discuss the Agency's requirements for water reuse.

Water is a commodity that is usually taken for granted until something goes wrong either with the supply or the quality. When this happens, the consequences can be anything from frustrating, to costly, to hazardous, to life-threatening. Here are just a few examples of some situations that have occurred when potable water has become contaminated through back-flow of nonpotable solutions.

1. Eighty (80) students developed undulent fever (brucellosis). The cause was a hose submerged in water containing brucella organisms. This hose was connected to a potable water faucet. A temporary reversal of pressure, possibly the consequence of a demand for water in another part of the system, had drawn the contaminated water into the drinking supply.

2. A potable water main was contaminated by back-flow from a sewage line. 2500 people suffered enteric disorders and two died.

3. A potable water line was cross connected to a fire line using river water. Following a fire, the connecting valve was left open contaminanting the potable supply with river water. About 150 people became ill with gasteroenteritis. In an almost identical case, 700 shipyard workers developed gastroenteritis when a potable line was contaminated by river water in a fire line.

Examples could be cited in the MPI industry of instances of contamination of potable systems that have resulted in product being contaminated to such an extent that hundreds of thousands of pounds of product have had to be destroyed. Needless to say, the cost of such mistakes reaches into the millions of dollars.

In verifying the integrity of a plant's water supply, the Agency relies on the expertise of the EPA and its designees. We use the EPA's definition of potable water as stated in the National Primary Drinking water Regulations (NPDWR). When discussing Agency policy, I think that it's easier first to list all of the givens --- the obvious things that you may or may not do and then to discuss the possible. FSIS policy is that only potable water may be used on or in edible product and equipment that contacts edible product. There may be no cross connections between potable and nonpotable water systems in a plant except for a potential cross connection that is allowed for use in case of fire.

Nonpotable water may be used/reused:

1. In inedible product areas.

2. In areas not in contact with edible product areas.

The nonpotable system must be clearly identified, totally separated and checked weekly. I might add that, from our experience, plants, that have old and/or complex plumbing systems would do well to trace these lines so that they know which lines cross connect as a safeguard against potential problems. Nonpotable water may be used only for: refrigeration condensers, vapor lines for inedible product, moving sewage solids and for product to be tanked.

Over the years, the industry has asked the Agency for permission to reuse water that it considers safe in order to effect savings of: water, energy, and money and to decrease the volume of effluent from plants. When I use the term water reuse, I am including: water, ice, brine, and certain other processing solutions such as propylene glycol. So, there are certain traditional reuses of water in the meat and poultry industry that are allowed as exceptions to this policy. I want to list some of the reuses of water that the Agency has found to be acceptable. These permitted reuses of solutions are as the airlines say "subject to further restrictions." These restrictions are listed in Attachments #1 and #3.

Thus, in addition to the general policy about "only potable water on edible product and equipment that contacts edible product." The Agency has developed policies that allow the reuse of water that has passed through a closed system such as a shell in tube condenser or a heat exchanger. Other accepted reuses include various chilling media such as brine, propylene glycol, ice and poultry chill water. A final category would be water that is judged "safe" for the particular reuse(s) such as water in the first 2/3 of the hog dehairer, retort water, can cooling water and boiler blowdown water. Each of these reuses whether now being accepted nation-wide or in a few plants has been approved on an individual basis after review by an Agency group called the water reuse subcommittee. The reuses are listed in Attachment 2 with references to the restrictions in Attachments #1 and #3.

In summary then, the Agency has a basic position requiring potable water for most processing situations but has allowed certain exceptions either because of traditional industry practice or because data has shown that the reuse is safe. So, basically, this is where we are right now and for the near future.

Where might we be heading a year or so down the road? We have held preliminary discussions with EPA and they have agreed that it should be feasible to define the parameters by which to judge the safety of process water. This was a big step. Our next step will be to meet with FDA and EPA to decide what those parameters will be and what types of process water will be treated.

Additionally, we hope to issue later this year in the Federal Register, a proposed rule that would deal comprehensively with our requirements for water certification, water reuse, and just about any other water related topics on which the Agency has ever written.

ATTACHMENT 1

Conditions for Reuse: Compliance Guidelines

May include one or more of the following:

a. Design, construct, and install all equipment employed in handling the reuse material so that cleaning and inspection are simple, and cross-connection is prevented.

b. Assure that there is complete drainage and disposal of the reused material, effective cleaning of the equipment, and renewal with fresh, potable water, brine, ice or propylene glycol accomplished often enough to have an acceptable supply of material for the intended purpose.

c. Maintain effective chlorination if needed. A level of 1 ppm residual chlorine is suggested.

d. Assure the system is closed and backflow is prevented.

e. Collect the material and handle in a manner acceptable to the IIC.

f. Reuse it the same day.

g. Maintain the integrity of the water supply by continuous monitoring to assure that affected operations will cease when the water is found to be nonpotable.

h. Remove visible surface contamination defects from the product before it is placed in the cooling solution.

i. Keep the medium free of visible meat or fat particles, and other objectionable conditions, by skimming, filtering, or other suitable means.

j. Assure that brine is only used to chill heat-processed product in (a) perforated, (b) edible, or (c) semipermeable casing, up to 24 hours, and maintained at a temperature of 40° F or lower.

k. Assure that brine used to chill heat-processed product in semipermeable casing for up to one week, has a minimum nine percent salt content (32° salimeter) and is maintained at 28° F or lower.

l. Assure that brine used to chill heat-processed product in semipermeable casing for up to four weeks, has a minimum 20 percent salt content (76° salimeter) and is maintained at 10° or lower.

m. Brine used to chill raw bagged poultry must be filtered and kept clean, clear, and aesthetically acceptable to the IIC.

n. Never chill cooked product in a solution that has been used to chill raw product.

o. Trim product that has been exposed to the chill medium, and discard the trimmings.

p. If a cooling solution, including propylene glycol, is used for more than 24 hours, prepare and submit a written control program to the IIC.

ATTACHMENT 2

Water/Brine/Ice Source	Permitted Reuse: Conditions
1. Water in vapor lines leading from deodorizers (condensers) used in preparation of lard and similar edible product.	For identical use: a, b, g
2. Water in equipment used for for chilling of canned product after retorting.	For identical use: a, b, c, d
3. _Overflow water from poultry chilling units.	To move away heavy solids in eviscerating troughs (not to flush trough sides). In scald tanks, feather flow always, picker aprons; to wash picker room floors: a, b, e, f, i
4. Water from condensers or compressors.	As potable water: a, b, d, e, g
5. In equipment used for producing flaked ice, water resulting from melted ice that collects in a space below the ice storage compartment.	To prechill water circulated in closed coils: a, b, d, e
6. Ice carried out of a poultry chiller with product, or ice used to chill turkey carcasses.	Return to chilling system; may not be used for further processing. Flush sides of eviscerator trough: a, e, f, n
7. Water from hog dehairer.	For identical use, in large installations only, except for use in the last 6 feet of dehairer, which must have potable water: a, b, d, e
8. Brine for chilling product.	May be reused as described in an approved program: a, b, c, d, h, i, j, k, l, m, n, o, p
9. Ice for Cut-up Poultry	For identical use: a, e, f, n
10. From heating or cooling transfer agent and having no contact with product or product surfaces, e.g., water from: jackets of coolers; cooling tanks; condensers; pumps; heat-exchangers; connecting pipes. Canning retort or boiler blow down water. Water treatment facility effluent that qualifies as safe for discharge into a Class A stream and has 0.5 ppm residual chlorine at point of use.	To clean livestock pens. Lines lines must be clearly identified, and cannot be cross-connected to potable water supply: a, d, e
11. Propylene glycol for chilling product.	May be reused as described in an approved program: a, b, d, e, h, i, n, o

ATTACHMENT 3
MPI BULLETIN 83-16
3-3-83

UNITED STATES DEPARTMENT OF AGRICULTURE
Food Safety and Inspection Service
Meat and Poultry Inspection Operations
Washington, DC 20250

ACTION BY: Inspectors in Charge

INFORMATION FOR: Regional Directors, Area and Circuit Supervisory Personnel, Plant Management, and Interested Parties

Reuse of Water or Brine Cooling Solutions on Product Following a Heat Treatment

This bulletin replaces MPI Bulletin 79-111 and restates current product chilling methods with special attention to reuse policy for solutions used to cool processed products following a heat treatment. The policy does not apply to the poultry chilling requirements in sections 381.65 and 381.66 of the Meat and Poultry Inspection Regulations. Rather, it supplements the information in section 18.20(e)(6) of the Meat and Poultry Inspection Manual.

Regarding this policy, a USDA inspector will evaluate a plant's product handling practices and processing procedures to assure that they are sanitary and that contamination or adulteration of the product will not occur.

PRODUCT CHILLING

Traditional Methods

Products may be chilled under a water spray, without special restrictions, when the runoff goes directly to the drain.

Products may be chilled in tanks and tubs when the solution is emptied after each batch

Continuous Cooling/Reuse of Solution

The advent of continuous cooling equipment introduced the concept of reuse of cooling solutions and created the possibility that the solution might become contaminated and adulterate the product. Therefore, in addition to the standard sanitary operating practices, the following safeguards must be observed:

1. Visible contamination defects must be removed from the product before it is placed in the cooling solution.

2. The solution must be kept free of visible meat and fat particles and other objectionable conditions. (Protection of the solution can be accomplished by effective filtration, skimming, or overflow).

Note: If management has not assured that these safeguards (#1 and 2 above) have been observed and that the solution is free from contamination, an inspector may require disposal and replacement of the cooling solution. Repeated violations may necessitate disposal of cooling solution on a scheduled basis as determined by the inspector. In the absence of dependable safeguards, the inspection may not permit reuse of the cooling solution.

3. When a cooling medium is used for one shift or longer, the solution must be discarded at the following specified intervals, and all equipment, tanks, lines, etc. must be thoroughly cleaned and sanitized.

	Cooling Solution	Duration of Use	Heat-Treated Product (Classes)	Additional Conditions*
A.	Water or brine	One production shift	All classes: No casing Perforated casing Edible casing Semipermeable casing	None
B.	Brine	Up to 24 hrs.	All classes: No casing Perforated casing Edible casing Semipermeable casing	1. Minimum salt 5% (19^o salimeter) 2. Maintain 40^o F. or lower
C.	Brine	Up to 1 week	One class: Semipermeable casing	1. Minimum salt 9% (32^o salimeter) 2. Maintain 28^o F. or lower
D.	Brine	Up to 4 weeks	One class: Semipermeable casing	1. Minimum salt 20% (76^o salimeter) 2. Maintain 10^o F. or lower

*Chlorination of these solutions to a residual of 1 ppm is recommended

4. Cooked product, for example, frankfurters, should never be chilled in a solution that has been used to chill raw product, for example, bacon bellies. (Raw product may be chilled after cooked product).

5. Products, in categories C and D, that have broken casings or that have been similarly exposed must be trimmed. The trimmings must be discarded.

6. If a cooling solution is to be used for more than 24 hours, a control program must be submitted to the inspector in charge (IIC). The IIC will add comments and forward the proposal through channels to the Sanitation Group, FESD, MPITS, Room 1140 South Building, Washington, DC 20250.

Deputy Administrator
Meat and Poultry Inspection Operations

TREATMENT OF CHILLER WATER FOR RECYCLING

Dr. Brian W. Sheldon and Dr. Roy E. Carawan[1]

In 1986, approximately 5 billion broilers and turkeys were processed in the United States in Federally inspected poultry processing plants. The poultry industry in the US withdraws an estimated 4 to 15 gallons of fresh water for processing each broiler carcass. This equates to a water consumption rate of 20 to 75 billion gallons of water per year. A major need exists to decrease the quantity of water used due to rising water costs, difficulties in obtaining large volumes of water, highly variable water supplies, and problems of wastewater treatment and disposal. Additional incentives for examining the issue of water conservation and recycling in the poultry industry have been provided by the USDA in the form of an amendment to the Federal Poultry Products Inspection Act. As stated in the Federal Register, this ruling allows for the recycling of chiller water.

Under this legislation, fresh water used in chillers can be reduced, provided the remaining intake is supplemented by reconditioned chiller water of such quality and such volume to assure that the bacterial load on the carcasses exiting the system will not be greater than under the current intake requirements. The type of water reconditioning is not specified. The ruling requires that the reconditioning treatment attain a minimum of at least 60% reduction of total microorganisms including coliforms, E. coli, and Salmonella spp., and the maintenance of light transmission at 500nm of no less than 60% of fresh water (Table 1). The minimum recycle rate is 1.75 gallons of recycled water to replace 1.0 gallon of fresh water. This rate decreases to a ratio of 1.10 gallons of reconditioned water:1.0 gallon of fresh water as the quality of the reconditioned water improves. Implementation of this regulation would help conserve fresh water and energy without resulting in increased costs or

Table 1. USDA criteria for recycling chiller water

Minimum percent reduction of micro-organisms in treated water[1]	Minimum percent light transmission in treated water (500nm)	Gallons of reconditioned water to replace 1 gallon of fresh water
60	60	1.75
70	70	1.50
80	80	1.35
90	80	1.25
98	80	1.10

[1]Total micro-organisms, coliforms, E. coli, Salmonella.

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threatening the wholesomeness of the product. Furthermore, this rule would reduce the burden on private and municipal wastewater treatment facilities, while maintaining sanitary conditions that are at least as effective as those provided under current practices.

Studies were conducted to identify effective and economical water treatments including disinfection processes that fulfill the U.S. Department of Agriculture's criteria for recycling broiler overflow prechiller water. Moreover, other process waters including neck chiller water and whole bird rinse waters were treated similarly to explore the feasibility of reconditioning these other process waters. Reconditioned chiller waters meeting the USDA criteria were used to chill hot broiler carcasses. The quality of the chilled carcasses was subsequently evaluated.

Several water treatments were tested on broiler prechiller overflow water including direct ozonation, a combination of screening, ozonation and rapid sand filtration, a combination of screening, diatomaceous earth (DE) filtration and either ozonation or UV irradiation, and a combination of screening and DE filtration using either a 3.14 in^2 (Walton filter) or 1.0 ft^2 vertical tank pressure leaf filter. The quality of the overflow prechiller water was significantly improved with all treatments examined, surpassing the USDA recycling requirements in nearly all trials. Most methods improved the water quality beyond what would be needed to recycle at the 1.1 gallons of reconditioned water to replace 1.0 gallon of fresh water recycle rate.

Ozonation alone significantly improved the quality of the chiller water which met all requirements for recycling within 10 minutes of treatment. Ten minutes of ozonation reduced the COD by 48 percent, total solids (TS) by 19 percent and fats/oil/grease (FOG) by 76 percent. Bacterial reductions of 3.43 logs or 99.96 percent for the aerobic microflora were seen after 10 minutes of ozonation in addition to the complete elimination of coliforms and E. coli. Continued ozonation beyond 10 minutes resulted in further improvements in water quality such that after 50 minutes, reductions of 62%, 33% and 90%, respectively, were achieved for COD, TS and FOG. The clarity of the ozonated water after 50 minutes of treatment was almost indistinguishable from tap water.

Both filtration treatments, sand (with ozonation) and DE, improved the water quality beyond federal recycling requirements. By far, the method employing screening, DE filtration through a Hayward Perflex filter and ozonation rated superior to the other treatments. Five minutes of filtration followed by 15 minutes of ozonation in a sparge bubble column resulted in an average percent transmission (500nm) of 97. This method also reduced COD by 87 percent, TS by 65 percent and FOG by 94 percent. Total microbial loads were reduced by more than 3 decimal reductions (99.9%) with no detectable coliforms or Salmonella isolated following disinfection. The findings of this study substantiate those of Lillard (1978) who found similar reductions in the organic loads of chiller water after passage through a vertical tank pressure leaf DE filter and postchlorination.

Passage of overflow prechiller water through a screen and DE pressure leaf filter (3.14 in^2, Walton filter) resulted in significant reductions in COD and aerobic bacterial counts (ABC) of 70.9 percent and 90-96 percent, respectively. Light transmission or clarity of the filtered water improved dramatically reaching a high of 97.9 percent. This treated water would qualify for recycling at a rate of 1.25 gallons of reconditioned water for every gallon of fresh water. Similar findings were obtained with several grades of DE using the one square foot vertical tank pressure leaf filter. Significant reductions in COD, ABC, coliforms and E. coli of 60.6, 95.8, 98.4 and 90.5 percent respectively, were obtained after treatment. Light transmission averaged 95.6 percent following the reconditioning treatment. Further microbial reductions ranging from 3.54 decimals to 4.24 decimals (99.97-99.99%) were achieved by adding a post-filtration disinfection step using UV irradiation.

The second phase of our experiments were conducted at a local broiler processing facility using the water treatment scheme consisting of screening and DE filtration through the 1.0 square foot vertical tank pressure leaf filter. The primary objective of these studies was to determine the effective filter run cycle time required for estimating the size of the pressure leaf filter that would be needed under actual commercial operations. Under the following filtration conditions: flow rate - 0.75 gallons per minute, DE precoat - 90 grams, body feed:suspended solids ratio (wt:wt) - 5:1, a projected filter run time of 5.6 hours is feasible before recharging is necessary. The quality of the filtered water remained consistently high throughout the 3.5 hour filter runs and surpassed the USDA recycling requirements in all trials. The average percent light transmission following treatment was 96.4 and ranged from 94.7 to 97.4 percent. Moreover, COD values were reduced on the average of 54.5 percent while the microbial loads were reduced on the average of 97.46 percent (1.59 decimal reduction).

In addition to treating whole carcass overflow prechiller water, the efficacy of screening, DE filtration (Perflex DE filter) and ozonation on reconditioning whole bird rinse and neck chiller waters was explored. The quality of these two process waters was significantly improved by passage through this water treatment. Both treated waters satisfied the USDA chiller water recycling requirements not to mention the potential for significant reductions in wastewater pollutants discharged to wastewater treatment facilities. This study thus provided evidence that would support the recycling of other poultry process waters not currently allowed by the USDA.

No significant carcass quality differences were detected between carcasses chilled in tap water and ice and those chilled in recycled chiller water and ice (1.1:1.0 recycle rate) with regard to skin color, meat flavor, shelf life or presence of coliforms or Salmonella.

Results of this study show that effective water treatments do exist for reducing effluent waste loads at their sources and that fresh water demands can be reduced in poultry chillers.

Potential Economic Impact

Current USDA regulations require that a half gallon of water be used to chill each broiler carcass. If a plant processes 200,000 broilers per day, then it uses at least 100,000 gallons of water daily to chill carcasses. If 85 percent of the overflow prechiller water could be reconditioned, then the plant would save 85,000 gallons of water per day or 21.2 million gallons per year. At $1.90/1000 gallons of water, a plant of this capacity could save over $40,000 per year in water and sewer service charges. Effluent discharge loads could also be reduced by approximately 154,000 pounds of COD and 70,000 pounds of TS each year. The BOD and suspended solids surcharge savings could be almost $25,000 per year. Furthermore, energy savings in refrigeration costs resulting from recycling reconditioned chiller water would approach $25,000 per year in addition to netting $600 per year by the sale of recovered solids to renderers. A total potential annual savings of nearly $91,000 is estimated by implementing the water reconditioning scheme presented in this paper. Costs for purchasing and operating these systems are presently being determined.

Water Conservation in Poultry Processing

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Water has been used in poultry processing as a medium of great convenience for transport, heat transfer and sanitation. The cost of this convenient medium has, however, increased more rapidly than any other cost in poultry processing. In the past twenty-five years labor rates have increased three to four times, fuel costs four to five times, and water and sewage treatment costs five to ten times. Broiler prices have about doubled during this same period. There is little a processor can do to prevent these increases; however, costs can be reduced by using less water.

To conduct a successful water conservation program there should be:

1. Commitment by management
2. Knowledge of water use by the plant
3. Continued management emphasis

Commitment by Management

The key to reduction in water use is <u>commitment by management</u>. Unless there is this commitment, little will be done to reduce water use. Does a commitment to water conservation make economic sense for your plant? In some cases, additional water conservation efforts may produce little return but in others water conservation may reduce costs more than any other single item.

Table 1. Comparison of Water and Sewage Costs

Cost of Water Sewage (1000 gallons)	Gallons per Bird			
	3.5	5.5	7.5	9.5
$1.00	0.35¢/bird	0.55	0.75	0.95
$2.00	0.70	1.10	1.50	1.90
$4.00	1.40	2.20	3.00	3.80

Table 1 shows the water and sewage cost per bird at various water and sewage rates and water uses. If a processor is using 9.5 gallons per bird in a high water and sewage rate area, water conservation can probably reduce costs more than any other cost-cutting activity. A plant using 3.5 gallons per bird has already committed the resources to water conservation and needs only to monitor and fine-tune the system.

There is always concern that reduction in water use will increase waste strength and that increased waste treatment cost will offset savings from water conservation. Literature reports and field observations indicate that the opposite seems to be true. When attention is given to water conservation, attention will also be given to waste loading. Carawan _et al_. (1974) studied the water use and waste loading of a broiler processing plant. Their initial study showed a water use of 12.9 gallons per bird and 0.06 pound of Biochemical Oxygen Demand (BOD_5) per bird. After conservation measures were instituted water use was reduced to 8.7 gallons per bird and BOD_5 was reduced to 0.02 pound per bird. Field observations have shown processors using 7 gallons per bird discharging waste loads of 0.07 pound of BOD_5 per bird whereas those using 3.5 gallons per bird load their wastestream with 0.03 pound of BOD_5 per bird.

If management commits itself to water conservation it must be a long-term and continuous commitment. Water use must be given high priority in processing efficiency evaluation. Management must be willing to commit resources, both time and capital, to water conservation.

Know Your Plant

Although poultry processing is generally the same, wide differences occur in plant-to-plant operations. To be effective in water conservation it is necessary to know your plant. Know where your water is being used and why.

Conduct a Twenty-Four-Hour Water Use Study

A starting point in water conservation is to read water meters at the end of each shift to determine the water use during processing, cleanup, and downtime. Most processors do this. To gain more information on water use, read the water meters hourly on one day per month to determine water use patterns. Additional sophistication can be added by continually measuring the volumes discharged by the plant. There are many types of devices from simple flow height recorders to sophisticated flow recording devices that are tied to computers.

Figure 1 illustrates the variation in water flow from a processing plant during one shift. Some of the events that were identified as causing the changes in the graph are:

1. Shift change (8:30 am)

2. Sump clogged with feathers and pumped out (9:50 am - 10:30 am)

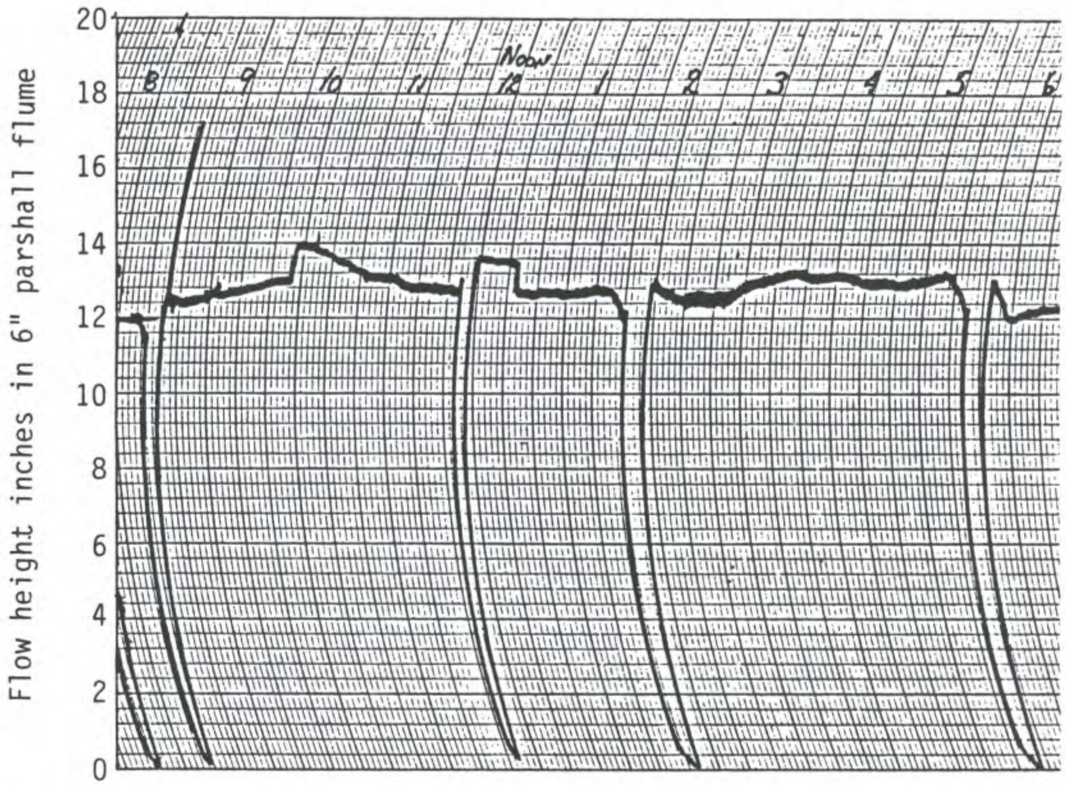
3. Break (11:50 am - 12:00 noon)

4. 1-1/2 inch water line left on (12:00 noon - 12:25 pm)

5. Lunch Break (1:30 pm - 2:00 pm)

6. End of Processing (5:30 pm)

Figure 1. **Water Flow from a Broiler Processing Plant**



As these data are collected, average water use and normal variations in water use can be calculated. Reduction in water use can be determined and variations in normal water use patterns can be explored and corrected.

Can you afford it? These are management decisions based on the situation of your plant. The 1-1/2 inch pipe left on from 12:00 - 12:25 pm cost the company $6.25 or $15 per hour, the wages of two workers. Using a continuous monitoring system, operational errors in water use can be determined and corrected.

In-Plant Water Use Study

Determine water use in the plant by various processes within the plant. Concentrate on:

1. Goosenecks

2. Bird Washers

3. Giblet Harvesting

4. Wasted Water

Goosenecks. Carawan et al. (1974) reported that hands could be properly washed at goosenecks using a nozzle that delivered 0.6 gallons per minute (gpm) at 8 psi. It is not uncommon to see unrestricted 1/2 inch goosenecks flowing at 3-4 gpm. Table 2 shows the annual cost of goosenecks at various flow rates and water costs.

Table 2. Annual Cost of Gooseneck Water Flow

	Cost/1,000 gallons		
GPM	$1.00	$2.00	$3.00
0.5	$ 62*	125	250
1.0	125	250	375
2.0	250	500	750
3.0	375	750	1,125

* 8 hrs./day, 260 days/yr.

If 20 goosenecks are flowing at 3 gpm and water costs $2.00/1,000 gallons, you could hire a person just to keep these goosenecks adjusted to 0.6 gpm and break even.

Bird Washers. Place water meters on your bird washers. Determine the spray pattern and pressure that will maintain a sanitary product with the least amount of water. Holes drilled into pipes, shower heads, etc., waste water. Replace them with efficient nozzles.

Giblet Harvesting. Giblet harvesting uses a significant amount of water, especially in the gizzard, heart and liver pumps. Carawan et al. (1974) reported giblet harvesting to consume 360 gpm. In two plants that I have studied, giblet harvesting accounted for about 20 percent of the water used during processing. With the amount of water consumed and labor required, giblet harvesting may not be profitable, especially if you are bulk packing giblets.

Wasted Water. Install quick cut-off valves so workers can easily shut off the water when not needed or while on break. Have supervisors make sure they do.

Evisceration workers at one processing plant could not turn off water easily so it was allowed to run during breaks, lunch and shift changes. The loss of 35,000 gallons per shift cost this processing plant $32,000 per year.

Small leaks are constant and the costs mount up over a year. One quart per minute at $2.00/1,000 gallons costs $263 per year, roughly a week's wages for one worker. Table 3 may give an idea of the number of mini-vacations you are giving away every year.

Table 3. Cost of Processing Plant Leaks in Man-Year Equivalents

Water & Sewage per 1,000 gallons	Man-Years at 10 gpm	25 gpm	50 gpm
$2.00	0.78	1.94	3.85
$2.50	0.97	2.43	4.86
$3.00	1.16	2.92	5.83

* 2,080 hrs. at $6.50/hr.

Water Reuse. Recycling water to flow away feathers is a common practice in poultry processing; however, there are other opportunities for water reuse. Work with your FSIS inspector on possible sources of water reuse.

1. Compressor cooling water is clean water. Could it be used for washing coops, cages, trucks, live haul areas, hanging, etc.? If water use from evisceration is reduced to the point that offal will not flow, could this water be used to assist offal flow?

2. Use lagoon water that meets discharge standards to wash outside areas.

3. Water from vent cutters, vent pullers and eviscerators can be introduced into the flume at a point where it can assist offal flow. This water is fairly clean water. Can it be taken directly to the city or into the final lagoon? Why pay the cost of treating clean water?

Mechanical Offal Removal. In an effort to reduce water use and pollution loads various mechanical offal removal systems have been tried. Vacuum systems and belts were commonly used. Whitehead et al. (1976) reported that a vacuum offal removal system reduced water use by 23 percent and BOD_5 load by 28 percent. In the mid-70s these systems were installed but abandoned due to operational difficulties. Some are still in operation to move feet and heads. Belts were also used to remove offal but were never sufficiently successful to enjoy widespread use.

An interesting new development is a positive displacement ram-type pump. The offal falls into a hopper where a ram piston pushes it through a pipe. This seems to be less complicated than vacuum systems and is being used to move DAF sludge and offal. The reliability of this system and its ability to reduce water requirements and pollution loads have not been thoroughly tested.

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THERMAL ENHANCEMENT OF DAF SLUDGE DEWATERING PROPERTIES

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Dissolved air flotation (DAF) systems are used extensively in the poultry processing industry for the primary treatment of plant wastewater. These systems inject air under pressure into the wastewater which then flows into a flotation cell. In some systems, chemicals to enhance flocculation are also added to the wastewater. In the flotation cell, suspended solids, fats, oil, grease, and other materials float to the top where these materials (DAF sludge or skimmings) are skimmed off. This sludge is typically loaded onto a tanker truck for shipment to a rendering plant for processing with the offal, blood, and feathers. The treated water leaving the DAF unit has significantly reduced levels of pollutants and can be discharged to a municipal sewer system often without any additional surcharges.

Processing the DAF sludge is a problem for the rendering plant. Sludge is initially about 90% water while offal is about 65% water. To yield the same amount of product (dry material) about 5 times as much water must be evaporated (or 5 times the energy input) from sludge as compared to water. One rendering plant in the southeast receives more than 1 million pounds of sludge per week from the 12 processing plants it services. Due to its watery consistency, the sludge must be transported in a separate tanker truck. The cost of transporting material that is primarily composed of water is clearly uneconomical.

Because the sludge can become rancid quickly, rendering plants which produce products such as pet food cannot use the material. The rancidity problem is further complicated in that tanker trucks often remain at the processing plant for several days waiting to be filled or at the rendering plant to allow for gravity dewatering of the material. Thus the material can be very rancid at the time it is rendered.

Some rendering plants have recently imposed additional charges on the processing plants for transportation and processing of DAF sludge. In some cases the rendering plant has refused to accept any sludge from the processor. Thus the processor is being forced to pay these charges, dewater the sludge, or find another disposal method.

Current dewatering techniques include gravity, thermal evaporation , or mechanical equipment. Gravity dewatering can produce a rancid sludge which is not acceptable for reasons discussed above. Thermal and mechanical equipment such as evaporators, pre-coat vacuum filters, centrifuges, and belt presses have high capital and operating costs. An economical system for dewatering of the DAF sludge is urgently needed by the poultry industry.

A laboratory test program initiated by Georgia Tech in 1984 included a preliminary comparison of conventional dewatering technologies. The conventional technologies studied included gravity separation, vacuum filtration and centrifuging. The gravity separation tests revealed that heating the sludge increased the rate of solid/liquid separation. In all cases the sludge layer was on the top and the liquid layer on the bottom. The sludge in a beaker maintained at room temperature (23^{oC}) showed no separation after two hours while the heated sludge showed significant separation after the same period. The room temperature beaker essentially simulated the dewatering which would have occurred in the tanker at the processing plant. After several trials it was concluded that thermally enhanced gravity separation is a viable dewatering option for DAF sludge that could possibly be implemented in the near future.

Based on the successful results of the laboratory tests, a program was initiated to develop a full-scale thermally enhanced sludge dewatering system. The program involved beaker tests, bench scale tank tests, and pilot scale batch tests. A summary of the test program is as follows:

Beaker Tests - A series of tests using laboratory beakers was conducted to establish the operational parameters of a thermal dewatering system. The tests investigated factors such as temperature, heating method, and heating tank size and compared the results to room temperature gravity dewatering.

Vertical Tank Tests - To determine the effect of sludge depth, a tank 2 1/2 feet deep with a 6 by 6 inch base was fabricated. The front and back of the tank were made from glass so that the interface level between the liquid and cake could be observed. The tank was placed in a constant temperature bath with the base immersed in 1 inch of water and hot water for the side-wall heat exchangers was pumped from the bath.

Horizontal Tank Tests - The vertical tank tests were successful and it was concluded that a sludge depth of 2 feet could be heated and dewatered; however, the vertical tank wall spacing was only 6 inches. A full scale system would require walls considerably further apart. A series of tests using a horizontal tank were designed to determine if wider separation between walls could be achieved. A horizontal tank was fabricated that was 2 feet long, 1 foot wide and 1 foot deep. The tank was operated with one wall heated and the second wall unheated. The tank simulated a system where the heated walls were separated by 30 inches.

Pilot-Scale Tests - A batch operation pilot scale unit for operation at a processing plant was built and tested. The unit is a rectangular tank 8 feet long, 4 feet wide, and 2 1/2 feet deep. The unit is one-tenth scale and designed to dewater approximately 500 gallons of sludge in a 5 hour period.

The unit was operated in a batch mode where the sludge will be loaded, dewatered, the liquid drained first, and then the sludge removed to a tanker. The tank is heated using immersion plate type heat exchangers.

A large 8 foot by 4 foot heat exchanger is located in the bottom of the tank. Two 8 foot by 2 foot heat exchangers are used for side wall heating. The side wall heaters can be moved to vary the side wall heating distance during a test. The top, bottom, and sides of the tank will be insulated to reduce heat loss. A liquid propane hot water heater was used to provide the hot water supply for the heat exchangers. The heater has an input capacity of 125,000 Btu per hour.

A total of 29 thermal sludge dewatering tests have been conducted to date and the pilot-scale unit has been used for 11 of these tests. The test program verified that the concept of thermally enhanced dewatering could be scaled-up from beaker to pilot plant and established the parameters required for a full-scale system. The test program verified that the pilot-scale system was capable of removing 50% or more of the water and reducing the moisture content of the cake to less than 80% in all but two tests. These two unsuccessful tests were conducted with some heat exchangers disconnected and verified that both bottom and side wall heat exchangers were required. In addition, the maximum energy required for operation of the unit was approximately 125 Btu per pound of water removed or about 1/10 of the energy required for evaporation.

Removal of 55% of the water from sludge that has an initial moisture content of 90% results in a cake that has a moisture of approximately 80%. An 80% moisture content will meet the proposed moisture content of one rendering company required to avoid surcharges.

The major findings of the testing program are as follows:

<u>Comparison of Pilot- and Laboratory-Scale Units</u> - The pilot plant results compared favorably with the beaker tests while the vertical and horizontal tanks produced less dewatering. It was concluded that this difference was due to the more efficient heat transfer of the pilot plant and beakers.

<u>Mass Balances</u> - Mass balances were conducted for the beaker, vertical tank, horizontal tank, and pilot plant tests. 90% of the total solids and COD present in the initial sludge remained in the cake for all of the tests.

The liquid from the dewatering unit is still a potent waste stream. This liquid could be recycled through the DAF and retreated. It could be discharged with the treated effluent from the DAF. Since the mass is only about 5% of the total plant discharge, the affect on the pollutant levels of the plant discharge would be only minor.

<u>Rancidity</u> - As discussed in a previous section, the sludge is processed by the rendering plant into animal food, and therefore the rancidity of the sludge is a major concern. Samples of the cake from the pilot scale tests were analyzed to determine if the process would cause any significant increase in rancidity. The data indicates that the process does not degrade the quality of the product.

Temperature Effects - Increasing the temperature results in an increase in the percent of water removed from the sludge and consequently a decrease in the cake moisture content.

Day to Day Variation - Other studies have shown that sludge characteristics vary from day to day depending on factors such as chemical addition and operator attention. The performance of the TED system is subject to these same variations in sludge.

Plant to Plant Variation - Just as sludge will vary from day to day at the same plant, it will vary from plant to plant depending on the type of DAF and other factors such as chemical addition and operator attention. The pilot plant performed better at the first of the two plants at which it was tested.

Heat Exchanger Surface Area Effects - An analysis was made of the effect of heat exchanger surface area on the percent of water removed from the sludge. The data indicates that an increase in the ratio of surface area to volume increases the percent of water removed from the sludge. The linear regression for the laboratory tests shows good correlation but the pilot plant only shows a trend. However, there are insufficient data points to verify correlation.

Temperature Variation - In order to measure the temperature variation with depth, a vertical thermocouple probe was placed in the sludge during the vertical tank tests. The data indicates that the sludge/cake does not exceed 90°F. However, once the liquid rises above the thermocouple, the liquid temperature rises rapidly to within 10 to 20°F of the heating temperature.

High temperatures tend to accelerate rancidity, and, since the cake remained at a relatively low temperature, it was thought that the process would not adversely affect the rancidity of the sludge. This supposition was later verified during pilot scale tests as previously discussed.

Additionally, since the liquid temperature tended to rise as the interface passed, it was thought that temperature might be used as an automatic control for a full scale system. A thermocouple probe with sensors located every inch was fabricated for the pilot plant. The results are similar to the vertical tank tests.

Semi-Continuous Test - A semi-continuous test was conducted to investigate the feasibility of operating the unit as a continuous system. During the test liquid was drained from the system at a rate of 60 gallons per hour. The energy required for the test was approximately 125 Btu per pound of water removed.

The test program has shown that thermally enhanced dewatering of DAF sludge is a viable concept. Testing conducted to date have also established the parameters need to design a full-scale batch operating system and a pilot-scale continuously operating system. Modifications of the pilot plant for continuous operation are currently underway and the test program should be completed within 2 months.

Implementation of Pollution Control Regulations That Affect the Poultry Processing Industry in Georgia

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The purpose of this paper is to discuss the environmental regulations that affect poultry processors in Georgia and how the Georgia Environmental Protection Division (EPD) administers these regulations. The waste characteristics and handling techniques are similar enough for both processing plants and further processing such as cooking, canning, and deboning operations that the regulatory requirements are the same. The sources of these requirements are the Georgia Water Quality Control Act and the Federal Clean Water Act.

It is well known that poultry processing produces a significant amount of wastewater and that the characteristics of concern are biochemical oxygen demand (known as BOD_5), oil and grease and probably of the most concern organic nitrogen and ammonia nitrogen together referred to as TKN which are derived from the chicken proteins.

A poultry plant has three options for wastewater disposal. The first is to discharge directly to a publicly owned treatment facility. In this case, the city sewer authority usually regulates the industry through a pretreatment permit for the facility or charges the company by both flow and concentration based on a schedule attached to the sewer ordinance.

The cities of Gainesville and Athens in Northeast Georgia both have large industrial poultry processing contributions. In general, the industries have pretreatment on-site in the form of screens, dissolved air flotation units, oil skimmers or grease traps. This is beneficial in that it reduces the cost of sewage disposal and most of the waste by-products can be sold to a rendering plant for a profit. The Georgia Environmental Protection Division in turn regulates the city which must meet either a NPDES permit for discharge to a stream or a LAS permit for final disposal by spray irrigation.

If a POTW is not available, the industry will submit a proposal to the Georgia Environmental Protection Division in Atlanta. The next two disposal options to consider are wastewater treatment followed by land application by slow rate spray irrigation or, when that is not feasible, followed by a direct discharge to a receiving stream.

The design approval and permitting process for land application is outlined in the Division's Criteria for Slow Rate Land Treatment, which are distributed free of charge. This booklet provides guidelines to be used in the design of a land application system. Many of these guidelines, such as buffer zone and storage requirements, aid in preventing nuisance problems as well as addressing environmental concerns.

When applying for a LAS permit, the company first submits a letter of intent to the Division. A Site Selection and Evaluation Report is then submitted along with a request for general site concurrence. A site inspection is made by an EPD engineer and site concurrence of denial is issued. If the site appears acceptable, a Design Development Report must be prepared by the company's engineer. This report is the basis for the facility design. It gives a site description including location, climate, geology, topography, buffer zones and soil testing results, followed by a scaled drawing with two-foot elevation contours showing the site layout including preapplication treatment as well as the wastewater characteristics and flows. A water balance and nitrogen balance are incorporated to determine acceptable loading rates and to determine storage requirements. This is a detailed engineering report which must be approved prior to construction.

After all comments are resolved, a Land Application System permit application is submitted. Once the permit is drafted by the Environmental Protection Division, it must go to public notice for 30 days prior to issuance. The company must also submit a detailed plan of operation and maintenance for the system which becomes part of the permit when it is approved.

LAS permit requirements emphasize:

1. Groundwater monitoring for NO_3, pH, conductivity and COD.

2. Monitoring flow and characteristics of irrigated wastewater to insure compliance with the design criteria.

3. Restrictions to insure runoff and overflow control.

Reports are submitted quarterly to EPD for review. Periodic inspections are made by Division personnel to insure compliance and that the treatment units are operating properly.

Experience shows that the biggest concern for LAS systems is the nitrogen and the possibility for nitrate contamination in the groundwater. Most fields are planted with Coastal Bermuda overseeded with winter rye to get maximum nitrogen uptake. When the monitoring results show elevated nitrates, the Division asks the company to do an engineering study to determine how to correct it.

Another factor is that the poultry industry is so successful in Georgia that major expansions resulting in a need to expand the wastewater treatment system are not uncommon. In fact, most of the nine poultry-related permitted LAS systems in Georgia used to have direct discharges to streams and rivers. Through both computer modeling and sampling of streams, EPD has found that water quality violations for dissolved oxygen could be expected if wastewater discharge loadings were increased as a result of increased production. EPD also found that the nitrification of NH_3-N to NO_3-N in the receiving stream uses approximately three times as much dissolved oxygen as the assimilation of BOD_5 for treated poultry wastewater.

NPDES permits are reissued every five years and when NH_3 limits which will protect water quality were put into the permits, it became apparent that most of the poultry industries in Georgia had outgrown their receiving streams. In fact, at this time there are only four poultry plants with NPDES permits to discharge directly to a river or stream.

The permitting process for direct dischargers is similar to that for LAS systems. The company submits two application forms to EPD. These are General Information Form 1 and NPDEs Form 2C. If a NPDES permit is appropriate, it will be issued within 60-90 days of the receipt of a complete application. Once the draft permit is provided to the company, it must go to public notice for 30 days prior to final issuance by the Director.

The NPDES permits require the submittal of monthly operation monitoring reports. In general, these require monitoring of the treated wastewater three times per week for flow, BOD_5, dissolved oxygen, pH, ammonia, and oil and grease. The Federal government has never promulgated effluent limitations for the poultry processing industry. Therefore, the limitations are based on the stricter of Best Professional Judgment and water quality standards.

Annual compliance inspections are made by a Division engineer or specialist. During the inspection wastewater samples are split. The Division's Water Quality Laboratory and the company's private or commercial laboratory each test for the permitted parameters. The results are then compared as quality control.

The majority of the permitted poultry plants in Georgia are currently in compliance with either their LAS or NPDES permits. The industry has been growing very successfully but has also spent considerable amounts of money to provide the necessary wastewater treatment and disposal to accompany these expansions. The issues of ammonia toxicity and whole effluent toxicity as determined by biomonitoring results are also being used more in the development of permit limitations.

The inherent value of the wastewater as a fertilizer in the rural locations of most of Georgia's land application sites combined with the ability this industry has for finding ways to more efficiently recycle water and to profit through the rendering of waste materials will enable Georgia's poultry processing industry to continue to successfully comply with both Georgia's Water Quality Control Act and all applicable Federal regulations.

POLLUTION CONTROL REGULATIONS AFFECTING POULTRY PROCESSING - ARKANSAS

By Doug Hamilton, Michael Core and Donna Parks

INTRODUCTION

Arkansas is one of the nation's leading poultry states. Over 830 million broilers, hens and turkeys are raised on Arkansas farms each year, as compared to a resident human population of 2.5 million. Seventeen percent of America's broilers, 9% of the turkeys and 5% of all eggs are produced in Arkansas; as a result, poultry production is a large industry, directly or indirectly employing 60,000 Arkansans.

POULTRY WASTEWATER

The poultry industry is located primarily in the western half of the state, as shown in Figure 1 (page 2). Table 1 below lists types of discharge permits issued for the approximately 60 poultry processing plants in Arkansas.

Table 1. Types of Wastewater Permits For Poultry Processing Plants

NPDES Discharge Permit	10
State Land Application Permit	4
Pretreatment and/or Discharge to POTW	33
Unknown or Unpermitted	13

Discharge limits for federal NPDES permits are determined using stream modeling and proposed guidelines based on production. Results of wasteload allocation studies (WLA) are compared to limits calculated from the EPA's Poultry Effluent Limitation Development Document (3) and the more stringent limits are used. A typical poultry processing plant discharging into a small stream will usually have discharge limits: 10 mg/l $CBOD_5$, 15 mg/l TSS, plus ammonia limitations. On larger streams, such as the Arkansas River, limits are commonly 30 mg/l BOD_5, 30 mg/l TSS.

The most common treatment arrangement consists of Dissolved Air Flotation (DAF) followed by some form of Activated Sludge (AS) process such as an oxidation ditch or extended aeration. Some plants have anaerobic lagoons in front of the aerobic process.

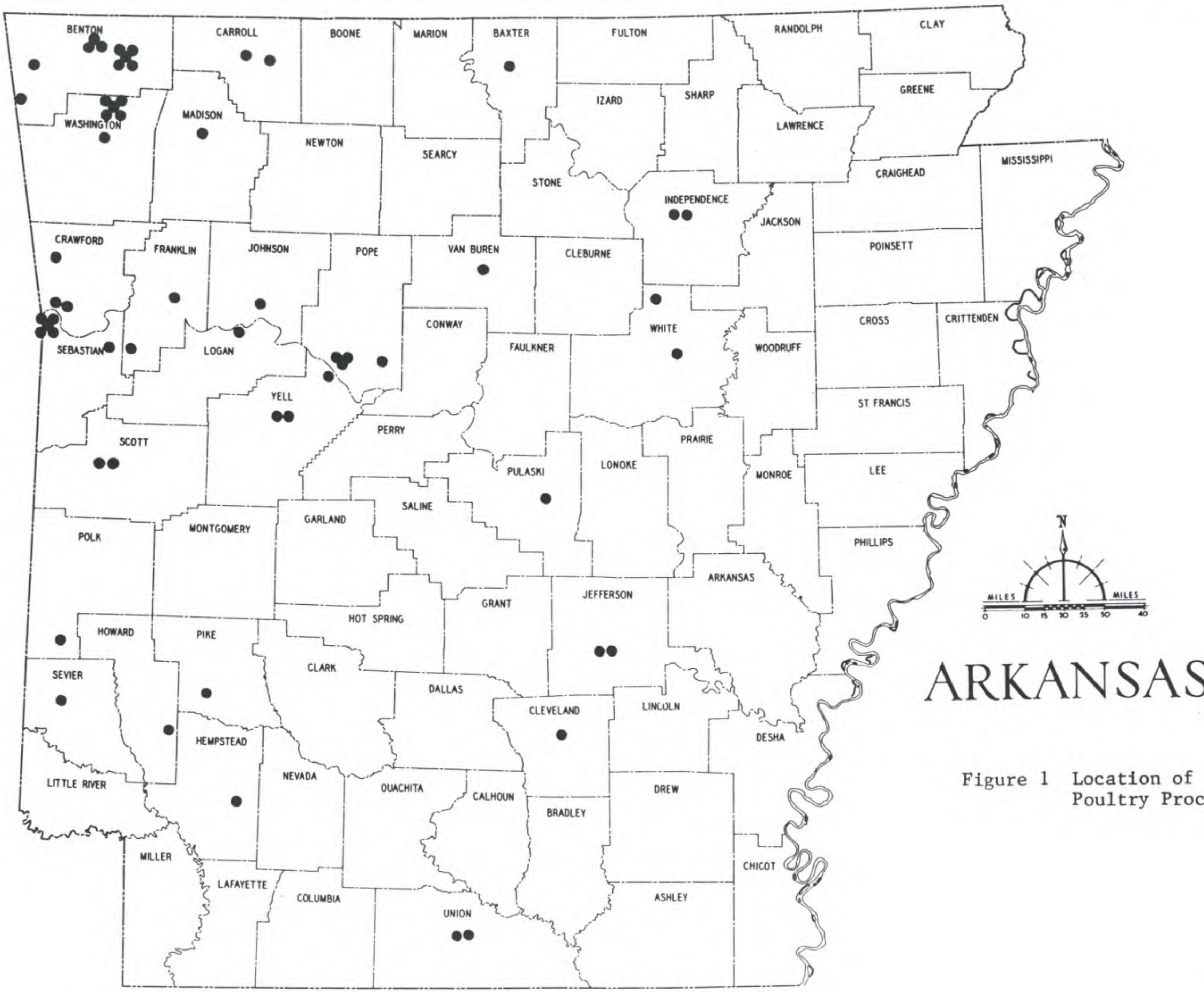

Figure 1 Location of Poultry Processors

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State permits are issued for land application of poultry processing wastewaters. At the present time, land application permits are issued for processing plants with very small flows and are similar to state permits for the land application of sludge. Sludge permits will be discussed in greater detail later.

Limits on wastewater discharged to city sewer systems depend upon the city's individual pretreatment requirements. Twenty-seven municipalities in Arkansas currently have a pretreatment program. DAF units are the most common pretreatment components.

POULTRY SLUDGES

Dramatic progress has been made in the last 30 years treating poultry processing wastewater. This progress has been accompanied by an equally dramatic increase in the volume of sludges produced by wastewater treatment plants. It is expected, therefore, that greater emphasis will be placed on regulation of poultry processing sludges in the coming years.

Currently, 3 methods of sludge disposal are used in the State of Arkansas: rendering, landfilling and land application. Because of the public nuisance problems associated with poultry sludges, conversion of sludge to feed in a rendering plant is the preferred method of disposal. Land filling of sludge is not practiced extensively in Arkansas except for wastes produced by hatcheries (egg shells, unhatched chicks, etc.). Land application is perhaps the most economically feasible disposal method, particularly when floculating agents are use to enhance the performance of DAF units.

The State of Arkansas has issued 17 permits for the land application of poultry processing sludges. The basic philosophy of sludge application in Arkansas is agronomic use. In other words, reducing pollution associated with sludge application while recycling nutrients for crop growth. Before a permit can be issued, the applicant must develop a general sludge management plan. The sludge management plan covers all aspects of sludge handling, including anticipated volume produced, storage, application method, calculation of land needed for application and location of all application sites. In addition, each application site must have a map showing buffer zones to water supplies, buildings and streams; field slopes; and cover crops.

Since the first land application permit was issued in 1982, the program has undergone considerable evolution. Listed below are five goals deemed essential to the improvement of any sludge management program:

1. Accurately characterize the sludge.

2. Apply sludge to meet crop needs.

3. Incorporate sludge into the soil.

4. Improve timeliness of sludge application.

5. Improve record keeping.

Poultry processing sludge is an extremely beneficial soil organic amendment with low amounts of contaminants; however, very few sludge applicators know the value of the sludge they are spreading. Sludge is analyzed for nutrient elements, oil and grease, and heavy metals while preparing the general sludge management plan. Sludge is then analyzed twice yearly for Kjeldahl Nitrogen, Ammonia Nitrogen, Total Phosphorus, Total Potassium and any pertinent metals (most commonly Cadmium, Copper and Zinc) for the life of the permit.

In almost all cases, sludge application rate is determined by the nitrogen content of the sludge. Nitrogen is applied to meet crop needs in the idea that nitrogen taken up by the crop will not be leached into groundwater. Arkansas has set 150 pounds of nitrogen per acre per year as the upper limit for sludge application. Yearly soil tests are taken of each application site to determine nitrogen application rate, general soil fertility and salinity conditions.

With the sludge properly characterized and application rate determined to meet crop uptake, the next goal of the permitting program is reduce nuisance conditions and increase efficiency of plant nitrogen uptake. Poultry processing sludges are perhaps the most odoriferous substances known to man, and the most effective way we know of reducing odors is to incorporate sludge into the soil. Unfortunately, most processing plants are located in areas of the state where incorporation is impossible due to steep slopes and shallow, stoney soils. Applicants in these areas are encouraged to render their sludges. When sludge must be applied without soil incorporation, application rates are severly reduced. Specifically, yearly applications of sludge are limited to 150 pounds of <u>total</u> nitrogen per acre as opposed to 150 pounds of <u>plant available</u> nitrogen allowed for incorporated sludges. Also, spreading is limited to 0.1 inch of sludge per application.

Sludge must be applied so that nitrogen is available when crops are actively growing to reduce nitrate leaching. Also, the acceptability of sludge application is greatly increased when people neighboring an application site are exposed to odors for only short periods. In order to increase timeliness of sludge application, the general sludge management plan must provide a minimum of 30 days storage capacity and demonstrate that the permittee has adequate application equipment. The soil incorporation requirement increases timeliness because sludge is more likely to be spread just prior to planting.

In order to insure compliance with the terms of their permit, a permittee must keep records of each load of sludge leaving the plant, showing time the load left and destination of the load. Similar records are kept of sludge entering and leaving the sludge storage facility. Every application of sludge is recorded on site maps, showing application rate and date of application. Land owners receive a copy of their soil analyses and are given reports showing amount of nutrients and metals applied to their fields in the current growing season, as well as, metal added since application began.

CONCLUSIONS

Poultry processing is a large, (and at the present time) growing industry in Arkansas. As wastewater treatment continues to improve, more emphasis will be placed on land application of sludge. Experience has shown that agronomic use of poultry processing sludges is enhanced by determining sludge chracteristics, applying sludge in a timely manner to meet crop nutrient needs, incorporating sludge into the soil, and keeping accurate records of sludge applied.

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IMPLEMENTATION OF POLLUTION CONTROL REGULATIONS THAT AFFECT POULTRY PROCESSING

BY
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Introduction

The Virginia Water Control Board (VWCB) has been authorized by the United States Environmental Protection Agency (USEPA) under the Clean Water Act and the Virginia Water Control Law (VWCL) to regulate actual or potential discharges of sewage, industrial or other wastes to State Waters. To accomplish this mission the Board has established six regional offices which process the necessary permits, monitor and inspect regulated facilities under procedural and technical guidance of the Headquarters Office in Richmond. The requirements of the Clean Water Act of 1987, Virginia Water Control Law, Chesapeake Bay Agreement of 1987, and newly adopted regulations establish the basis for several programs for water quality protection and enhancement which will affect both poultry processors and poultry producers. These programs include new initiatives in the National Pollutant Discharge Elimination System (NPDES) Permit Program, No-Discharge Certificate Program, and the Toxics and Nutrient Management Programs.

There are currently eleven poultry processing plants in Virginia which together process approximately 960 million pounds of live weight production of broilers and turkeys annually. Seven of the eleven processing plants treat and discharge their wastewaters directly to State Waters, while the remaining pretreat their wastewater prior to discharge to publicly owned sewerage treatment works (POTWs). The combined average daily flow of the direct dischargers is about 7 million gallons.

In addition to the processing plants, Virginia hosts a high density of poultry animal feeding operations. Approximately 154.0 million broilers, and 16.2 million turkeys were raised in 1987 for slaughter in Virginia which have a combined cash receipt value of $368 million. The amount of waste generated from these animal feeding operations is estimated at 500,000 - 700,000 tons, with an estimated total nitrogen load of about 19,000 tons. This nitrogen load is generated primarily in the counties of Rockingham, Augusta, Page and Shenandoah. The shrinking land base available for proper waste utilization combined with the karst geology in this area of the state underscores the need for a concerted effort to address both non-point as well as point source contributions of nutrient pollutants to State surface and ground waters.

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Applicable Statutes, Regulations, and Standards

The NPDES permit program which regulates direct point source discharges to State waters, is authorized by the Clean Water Act, the Virginia Water Control Law, and Regulation No. 6. The State No-Discharge Certificate program which regulates owners utilizing waste treatment alternatives designed to prohibit point source discharges to State waters is authorized by the Virginia Water Control Law and Procedural Rule No. 2. Regulation No. 6, recently modified by the VWCB (retitled Permit Regulation No. VR 680-14-01), will authorize the issuance of Virginia Pollution Abatement (VPA) permits instead of No-Discharge Certificates and should be effective in July 1988. The recent revisions to Regulation No. 6 also authorizes a new Pretreatment Program establishing legal requirements to implement National Pretreatment Standards for indirect discharges to publicly owned treatment works (POTWs). This program, however, is not expected to have a significant affect on poultry processors in Virginia.

Another significant revision to Regulation No. 6 includes Animal Feeding Operations as a special regulatory program. Under this program all animal feeding operations are required to maintain no discharge of pollutants except in the case of a 25 year 25 hour or greater storm event. Animal feeding operations of 300 or more animal units which require treatment works (pits, ponds, or lagoons) to prevent a discharge of wastewater pollutants except in the case of a 25yr-24hr storm event are required to obtain a Virginia Pollution Abatement (VPA) permit (formerly called a No-Discharge Certificate). Though this new regulation does not directly implicate poultry processors or broiler producers since broiler litter is usually managed as dry waste, improperly managed operations (e.g., improper storage or land application practices) may be designated as requiring a VPA permit on a case by case basis.

The VWCB also adopted a Toxics Management Regulation in March, 1988, which should be effective in July, 1988. The purpose of this regulation is to control the levels of toxic pollutants in surface waters discharged from NPDES permitted sources pursuant to Regulation No. 6. The goal of the regulation is to assure that toxic pollutants are not present in surface waters at levels which are causing or may cause toxicity, and provides standards and procedures by which the permittee shall minimize, correct, or prevent any discharge of toxic pollutants which have a reasonable likelihood of adversely affecting human health or the environment.

The VWCB's Water Quality Standards as amended in 1986 provide the standards and criteria for the basis of all water quality based permit limitations for operations regulated by either a NPDES permit or No-Discharge Certificate. These standards address both surface water and ground water quality.

GENERAL PERMIT/CERTIFICATE PROCESSING PROCEDURES

Figure 1 summarizes the NPDES permit and No-Discharge Certificate processing procedures utilized by the Board. The major processing steps for NPDES permit processing include the receipt of a complete application, local approval that the proposed discharge meets all applicable local ordinances, preparation of a draft permit with all appropriately justified limitations, EPA review and approval ("major" facilities only), public notice of the permit (30 days), and final issuance. The process is required by law to be completed by 120 days from receipt of a complete application.

The No-Discharge Certificate application for industrial wastes is comprised of a transmittal letter and a three part submission of conceptual engineering design and plans, and site specific soils and geohydrologic justification for the treatment works (usually engineered storage/treatment works and land treatment systems). There is a separate application form to obtain a No-Discharge Certificate (VPA) for animal feeding operations which is more simplified. The certificate processing steps are essentially the same as that for a NPDES permit with the exception that EPA does not review these certificates.

NPDES Permits	No-Discharge Certificates
1. Application Received	1. Application Received
2. Application Reviewed	2. Application Reviewed
3. Application Deemed Complete (Local Approval Required new Sources)	3. Application Deemed Complete (Local Approval Required for new Systems)
4. Site Inspection	4. Site Inspection
5. Stream Model Work	5. Draft Certificate
6. Draft NPDES Permit ("Majors" sent to EPA for Review)	6. Public Notice (After authorization received from Owner)
7. Public Notice (After authorization received from Owner)	7. Public Hearing (Only when significant public response is received)
8. Public Hearing (Only when significant public response is received)	8. Final Certificate Drafted and Issued
9. Final Permit Drafted and Issued	

Figure 1. General Steps in the Processing of NPDES Permits and No-Discharge Certificates

TECHNICAL BASIS FOR PERMIT/CERTIFICATE LIMITATIONS AND SPECIAL CONDITIONS

NPDES Program

EPA proposed technology based limitations for Poultry Processing Products in April, 1975. These limitations represent Best Practicable Control Technology Currently Available (BPCTCA). Although these limits have never actually been promulgated by EPA, Virginia exercises best professional judgement and utilizes BPT limits to determine the Best Conventional Control Technology Economically Achievable (BCTEA) limits (currently established by EPA as minimum treatment required for conventional pollutants for all industrial categories). EPA does not envision any further rulemaking for this industry. The conventional pollutants addressed by technology based limits include BOD_5 ,TSS, Oil and Grease, pH and fecal coliform. The basic procedure for establishing technology based permis utilizes a "building block" approach established by EPA: (1) an assessment is made of the operation for all applicable EPA established subcategories of wastewater flows within the processing plant, (2) the appropriate multiplier is utilized to determine the limitations for each applicable pollutant within each subcategory (daily maximum and monthly average limits), and (3) the limitations assigned to each pollutant for each applicable subcategory are summed. The final summed value for each pollutant is what appears in the NPDES permit.

Where the staff finds that the above technology based limitations for BOD_5 are unable to meet Water Quality Standards for dissolved oxygen or other parameters, more stringent limitations are justified. Of the seven direct dischargers in Virginia, only one has technology based limits for BOD5. Limits established to meet the water quality standard for dissolved oxygen during critical low flow conditions (minimum of 5.0 mg/l for non-tidal or mountainous zone waters) have involved tiered permit limits for winter and summer conditions, and have included both CBOD5, TKN and dissolved oxygen (D.O.) as limited parameters. Whether the permit is tiered for summer and winter limits, or whether TKN or D. O. is included depends on the site specific requirements of the water quality studies and modelling efforts undertaken by the VWCB staff or the owner.

Water quality effluent limits may also be placed in permits to assure that known toxic pollutants are not present in surface waters at concentrations which cause or may cause toxicity. Such limits are established when data developed in effluent testing or monitoring indicate a violation of the standards or criteria would occur after mixing, at critical low flow conditions and compliance with technology based limitations would not prevent such violations. Figure 2 summarizes the decision making process for establishing such water quality based limits.

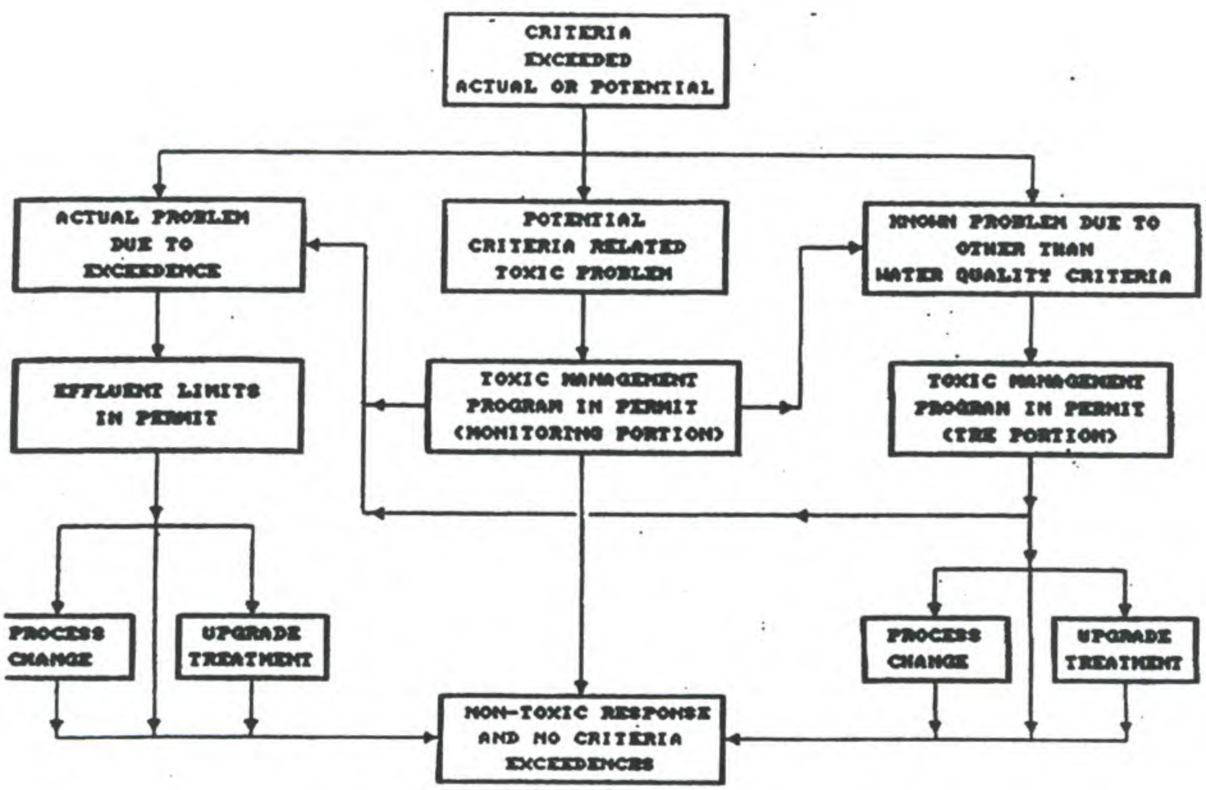

Figure 2. General decision-making process for the toxic management program.

Under the Toxic Management Regulation all dischargers will be screened to determine if toxics management will be required. Permit special conditions for those discharges where potential or actual toxicity exists will require initial toxicity testing to assess effluent toxicity, and if necessary, toxicity reduction or elimination. Effluent limitations for identified toxic constituents and compliance monitoring will also be included in NPDES permits. Currently, ammonia has been identified as one toxic constituent for poultry processors. Total chlorine residual (TRC) has also proven to be a toxic constituent requiring effluent limitations for certain processors utilizing chlorine to disinfect wastewater. Two processors have ammonia limits in their permits due to actual toxicity concerns. Two other processors are monitoring ammonia, additional effluent constituents,and in-stream water quality to establish an adequate data base should limitations of specific constituents be required in the future. Further testing of treated wastewater under compliance monitoring may reveal other toxicity concerns requiring toxicity reduction.

The 1987 Chesapeake Bay Agreement (CBA) includes a series of goals and objectives that establish a framework for continued cooperative efforts to restore and protect the Chesapeake Bay. One of the goals of this agreement is to "Reduce and control point and non-point sources of pollution to attain the water quality condition necessary to support the living resources of the Bay". As a signator of the CBA, Virginia has agreed by July 1988 to develop, adopt, and begin implementation of a basin wide strategy to equitably achieve by the year 2000 at least a 40 percent reduction of nitrogen and phosphorous entering the main stem of the Chesapeake Bay. To help accomplish this objective the VWCB in March, 1988, adopted a policy providing for the control of discharges of phosphorus from point sources affecting State waters that have been designated "nutrient enriched waters". This policy calls for a monthly average effluent limitation of 2.0 mg/l total phosphorus for existing discharges of 1.0 MGD or greater. New discharges of 0.05 MGD or more will also be required to meet the 2.0 mg/l TP limitation. With the exception of one of two processors - one located on the Chickahominy River (an effluent limited stream), and another discharger on the Eastern Shore of Virginia it does not appear that poultry processors will be directly affected by this new policy in the near future for two reasons: (1) either the effluent quality is below the 2.0 mg/l TP limitation or (2) the facility is not located in waters designated as "nutrient enriched". However, as EPA and the State gains more accurate estimating and predictive capabilities regarding the origin, quantities and fate of point and non-point source loads of nitrogen and phosphorus, additional direct discharges may be required to accomplish nutrient reduction in accordance with the interstate basin-wide strategies. Such predictive capabilities are not anticipated until 1991.

No-Discharge Certificate Program (VPA Permits)

No-Discharge Certificates are required for construction of storage/treatment impoundments and subsequent land application of industrial wastes or other wastes to assure that the system design and operation does not result in a point source discharge of wastes to surface waters except under prescribed worst-case rainfall conditions (25 year - 24 hour or greater storm), and that ground water quality is not degraded. When wastewater or sludges are applied to land for treatment/reuse, special conditions are incorporated into the certificate which specify approved application rates and management practices. When wastes are applied at rates which equal "agronomic" rates (Plant available nitrogen (PAN) loading lbs./Ac. equals plant nitrogen requirement) on an annual basis, ground water monitoring is included as a special condition of the certificate. Storage and treatment facilities are required to have engineered liners with a maximum permeability of $1x10^{7}$ cm/sec and include ground water monitoring programs. Other special conditions routinely incorporated in such certificates for land treatment systems include: (1) minimum buffer distances to drinking water wells (100 ft.), and surface waters (50 ft.); (2) development of an Operation and Maintenance Manual or Plan; (3) routine monitoring reports; (4) an annual summary of the preceeding year's activities; and (5) when applicable, surface water monitoring.

Two poultry processors have recently made application to land treat dissolved air flotation (DAF) sludge. The generation and need for disposal of this sludge resulted from localities' new pretreatment requirements. Due to the lack of knowledge regarding organic nitrogen mineralization rates, the agency is recommending such DAF sludges be utilized only on hay and pasture land until more accurate decomposition rates can be established for standard agricultural use on row crops. It is anticipated that land treatment of DAF sludge will be used increasingly by processors required to pretreat wastewater since this alternative bypasses the necessary dewatering step necessary prior to disposal by landfill. Another processor has installed sludge processing units which dewater the primary and secondary sludges prior to land application. The dewatered sludge is hauled to privately owned agricultural land for application at agronomic rates at a frequency of one application every five years. The supernatant is stored and land applied annually on the processor's property at agronomic rates.

No-Discharge Certificates may be required for animal feeding operations (including poultry producers) which, as a result of a staff finding, have not implemented proper waste management plans and operating procedures. If such becomes the case, a detailed waste utilization plan will be required of the producer, and special conditions such as those itemized above for industrial wastes may be incorporated into the permit. Such determinations will be addressed on a case by case basis. The VWCB encourages all producers to work with the VPI&SU Cooperative Extension Service and the Virginia Soil and Water Conservation Service to formulate and implement detailed waste utilization plans to assure that proper waste management is maintained on an annual basis to avoid possible regulation as a designated facility.

The CBA also identifies two objectives which will directly affect poultry processors and producers: (1) to reduce the levels of non point sources of pollution and (2) to manage ground water to protect the water quality of the Bay. The Virginia Chesapeake Bay Non Point Source Pollution Control Program administered by the Virginia Department of Conservation and Historic Resources, Division of Soil and Water Conservation, has targeted seven counties in the Shenandoah - Potomac River Basin as an animal waste priority area due to high animal waste production. Cost share programs have been instituted as incentives for owners of animal feeding operations (including poultry producers) to provide proper storage and implement proper waste utilization procedures.

Program Enforcement

A new enforcement program utilizing a computerized point assessment system was implemented in July 1987 in Virginia to address all violations of issued certificates and permits or applicable statutes and regulations, and policies. The system is designed to establish compliance and enforcement procedures which when implemented by VWCB staff will achieve timely and consistent enforcement actions against all violators. This system utilizes the Notice of Violation to inform the violator of non compliance problems, and requires action to correct the violations to avoid a potentially higher level of enforcement resulting in court action and penalties.

All violations are initially addressed by Regional Office compliance action, such as phone calls, letters, and site visits designed to correct minor compliance problems before they reach the formal enforcement action stage. When such efforts do not gain the satisfactory level of compliance, the matter is referred to the Office of Enforcement. For violations which are significant enough to warrant formal enforcement action, Headquarters enforcement staff then proceed to prepare the appropriate enforcement response to address the violation. Figure 3 summarizes the general decision making process and selected activities evaluated for determining NOV issuances and when formal enforcement actions will occur.

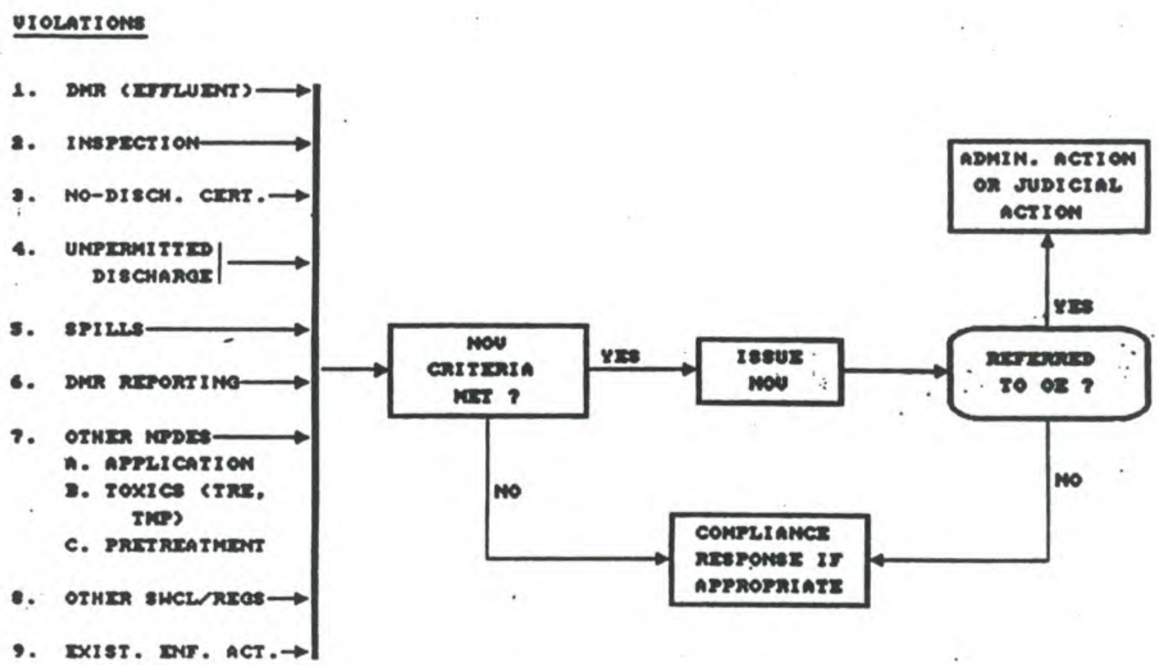

Figure 3. General decision-making process for program enforcement.

AGRICULTURE IN AN URBAN SOCIETY
THE URBAN-AGRICULTURE DILEMMA

Kirklyn M. Kerr

Director
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Welcome to The Ohio State University and the Poultry Waste Management Seminar. We consider it an honor to be able to host such a diverse group of people with interest in a subject such as poultry waste management. At this meeting there are people representing industry, farming, agribusiness, universities and state and federal government. With a group of people such as this combining their talents, we will certainly be able to advance our knowledge in poultry waste management systems.

Everyone should be aware that in this country we are faced with what is called the urban-agriculture dilemma. Agricultural land is being encroached upon by urban development. At the same time, a highly productive agricultural system is accused of contaminating our environment.

Clean water is essential to all life on earth. To have a successful agricultural enterprise, we must have high productivity and economic viability. Will we be able to maintain productivity with economic viability and also have safe surface water, safe ground water and a safe food supply? In order to do so we must become more efficient in agricultural systems and more knowledgeable concerning protection of the environment. It is our responsibility to insure a safe environment and food supply for future generations.

Contamination of the environment is a problem that must be faced by both agricultural and urban interests. The most common sources of point and non-point environmental contaminants are industrial wastes, petroleum products, road salt, municipal sewage, septic tanks, dry-cleaning agents, fertilizers and pesticides. As you can see, both agricultural enterprises and urban development are responsible for environmental issues.

The importance of agriculture in preserving our natural resources cannot be underestimated. Three major problem areas are of great concern:

1. Sediment damage--soil erosion results in sediment that reduces productivity of land and also increases turbidity of water used for aquatic life, fishing, swimming and boating. Sediment has numerous other deleterious effects on our water resources.

2. Nutrient damage--Agricultural nutrients such aas nitrogen and phosphorus runoff of agricultural land into our water resources. Other sources of nutrients that contaminate our water resources include manure, municipal sewage and runoff from urban lawns, gardens and parks.

3. Pesticides in water--The most poorly documented and understood problem is runoff of pesticides into our water resources. Pesticides have been incriminated as poisons that have harmed aquatic organisms even though it has been reported that less than 5% of pesticides applied to land actually reach a body of water.

We must conduct research that will provide answers to questions concerning protection of our environment and at the same time provide for agricultural productivity and economic viability. We must insure a safe and peachful world for future generations. I was privileged to hear Dr. Wes Churchman present a talk on peace and conflict at a recent meeting near Houston, TX. That meeting was for the purpose of developing a social research priority agenda. He stated that peace and conflict were an ongoing dynamic process. The goal of developing world peace is to design a just world for future generations. As a part of the peace process we must insure adequate and safe water and food supplies for all mankind. World peace will be impossible if we fail to produce quality food for all who need it.

How are we doing? Some studies indicate that approximately 15,000 die from hunger each day. Information from the United Nations indicates that there are approximately 40 wars going on somewhere in the world today. We must feed 20% more people by the year 2000 and 60% more by the year 2030. We must be able to accomplish this on less land, no additional water supply and no abatement of urban encroachment. Therefore, we must speculate on a more peaceful and unified world.

Current agricultural surpluses are masking the problem. Who should decide what we do? We live in a society where all people want to participate in decision making. People in both agricultural and urban settings must collaborate in making the appropriate decisions for solving the urban-agricultural dilemma.

We must learn from experience and feedback. We must work for future generations. We must help ourselves and fellow mankind. We must assist God in designing a peaceful and unified world through providing safe food and water supplies.

This has been an excellent conference. You have advanced knowledge on poultry waste management systems. This is one step toward developing a more productive and economically-viable agricultural enterprise with concern for protecting our environment. Research must continue--businesses must prosper--the challenge must be conquered. You are on the way.

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