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Research Needs Assessment— Livestock Manure Management in the United States

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RESEARCH NEEDS ASSESSMENT - LIVESTOCK MANURE MANAGEMENT IN THE UNITED STATES

by

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FOREWORD

The Environmental Protection Agency was established to coordinate administration of the major Federal programs designed to protect the quality of our environment.

An important part of the Agency's effort involves the search for information about environmental problems, management techniques and new technologies through which optimum use of the nation's land and water resources can be assured and the threat pollution poses to the welfare of the American people can be minimized.

EPA's Office of Research and Development conducts this search through a nationwide network of research facilities.

As one of these facilities, the Robert S. Kerr Environmental Research Laboratory is responsible for the management of programs to: (a) investigate the nature, transport, fate and management of pollutants in groundwater; (b) develop and demonstrate methods for treating wastewaters with soil and other natural systems; (c) develop and demonstrate pollution control technologies for irrigation return flows, (d) develop and demonstrate pollution control technologies for animal production wastes; (e) develop and demonstrate technologies to prevent, control or abate pollution from the petroleum refining and petrochemical industries, and (f) develop and demonstrate technologies to manage pollution resulting from combinations of industrial wastewaters or industrial/municipal wastewaters.

This report contributes to the knowledge essential if the EPA is to meet the requirements of environmental laws that it establish and enforce pollution control standards which are reasonable, cost effective and provide adequate protection for the American people.

William C. Galegar

William C. Galegar, Director
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ABSTRACT

The purpose of this report is to identify and assess research needs for livestock manure management as related to environmental quality. Task groups of six to nine professionals were formed to assess research needs for each of the areas studied. The areas considered were:

1. Unconfined animal production
2. Small livestock facilities (less than 300 animal units)
3. Resource recovery from animal manures
4. Conservation of energy and nutrients in animal manure management systems
5. Land application of animal manure and wastewater
6. Odors: cause and abatement in animal production

The research needs identified are all important but were put into three categories of priority, first, second and third. No rating was made within these three groups. For each research need a focus was noted, whether the need was related to environmental quality, demonstration, livestock production, education or energy.

This report was submitted in fulfillment of Grant No. R-806025 by the Ohio Agricultural Research and Development Center under the sponsorship of the U.S. Environmental Protection Agency. This report covers the period, May 22, 1978 to April 30, 1979, and work was completed as of June 1979.

CONTENTS

LIST OF ABBREVIATIONS AND SYMBOLS

Abbreviations

ARM - agricultural runoff management
ASCS - Agricultural Stabilization and Conservation Service (USDA)
BLM - Bureau of Land Management (USDI)
BMP - best management practice
BOD - biochemical oxygen demand
BTU - british thermal unit
CAST - Council for Agricultural Science and Technology
DOE - Department of Energy (United States)
EPA - Environmental Protection Agency (United States)
GLC - gas liquid chromatography
NCLWM - National Conference on Livestock Waste Management
NPDES - National Pollution Discharge Elimination System
PL - public law
SCS - Soil Conservation Service (USDA)
SEA - Science and Education Administration (USDA)
USDA - United States Department of Agriculture
USDI - United States Department of the Interior
USLE - universal soil loss equation

Symbols

C:N - carbon nitrogen ratio
NH_4-N - ammonia nitrogen
NO_3-N - nitrate nitrogen
N_2 - free nitrogen
N_2O - nitrous oxide

ACKNOWLEDGMENTS

The author gratefully acknowledges the many individuals and agencies which contributed to this research needs assessment publication. The research needs assessment task groups, whose names and membership are listed in the Introduction, are acknowledged for their major role in the development of this publication.

In connection with the development of this publication a National Conference of Livestock Waste Management was held in Columbus, Ohio on May 23 and 24, 1978. The impact of the conferees to the research needs assessment workshops is acknowledged. The U.S. EPA Environmental Research Information Center, Cincinnati, Ohio was a co-sponsor of the conference and their help is acknowledged in this project.

The author is also indebted to Lynn Shuyler, Chief, Animal Production Section and Douglas Kreis, Project Officer of the U.S. EPA, Robert S. Kerr Environmental Research Laboratory, Ada, Oklahoma for their cooperation in the National Conference on Livestock Waste Management and for providing direction concerning the scope of this project.

SECTION 1

INTRODUCTION

Over a decade of federal funding has been directed towards research and demonstration projects related to the handling and disposal/utilization of livestock manures and wastewaters. More recently, federal funding has been used for developing educational materials on livestock waste treatment and system management. At this point in time there is a need to assess the completed research and to identify areas that need additional research. This is particularly important in light of changing national priorities . Duplication of past research efforts must be avoided.

This Research Needs Assessment document was prepared by task groups of professionals working in the area of their topic assignments. These task groups prepared working papers which were used as a basis for workshop sessions held as part of The National Conference on Livestock Waste Management (NCLWM), May 23-26, 1978, Columbus, Ohio. The task groups then prepared their respective sections of this publication. Each of these sections were based on the respective working papers, conference presentations and subsequent workshop discussions.

The six research needs-assessment areas and the task group memberships were as follows:

1. UNCONFINED ANIMAL PRODUCTION
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   - J. Powell**, Oklahoma State University, Stillwater, Oklahoma.
   - J. W. Doran, USDA-SEA, Lincoln, Nebraska.
   - H. Geyer, USDA-SEA, Washington, D.C.
   - P. R. Middaugh, South Dakota State University, Brookings, South Dakota.
   - J.W.D. Robbins, Louisiana Tech University, Ruston, Louisiana.
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2. SMALL LIVESTOCK FACILITIES (LESS THAN 300 ANIMAL UNITS)
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5. LAND APPLICATION OF ANIMAL MANURE AND WASTEWATER
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   S. E. Bishop, University of California, Riverside, California
   S. Klausner, Cornell University, Ithaca, New York
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6. ODORS: CAUSE AND ABATEMENT IN ANIMAL PRODUCTION
   C. L. Barth*, Clemson University, Clemson, South Carolina
   J. R. Miner**, Oregon State University, Corvallis, Oregon
   L. F. Elliot, USDA-SEA, Washington State University, Pullman, Washington
   D. T. Hill, University of Florida, Gainsville, Florida
   C. E. Ostrander, Cornell University, Ithaca, New York
   D. J. Warburton, University of Illinois, Urbana, Illinois

In each of the respective sections there is a description of the needs area, a discussion on the scope of present information and a listing of research needs. All the research needs are important but they are placed into one of three priority categories: first, second and third. The numbering of research needs within each category does <u>not</u> indicate priority rating. The judgment of importance may have regional differences and will need to be evaluated by researchers and by those who support the research.

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The research needs were categorized according to relationships with the following areas: environmental concerns, demonstration, livestock production, education (service) functions and energy issues. These foci of research may be used by agencies and institutions to identify research needs related to their emphases. For example, an educational focus can be related to extension programs; environmental concerns are of primary interest to the United States EPA and State pollution control agencies; livestock production needs are related to the USDA-SEA and to livestock associations; etc. All of these needs are of interest to universities and research organizations.

SECTION 2

SUMMARY OF FIRST PRIORITY RESEARCH NEEDS

Each research needs section is comprised of a list of topics prioritized into three groups, which are delineated first, second or third. This summary will present the needs in the first priority category for each research area. The reader is referrred to the respective sections for more detailed discussion and a complete list of research needs.

It is important that research activities be coordinated so that data are comparable, have maximum usefulness and address the particulr research area completely. In many instances it is appropriate to use multidisciplinary research teams to obtain the necessary results.

UNCONFINED ANIMAL PRODUCTION

A coordinated multidisciplinary study, incorporating representative locations of (1) nongrazed (background conditions), (2) well managed and (3) poorly managed grazing land, to evaluate water quality impacts and to provide data base information to assess the technical reliability of bacterial indicators is the overall first priority research need. Specific subsets of this overall research need are as follows:

1. Determine the relationships between grazing practices, site conditions and water quality parameters, especially sediment.
2. Adapt and/or develop new methods of survey, analysis and statistical interpretation for evaluating the impacts of animal management practices on aquatic and terrestrial ecosystems.
3. Determine the effectiveness of promising alternative management practices for reducing pollutant loads in receiving waters.
4. Determine the feasibility of using plant biomass as an indicator of and criterion for assessing water quality by determining the qualitative relationships between livestock grazing pressure, plant biomass and runoff water quality.

SMALL LIVESTOCK FACILITIES (LESS THAN 300 ANIMAL UNITS)

1. Evaluate the effectiveness of small feedlot runoff controls.

2. Establish criteria for defining and communicating information on best management practices (BMPs) for livestock production facilities and related pollution control practices.

3. Identify institutional and social constraints related to and develop a strategy for the implementation of environmental improvement technologies and management practices.

4. Evaluate modifications of small livestock facilities which are necessary to meet pollution control requirements.

5. Define the impact of federal, state, and local environmental regulations on small livestock operations.

RESOURCE RECOVERY FROM ANIMAL MANURE

1. Improve materials handling equipment and systems to maintain the "freshness" of waste material and minimize the loss of nutrients and energy.

2. Assess the safety of feeding processed animal manure with respect to human and animal health and develop methods of processing that eliminate hazards.

3. Design turn-key systems for on-farm applications of thermochemical processes and evaluate economics of their mass production.

4. Evaluate the flexibility of thermochemical processes relative to user's need for gas, liquid or solid fuels.

5. Develop methods for direct utilization of methane produced from manure or converting it into an easily stored and transported fuel.

6. Develop turn-key anaerobic digestor design through evaluation of on-farm size units considering management requirements and logistics of increasing waste volumes.

CONSERVATION OF ENERGY NUTRIENTS IN MANURE MANAGEMENT SYSTEMS

1. Determine the fundamental factors affecting energy use and nutrient conservation.

2. Conduct a state-of-the-art analysis of energy use and nutrient conservation possibilities.

3. Evaluate available analytical, predictive and management models for manure application to land and for economic analysis of animal waste management systems.

LAND APPLICATION OF ANIMAL MANURE AND WASTEWATER

1. Characterize the nitrogen and other nutrient transformations that take place in manure and soils as they are influenced by handling methods, soil types, crops and climate.

2. Evaluate the environmental impact of runoff from manured cropland on receiving waters as influenced by method of application, tillage and soil conservation practices.

3. Extend models of cost analysis to complete manure systems by regions and by animal species and to include environmental impact.

4. Establish critical application rates of nitrogen (N), phosphorus (P), potassium (K) and micronutrients in manure in relation to plant uptake of these elements and quality of grain or forage.

ODORS: CAUSE AND ABATEMENT IN ANIMAL PRODUCTION

1. Locate all foreign and domestic research on odor identification, measurement and control for all odor sources so that successful techniques may be adapted or altered for use with animal manure odors.

2. Standardize the measurement and evaluation of odors with respect to measurement techniques, background odor information and odor transport.

SECTION 3

UNCONFINED ANIMAL PRODUCTION

Unconfined animal production refers to the grazing or pasturing of livestock on range land and pastures. The current trend in livestock production is towards confinement. However, a significant portion of livestock production can be included in the unconfined animal production category. Beef feeder calves are produced almost exclusively on pasture or range; about 30 percent of hog production is still on pasture; most dairy farms, except in the Southwest, use pasture when seasonal conditions permit; and sheep production is mainly a range and pasture operation. Over 50 percent of the land within the United States is used for unconfined animal production.

Identifying research needs relating to unconfined animal production is an inherent necessity for the technically valid, cost effective and practical implementation of Public Law (PL) 92-500, especially Section 208 and the Rural Clean Water Program.

SCOPE OF PRESENT INFORMATION

Most available data and on-going work, primarily sediment oriented, are fragmented and not designed, executed, or analyzed in a manner which permits a technically adequate assessment of the environmental impact of unconfined animal production. Most appropriate information is referenced and summarized by Robbins, 1978. Conference attendees agreed that the information available to control pollution from unconfined animal production is insufficient and that the potential for impact is significant because over 50 percent of the land in the United States is used in unconfined animal production.

Grazing practices result in elevated counts of fecal coliforms, which may indicate the presence of pollutants. The importance of such elevated counts must be interpreted in light of how they affect the ecological balance of receiving waters, how they compare with background levels, and their significance from a health standpoint. Increased levels of nutrients in runoff from grazing lands are often related with hydrologic erosion phenomena but also result from unique management situations (i.e., congregation of cattle in localized areas, cattle entering receiving water, runoff occurring shortly after fertilization, etc.). Terrestrial and aquatic wildlife populations in grazed and ungrazed watersheds are known to have an influence on water quality but these influences have not been characterized or quantified. The effects of normal populations of wildlife (established populations at the natural carrying capacity for the area) should be used to determine baseline levels of pollutants. Differences in type, amount, and distribution of and successional and manipulative changes in vegetation are known to affect water quality but these effects have not been quantified.

Specific bacterial indicator groups appear to have some value for determining the relative contributions to water quality of wildlife and various unconfined animal production units (i.e., numbers and grazing distributions). The use of the ratio of total numbers of fecal coliforms to fecal streptococci in water as a method to differentiate between human and animal origin of fecal water pollution was described by Geldreich (1976). This ratio was applied by Harms et al. (1975) and Doran and Linn (1978) to differentiate between human and animal sources of water pollution. This technique may be utilized in ecological studies to determine the impact of grazing animals on the relative quality and disease potential of receiving waters.

Another bacteriological technique which may be useful in assessing the impact of unconfined animal production on receiving waters utilizes the presence of starch hydroloyzing bacteria from the ruminant as a unique indicator of recent bovine fecal pollution of aquatic systems. The organisms of the *Streptococcus boves* group can be readily detected by indicator media and so serve as a specific assay for unconfined animal inputs.

Information is available on the plant production capabilities on natural grazing lands and introduced pastures under different ecological conditions and in the absence of grazing livestock. Information is also available, but to a lesser extent, on the effects that grazing pressure (animal-unit equivalents per unit of plant biomass) has on plant maintenance and production under certain ecological conditions and management practices. Limited information is also available which defines the optimum or minimum forage supply at a point in time for maintenance of long-term, sustained vegetation and grazing livestock production. Reliable methods are available to assess plant biomass under many ecological conditions and managment practices. Adequate methods are available to approximate the quality of runoff water. This approach, when combined with a determination of a minimum forage residue which will maintain runoff water quality, presents a viable monitoring and management tool suitable for use over a wide geographic range.

Under PL 92-500, various Section 208 planners are utilizing mathematical models to evaluate pollution impact from animal production and other agricultural practices. The Agricultural Runoff Management (ARM) model developed for the EPA is effective in modeling the hydrology of and to a lesser degree erosion and certain chemical processes in small watersheds. At present, the model is designed to predict stream inputs of sediment, nitrogen, phosphorus, and certain pesticides. Testing on small watersheds in Georgia and Michigan indicate the model is more accurate for sediment-associated chemicals than for highly soluble chemicals. Conceptual and mathematical relationships are currently being developed for transformations, attenuation, and water transport of nutrients, organics, and microbial parameters where animal manure has been applied.

However, there is inadequate data for the testing, calibration, and validation of these models. In spite of the data and basic research voids, modeling of a system forces researchers to identify these voids and direct research needs into critical areas. Interdisciplinary teams are needed to integrate the hydrological, soil, climatic, management, chemical, biological and other factors involved in a modeling approach.

RESEARCH NEEDS

The research needs in this section are presented first in an overall or holistic approach. The additional priorities will detail specific subsets of the holistic objective. These prioritized research needs could serve as independent projects where funds are limited.

It will be important to coordinate the appropriate research activities so that generated data are compatible, have maximum usefulness and adequately fulfill the needs of the researched subject.

First Priority Group

Holistic approach. A coordinated multidisciplinary study, incorporating respresentative locations of (1) non-grazed (natural or background conditions), (2) well managed, and (3) poorly managed grazing land, to evaluate water quality impacts and to provide data base information to assess the technical reliability of bacterial indicators. Continuing model development should be directed towards evaluating cost-effectiveness and implementation strategies of alternative managment practices for unconfined animal production (Focus - Environmental, Production and Demonstration).

This research need should be integrated into on-going programs or projects such as the seven regional non-point source studies and should involve appropriate agencies such as USDA, EPA, BLM, USDI, Forest Service, Department of Commerce, and DOE in selecting multidisciplinary research teams. The goal should be to expand and coordinate project planning and execution rather than initiate new administrative units and totally new research procedures.

A demonstration-research type project would maximize use benefits, motivate voluntary compliance and provide practical and effective research stimulation and direction.

1. Determine the relationships between grazing practices, site conditions, and water quality parameters, especially sediment (Focus - Environmental, Production and Demonstrations). This research would:

    a) Determine the possibility of using sediment yields as an index to water quality impacts resulting from unconfined animal production.

    b) Establish values of unconfined animal production activities for use in the universal soil loss equation.

2. Adapt existing and/or develop new methods of survey, analysis, and statistical interpretation for evaluating the impact* of animal management practices on aquatic and terrestrial ecosystems (Focus - Environmental). This research would:

   a) estimate short-term impacts as related to elevated levels of bacterial indicator counts, sediment, and nutrients in runoff from grazing areas as compared to ungrazed or background areas; and

   b) evaluate and compare (1) long-term impacts of animal grazing practices as related to management levels on aquatic and terrestrial ecosystems and (2) alternative land use practices in areas adjacent to grazing areas under study through surveys and statistical analysis/interpretation of terrestrial (wildlife population, plant communities) and aquatic ecosystems (macroinvertebrates, fish and plant species diversity and community structures).

   This evaluation should investigate the feasibility of using high and low altitude remote sensing to detect larger scale ecological changes which are related to (1) changes in terrestrial and aquatic vegetation (density and characteristics), (2) management and livestock patterns (mowing, fertilization, loafing areas, etc.), and (3) water quantity and thermal changes associated with clearing operations in establishment of new grazing areas.

   Also, it will be important to standardize the research methods adapted or developed so they can be used by the maximum number of disciplines and compiled for evaluation and modeling.

3. Determine the effectiveness of promising alternative management practices for reducting pollutant loads in receiving water (Focus - Environmental, Production and Demonstration).

   State-of-the-art information is being developed by an EPA funded project entitled "Best Management Practices for Unconfined Animal Production". Evaluation of the effectiveness of a number of management practices that hold most promise for limiting movement of pollutants to water and for receiving widespread adoption is urgently needed. Examples of these practices include fencing, site surface modification to change runoff patterns, role of buffer zones between grazing site and streams, modification of dung degradation, livestock traffic/congestion control, role of farm ponds in water quality improvement, and use of remote sensing to detect likely problem areas such as high impact and poor site conditions.

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*Impacts or changes are considered deviations from the normal seasonal or yearly climatic variation as evaluated by comparison with a control or established baseline.

4. Determine by evaluating the qualitative and quantitative relationships between livestock grazing pressure (animal-unit equivalents per unit of plant biomass), plant biomass and runoff water quality, the feasibility of using plant biomass as an indicator of and criterion for assessing water quality (Focus - Environmental and Production).

   The relationships between plant biomass (live, standing dead and ground litter) and runoff water quality from different lands grazed by livestock are virtually unkown. Effects of various kinds and amounts of vegetation, including species composition, density, morphology, root concentration, and ratio of live, standing dead and ground litter, on runoff water quality should be determined for different ecological situations, management practices and seasons. The economic and environmental benefit and cost-benefit ratio of maintaining various plant biomass levels should be determined. Studies designed to determine these relationships should consider and endeavor to eliminate, or at least document, the potential for confounding by all factors contributing to water quality, plant biomass and livestock production. The impact of improving water quality by altering plant biomass grazing residues on animal production and health should not be ignored. Techniques such as remote sensing, which provide large-scale, low-cost inventories should be incorporated. Whenever possible, studies should be conducted under representative farm and ranch conditions.

   The successful achievement of this objective requires active cooperation in the planning, implementation and evaluation stages of the research by a multidisciplinary team of scientists in such disciplines as animal science, agronomy (pasture and soil), range science (ecology and grazing management), water chemistry and biology, hydrology and engineering. Interdisciplinary funding will be required. Implementation guidelines that are developed should be standardized for use by individuals without in-depth experience in all the disciplines noted.

Second Priority Group

1. Evaluate the ARM model or models with similar capability for predicting stream inputs from grazing lands under various hydrological, climatic, and management conditions, and further develop and refine the models to include oxygen demand and microbial parameters (Focus - Environmental).

   With the incorporation of relationships developed for animal manure, the ARM model can be an excellent evaluation and planning tool for predicting stream inputs from pastures and rangelands, but there are still many facets needing further research. Until more data are gathered for testing the model on grazed lands, the ARM model should be used mainly as a research tool and not be commonly applied for predicting pollution impacts of unconfined animal production. Other models predict inputs, and may be more appropriate than the ARM model for certain uses.

Specific aspects of research needed in modeling runoff from unconfined animal production areas are:

a) add modeling of oxygen demand and microbial parameters;

b) use available data to determine model prediction capability;

c) identify critical inputs and relationships needed to improve the model, and determine minmum data requirements for desired accuracy;

d) evaluate as a planning model to determine cost-effectiveness of changing management practices and contiguous land use activities ;

e) continue to test the model as data become available; and

f) refine the model to include large watershed capability.

2. Identify and evaluate models with the capability to determine impact of stream loadings on receiving waters (Focus - Environmental).

Models to predict impact of agricultural activities on receiving waters are not presently available. However, 208 planners are extensively using very limited models to indicate the impacts of agricultural activities. Until these models are refined and combined to predict importance of stream inputs in determining impact on receiving waters, many erroneous conclusions may be reached regarding water quality impact of agriculture, especially unconfined animal production.

Modeling efforts have been primarily in three main areas for predicting (1) stream inputs, (2) in-stream changes and their impact, and (3) inputs to ponded or impounded waters and their impact. However, the combining of these three modeling areas in order to predict the total agricultural impact on receiving waters has not been achieved.

<u>Third Priority Group</u>

1. Develop and utilize the best standardized bacteriological methods to determine the source of fecal bacteria (pathogens and indicators) and their significance to receiving waters and contamination (Focus - Environmental).

Much of existing bacterial information is incorrect or misleading because methodologies developed for different wastes have not yielded consistent and reproducible results. Therefore, standardized bacteriological methods should be developed for uniform use in multidisciplinary studies of bacteriological water quality of grazed and ungrazed terrestrial and aquatic ecosystems. Specific methods for detection and enumeration of zoonotic pathogenic bacteria, salmonellae, etc. should be employed to determine the kinds, numbers and significance of these pathogens in the ecosystems.

2. Determine the levels and importance of animal fecal pathogens and indicator microorganisms which are added to receiving aquatic environments by (a) native fauna (background or natural conditions), and (b) unconfined grazing livestock (Focus - Environmental).

Bacteriological studies of runoff waters and receiving rivers and lakes by Harms et al. (1975) and Doran and Linn (1978) provide information on unconfined grazing land runoff. Both studies indicate the presence of significant numbers of fecal indicator bacteria including fecal coliforms and fecal streptococci in runoff from grass and cropland which was not grazed or fertilized within a four-year period.

Further bacteriological research is needed to establish the levels and significance of the indicator bacteria (and possible zoonotic bacterial pathogens such as the salmonellae) in waters receiving runoff from land which has not been grazed or treated with manure. The number of fecal coliform and fecal streptococci from ungrazed land were frequently greater than the federal water quality standards (Harms, 1975). The presence of large numbers of wild animals and rodents (e.g., mice, ground squirrels, rabbits) should be evaluated as contributing sources for ungrazed lands. The present water quality bacterial standards should be re-examined after these added data are obtained.

The significance of grazing land runoff as to contributions of pathogenic and indicator bacteria should be determined and reassessed in light of infrequent storm runoff events and the die-off of intestinal indicator and bacterial pathogens (e.g., salmonellae). In many grazing area bacteria may serve as short-term indicators of water pollution and often will demonstrate that little or no significant fecal pollution of receiving waters has occurred.

SECTION 4

SMALL LIVESTOCK FACILITIES (LESS THAN 300 ANIMAL UNITS)

Small confined animal production units not subject to the National Pollutant Discharge Elimination System (NPDES) regulations are essentially those with less than 300 animal units that have no point source discharges of pollutants into navigable waters. An animal unit is defined as one beef animal being fed for slaughter. Equivalent animal units are assigned for other species. The majority of livestock operations in the United States fall into the category of this chapter. Since the large feedlot operations produce such large quantities of manure with accompanying pollution problems, the ensuing publicity has caused the major research efforts in animal waste management and pollution abatement or elimination to be focused on large operations. However, many people are not aware that the majority of livestock operations in the United States belong to the "small" category, and that many management systems and technologies developed for the large feedlots are not economically and/or technologically feasible for the small operations.

Past research funded by EPA, and other federal and state agencies, has been geared to large animal production operations and to exotic technologies. Such research has not been applicable in many respects to the water quality and other environmental-related problems of small confined animal feeding operations.

Therefore, it is imperative that research directed toward assisting the small units to control and prevent pollution be emphasized more in the total program of environmental protection.

SCOPE OF PRESENT INFORMATION

There is a wealth of information in extension and livestock industry publications on manure management for small livestock facilities. The information is the result of university and government research and farmer implementation. A recent summary of information on this topic is, a manual on the evaluation and economic analysis of livestock waste management systems by White and Forster (1978). In most topics there are gaps in the research information, and guidelines have been developed based on field experiences. An example is anaerobic lagoons. There has been much research of an applied nature for specific sites. Anaerobic lagoons are being used as low-cost manure treatment systems in many states. Yet other states are "regulating" them out-of-use. An area where little data exists is on the benefit-cost technologies or practices for small livestock manure systems.

It is generally accepted that a major weakness of waste handling is the level of management or lack of management. Most research to date has dealt with the functional aspects of equipment, unit operations and systems. There is a need to integrate management requirements into manure systems. This may entail selecting an alternative technology with less equipment and management input to insure system reliability. Also, the lack of education as to management requirements has caused systems to fail. The development of educational materials and programs needs to be extended to cover management guidelines.

In many cases, research information is available for alleviating environmental problems associated with manure systems. This information has not been made available to farmers, 208 planners and others involved in implementation. Therefore, the following list of research needs includes a number of items identified as education and demonstration.

RESEARCH NEEDS

First Priority Group

1. Evaluate the effectiveness of small feedlot runoff controls (Focus - Environmental and Educational).

   Various feedlot (barnlot) runoff control technologies have been developed. They need to be evaluated as to their effectiveness in improving surface water quality, e.g., vegetative areas for runoff infiltration. Management requirements of the runoff control technologies must be included in their evaluation. It would be highly desirable to develop a model to predict which control technologies are best suited for various site conditions, localities and species. This model could then be used by service agencies in designing runoff control systems for farmers.

2. Establish criteria for defining and communicating information on BMPs for livestock production facilities and related pollution control practices (Focus - Environmental, Production and Educational).

   Alternative management practices have been researched but little has been done to evaluate them in relation to effectiveness in environmental quality control or economic benefit/loss to farmers. Runoff control, infiltration to ground water, odor potential, equipment costs, labor requirements, benefits from nutrients, etc. must be weighed. Regional and species differences are significant in these alternative management practices.

   Information on acceptable management practices needs to be communicated to decision makers in planning and regulatory roles. This information will then be the basis for selecting BMPs.

3. Identify institutional and social constraints and develop a strategy to implement environmental improvement technologies and management practices on small livestock facilities (Focus - Educational and Demonstration).

Area and regional implementation of best management practices will require a detailed educational and demonstration program involving many institutions.

4. Evaluate modification(s) of small livestock facilities which are necessary to meet pollution control requirements (Focus - Production, Environmental and Demonstration).

   If BMPs are prescribed for a region, modification of existing facilities will be required. It will be essential to implementation that the producer be shown how the alternative practices will benefit him. An example is how a manure storage structure will facilitate scheduling and reduce labor inputs into spreading of manure on land. Environmental and economic benefits from investments must be delineated.

5. Define the impact of federal, state and local environmental regulations on small livestock operations (Focus - Environmental and Production).

   In most cases small livestock facilities are under state regulations. The impact of the regulations from different states and localities should be identified. This study should assess the environmental improvement obtained by implementation as well as the economic impact upon individual farms and local areas. Social implications should also be studied.

Second Priority Group

1. Study the treatment efficiency of non-emptied holding ponds (Focus - Environmental and Production).

   Many runoff detention ponds are not emptied (irrigated) on a regular basis due to management decisions. It is possible that these detention ponds, if properly designed, might function as treatment units and meet water quality criteria without irrigation being required. Management of overflow during rainfall would be part of the system.

2. Develop management and operation guidelines (regional and/or state) for lagoons and storage structures (Focus - Production, Educational and Environmental).

   Items to be considered are: rate of sludge build-up, solids removal techniques, odor control methods, cost-effective disposal alternatives, etc.

3. Establish the conditions for effective natural sealing of earthen storage structures and lagoons (Focus - Environmental and Production).

   Several research projects have been completed on this topic. Yet, it is not considered effective by some State regulatory agencies and commercial liners are required. The scope of this research priority should be to pull together the results of completed research, fill in the "holes" as needed and promulgate criteria for acceptable natural sealing.

4. Develop acceptable management practices for handling milking facility wastewaters (Focus - Environmental, Production and Demonstration).

   With the trend to larger diary herds, the problem(s) of handling milking facility wastewater increases. Dairy production is usually concentrated in local areas and the impact of wastewater discharges is significant to the area. This wastewater is usually high in Biochemical Oxygen Demand (BOD) and suspended solids. It is important to develop cost-effective methods which will maintain the quality of the environment.

Third Priority Group

1. Develop procedure for "on-farm" tests to determine (or estimate) fertilizer nutrients in manures or wastewaters (Focus - Production, Educational and Environmental).

   Difficult nutrient analyses are a major drawback to effective use of manure and wastewater as a fertilizer. With a knowledge of the nutrient content of manure, a farmer could then develop a total fertilization program to minimize cost and avoid environment insult.

2. Identify economic and social impacts of small livestock operations on rural economies (Focus - Educational).

   Livestock production is being stopped on small farms in many localities. Usually, monoculture of grain or other commodities is substituted. This change is bound to have an impact on rural economies. The desirability or non-desirability of phasing out small livestock production units needs to be determined.

3. Identify control technologies and management guidelines to prevent silage drainage from degrading water quality (Focus - Educational and Environmental).

   Fish kills due to silage drainage entering streams occur each year. There is a need to identify and promulgate acceptable management practices to prevent silage drainage problems.

GENERAL CONSIDERATIONS

Physically and economically, it is impossible to implement all the short-term requirements for achieving water quality standards in the time period legislated. Therefore, federal and state agency planners must re-evaluate the priorities to determine which alternative management practices should be implemented by 1983. Costs of making additional improvements in water quality will become higher per unit of improvement. Policy makers must make a long-term commitment to cost-sharing (grants, loans, cost-sharing aby SCS, ASCS, etc.) if these improvements are to continue to be made at the local level.

SECTION 5

RESOURCE RECOVERY FROM ANIMAL MANURE

Resource recovery from animal manure offers an economic incentive for utilization of management practices which will protect environmental quality. The economic returns can be from several products including nutrients for animal feed and energy. Thus, benefits can accrue not only to environmental quality but also agricultural productivity and energy production.

SCOPE OF PRESENT INFORMATION

Processed animal manure as a feedstuff is a valuable resource that contains crude protein, phosphorus, and energy. These wastes are utilized efficiently by ruminants after processing and/or biological enhancement. Processing methods used include dehydration, ensiling alone or with other materials, composting, oxidation ditch treatment, solids-liquid separation, fermentation and chemical treatment. A major purpose in processing is to destroy pathogens and parasites. Increasing interest exists among producers in utilizing animal waste for feed. The current information on refeeding is summarized in a recent report prepared by a task force of the Council for Agricultural Science and Technology (CAST, 1978). Data available indicate that residues from drugs, pesticides, and toxic materials in animal wastes have not been a hazard to receiving animal health.

Because of the high moisture content of animal excreta, frequent collection and processing are desirable to minimize loss of nutrients and maintain palatability. Materials handling problems arise in attempting to collect, transfer, blend and store animal wastes for feeding.

Several thermochemical processes for the conversion of biomass and biomass residues into useful liquid and gases for fuel or other uses are being developed by interests within the private sector and government agencies. These processes involve controlling pyrolysis or converting the products of pyrolysis so that useful products are obtained. The trend in these developments if toward increased utilization of catalysts for conversion to end-use products such as ammonia and methanol. Most of these concepts are at the bench or pilot plant stage with some at or ready for the demonstration phase. These processes are directed toward applications with waste production capacities ranging from 100 to 1000 tons per day.

Most investment/cost evaluations indicate that the current thermochemical designs will not have the necessary economy-of-scale for single on-farm application. There is a potential of combining manure with other organic wastes, e.g., field stover, municipal sludge or refuse, etc., to make the energy conversion efficiency and economics more attractive.

Advantages of thermochemical processes suggest, however, that they be evaluated to help satisfy the environmental and energy needs of farm-size applications. One advantage is that batch or semi-continuous units can be designed to provide an on-off capability which can be adapted to on-farm needs/management. Another advantage is that liquid, gas, or solid fuels can be produced and stored.

Anaerobic digestion is another method of resource recovery. When residual organic matter is exposed to microorganisms in an environment that is devoid of oxygen (anaerobic) some of the carbon in the organic matter is converted to methane and carbon dioxide gases. This natural process has been used in municipal sewage treatment plants. The technology is well-developed and, in general, operating conditions are well known.

Digesters fed livestock manures have been investigated since the late 1700's, but working units weren't developed for small farms in India and Germany until the early 1900's. Most recent work has centered in the United States because large concentrations of livestock in confinement offered unique problems of manure management. Unlike municipal sewage sludge, it has been found that day-to-day variations in feed composition present little difficulty to a livestock manure digester. Other problems, however, have been encountered. Mechanical problems assocated with transporting and handling the fibrous manure are of major importance. Some chemical compounds and possibly drug residues may upset the digester and are of concern. The gas must be used as produced due to the high cost of compression and storage.

Active research on several aspects of manure digestion shows that manure from all species of livestock can be digested to produce methane, but there will be a residue of 40-60 percent of the original organic matter. Process conditions must be tailored to the manure of each species. A major concern is with equipment configuration and cost. Additionally, manure in many cases msut be diluted and therefore, the total volume to be handled and disposed of is increased proportionately by the dilution volume.

Present energy prices do not make on-farm methane production economical, but there are major environmental advantages that are difficult to quantify economically. The process offers pollution abatement through stabilization of the organic matter. This stabilization provides some odor control and reduction of the water pollution potential. It may be possible to recover minerals and nutrients from the liquid and solid residues that can be useful in animal feeds.

RESEARCH NEEDS

In this section on resource recovery, research needs in four categories are considered: (1) general needs, (2) feeding processed animal waste, (3) thermochemical processes for energy and product recovery, and (4) anaerobic digestion. The research needs are prioritized for each of the categories.

General Needs

Materials handling is a primary concern. Altering the handling characteristics of manure by changing the animals' ration needs specific study in the total production system.

First Priority--

Improve materials handling equipment and systems to maintain the "freshness" of the waste material and minimize the loss of nutrients and energy (Focus - Production, Educational and Energy).

Equipment used for other manufacturing processes can often be adapted to solve materials handling problems. The developmental cost of equipment and system adaption are too great to be borne by individual livestock producers. Individual areas of materials handling to be considered are: (1) collecting manure in the shortest time after deposition, (2) conveying fresh manure, e.g., in pipelines, (3) blending manure with other feed materials, (4) transporting blended feed mixture to storage or to the utilization point, and (5) storing the manure and blended mixtures.

Second Priority--

Improve the quality or characteristics of manure through "tailoring" animal rations to increase the efficiency of the manure processing system(s) (Focus - Production).

Feeding Processed Animal Manure

The main informational voids are in the area of the effects on animal and human health. Aspects of preserving and enhancing the nutritive value and implementing the practice also require additional research.

First Priority--

1. Assess the safety of the practice by evaluating pathogens, heavy metals, pesticides, drugs, and metabolities in the wastes from commercial operations (Focus - Environmental and Educational).

2. Develop methods for processing animal waste feeds that eliminate hazards from pathogens, microbial toxins, and internal parasites (Focus - Environmental and Production).

3. Establish the concentration of mineral elements in processed animal wastes and determine the accumulation and depletion of these elements in the tissue or products of the recipient animal (Focus - Environmental and Production).

4. Determine the concentration of pesticides and drugs in animal wastes before and after processing, their accumulation and depletion in tissue, and products of the recipient animal (Focus - Environmental).

Second Priority--

Improve continuous ensiling processes for blends of livestock wastes and plant materials (Focus - Production). A major need is suitable equipment for blending and conveying products.

Third Priority--

Develop microbial enhancement processes, such as single cell protein production from animal manures and process effluents, for use as feedstuffs (Focus - Production). Process optimization, animal response, and safety must be analyzed as outlined in the preceding research needs. Processes may include aerobic, anaerobic, or photosynthetic processes.

Thermochemical Processes

Because current investment/cost benefit studies indicate that these processes will not be economical for single, on-farm installations, two research needs arise (Focus - Energy and Demonstration).

First Priority Group--

1. Design turn-key processes for on-farm applications and evaluate economics using mass-production costing which is employed by agricultural equipment manufacturers (Focus - Energy and Demonstration).

2. Evaluate the flexibility of thermochemical processes relative to user's need for gas, liquid, and solid fuels (Focus - Energy and Educational). This evaluation should include catalysis for the conversion of residues to liquid fuels.

3. Design large scale equipment which interchangeably uses all available feedstocks (manure, municipal wastes and refuse, field and gin trash, etc.). These facilities should provide a depository where the farmer can sell or have his manure pick up some amenable considerations for value vs. disposal (Focus - Energy).

Anaerobic Digestion

There is much research remaining to be performed before digestion technology can be economically integrated into agriculture. A major drawback of anerobic digestion is that the product fuel, methane, cannot be liquified at room temperatures like the longer chain alkanes, propane and butane. It is necessary to ensure that designs of on-farm digesters do not put an unnecessary management burden on the livestock producer.

First Priority Group--

1. Develop methods for utilizing methane directly or converting it into an easily stored and transported fuel (Focus - Energy).

2. Develop turn-key designs through evaluation of on-farm size units, considering management requirements and logistics of increasing waste volumes to make units feasible (Focus - Demonstration and Educational).

Second Priority Group--

1. Improve the efficiency of the digestion process through substrate utilization, diagnostic methods and auxiliary equipment.

2. Develop alternative uses of the liquid and solid residues.

Summary of Resource Recovery Research Needs

The research priority relating to materials handling relates to all the areas of resource recovery. Research on equipment development should be coordinated over all the areas. The development of turn-key systems for on-farm use should be an ultimate objective and kept in view when other research is conducted.

Some general concerns for all areas of resource recovery research are: (1) safety and health of operators, (2) optimization of energy and product recovery, (3) enhancement and protection of the environment, and (4) the economics of alternative systems particularly in relation to total farm income.

SECTION 6

CONSERVATION OF ENERGY AND NUTRIENTS IN ANIMAL MANURE MANAGEMENT SYSTEMS

This topic addresses the possibility of conserving energy and nutrients in animal manure management systems. Topic covered include: (a) the conservation of labor and input energy used to handle, transport, and manage animal manure so as to minimize the energy input to these systems, (b) the conservation of nutrients, such as nitrogen, phosphorus, and potassium, that are part of animal manure and can be used as crop fertilizers, and (c) the conservation of manurial energy and minerals. Also addressed briefly are other constituents, such as recovered solids, that may have economic and environmental value if conserved.

The topic does not address the production or conversion of energy from manures. This topic is considered in the previous section.

During the first half of this century, manure was regarded as a valuable fertilizer, and considerable research was aimed at conserving and maximizing the fertilizer value. However, large supplies of chemical fertilizers were available at about the same time, during 1950's and 1960's, that changes in the animal production industry were occurring to produce, meat, milk, and eggs more efficiently through confinement livestock production. The low cost of such fertilizers lessened the value of animal manures to the point where they were no longer considered as a resource but rather a waste not worth hauling for use as a fertilizer and to be disposed of as inexpensively as possible. During this same period, energy costs were much lower than current costs. Mechanical and electrical energy were utilized to increase animal and crop production and for environmentally sound manure management systems.

The three primary uses for animal manure are as fertilizer, feed, and energy. Other potential applications include structural products, building material, horticultural use, and various industrial products.

In considering possibilities for conservation of energy and nutrients, the technical and economic feasibility of individual components and of total systems must be examined. It is possible that the cost of conserving energy or nutrients in a particular component may be high but the application of that component may make the overall costs of energy or nutrient conservation lower. In addition, it is also necessary that there be a use for the conserved nutrients, since if they are conserved in a form or at a time that they are unable to be used, the conservation effort will be of little value.

SCOPE OF PRESENT INFORMATION

The land has been, and will likely continue to be, the most appropriate utilization method for animal manures and for the conservation of nutrients in the manures. Spurred by increased energy and fertilizer costs, the utilization of the nutrient content of manures for crop production is again being emphasized. In addition, there is the widespread recognition that the energy and fertilizer resources of the United States are finite, and that the people as a nation should utilize approaches that conserve rather than lose these resources.

The amount of energy associated with fertilizer production and the amount of nutrients in manure is significant. The total annual energy requirement for fertilizer production in the United States is about $6x10^{14}$ Btu, with nitrogen fertilizer production consuming 85 percent of that energy. This far exceeds any other agricultural activity in energy intensity. In addition, in the 1970s, the cost of fertilizers rose more rapidly than the cost of fuel or labor. The conservation of nutrients currently being lost from animal manures, and the concommitant substitution for inorganic fertilizer, can reduce the energy and energy intensive process feedstocks required for the production of chemical fertilizer.

About 4.1 million tons of total nitrogen were in manure voided by livestock and poultry in 1974. Of this amount, about 2.6 million tons remained after storage and handling losses. Of this, only about 1.4 million tons were estimated to have been economically recoverable for use elsewhere. The phosphorus initially voided, that remaining after losses from manure handling systems, and that available for recovery and use elsewhere were about 1.0, 1.0, and 0.5 million tons, respectively, for all livestock and poultry in the United States in 1974 (Van Dyne and Gilbertson, 1978). The potassium in manure voided by livestock and poultry was an estimated 2.4 million tons. About 52 percent of this amount was estimated to have been economically recoverable.

Based upon 1972 statistics, the collectable nitrogen in livestock manure was about equal to the total nitrogen in the harvested soybean crop of that year. It is interesting to note that there is considerably more emphasis placed on saving a few percent of soybean nitrogen losses when compared to the support given to minimization of the large nitrogen losses in manure.

When considering the possibilities to conserve nutrients and energy in animal manure management systems, it is important to recognize that an animal manure management system is part of an overall animal production system. Selection of a manure management system is based upon many factors, such as air and water pollution control constraints, cost, labor requirements, site considerations, land area availability for application, crops grown, system flexibility and dependability, and operator preference. <u>There is no single best system for a specific type of animal production or for a specific climate or geography</u>. Each system has advantages and disadvantages that must be considered for a specific production operation.

The following areas of information which are commonly considered to be known include:

1) manure management systems by commodity and region;

2) quantity and constituents of manure and associated animal wastes (urine, bedding, milking center wastes, etc.);

3) general costs and energy requirements of system components; and

4) general nutrient losses that occur in the management systems.

Caution should be used, however, in indicating that adequate details are known about the above items. Unfortunately, the information is known primarily in general terms from limited studies.

While some of the quantity and quality values are known for fresh manure and extraneous material, little real knowledge is available concerning the actual characteristics resulting form existing management systems. The operation of each management system varies and so will the resultant characteristics of the wastes. The quantity and quality is related to the feed and water intake of the animals as well as to the type of management alternatives.

Comprehensive research to identify the effect of feed, water, housing, climate, and management on waste characteristics, energy use and nutrient conservation is not recommended due to the cost and difficulty of such research. However, to the extent possible either in each research project, actual situation, or published report, information on the detailed waste characteristics, energy use and nutrient conservation should be determined, discussed and interpreted in terms of these variables. Too often data on these items are reported sparsely and are rarely related to management conditions.

RESEARCH NEEDS

The research needs are formulated to acquire the unknown but required information that can identify the quantity of energy and nutrients that can be conserved as part of manure management systems and the cost of that conservation. Such information can be used to develop processes and systems that are compatible with animal production systems. In addition to conserving energy and nutrients, these processes and systems must be environmentally sound in other aspects, must result in an economically viable production system, and should enhance the overall energy efficiency of the total production system.

The research needs that were identified are briefly described below.

In addition to the technical research activities that are described, labor and other management considerations should also receive careful evaluation as follows:

1. the skill and time needed to manage the "better" conservation approaches;

2. the ability to integrate such approaches into existing animal production systems and practices;

3. determination of management techniques necessary to achieve maximum energy and nutrient conservation for different systems;

4. documentation of effects of poor nutrient and energy conservation on production economics; and

5. interaction of manure management systems, environmental requirements, energy use and economics on utilization of manures.

In each of these research areas, there must be appropriate multidisciplinary inputs and activities to develop the necessary results.

First Priority Group

1. Determine the fundamental factors affecting energy use and nutrient conservation (Focus - Environmental and Production).

   This information is needed to identify the type of nutrient losses and energy use that occurs in a manure management system, the processes to which conservation approaches should be best applied for maximum benefit, the type of conservation that may be considered, and the alternative approaches that can be used. Conservation of the maximum amount of nutrients for subsequent use reduces the threat of air and water pollution from uncontrolled entry of these nutrients into the environment.

   Specific needs that can be included under this area of need include:

   a) losses of nutrients such as nitrogen in different handling, storage, and land application units or systems;

   b) effect of bedding on nutrient retention, energy for handling and transport, and ultimate impact on animal health and product quality;

   c) relative amounts of labor and input energy required per animal unit per unit time for all waste handling and management operations for different production conditions;

   d) comparison of the costs of different energy forms--petroleum, electrical, etc.--needed for specific tasks and for alternative equipment that can accomplish those tasks;

   e) biological, chemical, physical mechanisms affecting the conservation of nutrients; and

f) effect of time, climate, feed, types of bedding, water use, and management alternatives on energy use, manure nutrient content, and nutrient conservation.

2. Conduct a state-of-the-art analysis of energy use and nutrient conservation possibilities (Focus - Environmental and Educational).

There is a diverse amount of information on the energy use and nutrient conservation that accompanies currently used and other possible waste management components and systems. This information should be assembled and critically analyzed to ascertain the amounts of energy and nutrients that can be conserved and identify the more feasible possibilities. This analysis should be done for different commodities and management possiblities.

These analyses should include:

a) a summary of the cost associated with specific manure management possibilities that enhance conservation;

b) an estimate of the amount of nutrients and energy that can be conserved with utilization of "better" conservation approaches throughout all components of a system; and

c) the possibilities of utilizing the conserved nutrients.

The analysis should be assessed on the basis of possible management systems and on the basis of specific topics such as:

a) nutrient conservation--handling, processing, economics, energy, nutrients, size of operation, type of animals, general management options, technical components, environmental impact, and acceptance by users and the public;

b) energy conservation (handling, processing, etc.); and

c) manure as a feed source (handling, processing, etc.).

3. Evaluate available models for manure application to land and for economic analysis of livestock waste management systems (Focus - Environmental and Production).

The available analytical, predictive, and management models greatly enhance the opportunity to make maximum use of nutrients and energy in livestock waste management systems, thus minimizing uncontrolled discharge to the environment. For widespread use of the models, the assumptions and coefficients need to be verified and calibrated under different climatic and management conditions. Perhaps as many as eight separate studies, with different commodities, in different parts of the United States should be conducted. The studies should include energy inputs, specific costs, types of soils and crop yields, environmental impacts, and feed and waste characteristics. The studies should be conducted on a large enough scale to obtain realistic data.

4. Demonstrate the better components/systems for energy and nutrient conservation as related to animal waste management (Focus - Environmental, Production, Educational and Energy).

   There are several components and/or systems for waste management that can be used now to demonstrate the better approaches for nutrient conservation and energy use. These should be demonstrated at either actual or experimental farms generally on a "side-by-side" situation to obtain reasonable comparisons and meaningful cost and conservation values.

   Such possibilities include:

   a) methods of loading and unloading storage units to maximize nutrient savings;

   b) incorporation of manure handling with irrigation water;

   c) nitrogen losses in land application - surface spread vs. immediate incorporation - with differences evaluated by crop yield comparisons;

   d) variations in collection and storage systems - more frequent manure removal and handling; covered and uncovered storage; flushed vs. scraped manure systems; and

   e) effect of bedding and types of bedding.

<u>Second Priority Group</u>

1. Evaluate the utilization of conserved nutrients when applied to land (Focus - Environmental and Production).

   Incorporation of animal manures and conserved nutrients in land for crop production continued to be the most appropriate approach to use the constituents in the manure. Consideration must be given to the ultimate use of the conserved nutrients, since if they are conserved in a form or at a time that they are unable to be used, the conservation will be of little value. In addition, the cost of energy required to conserve and use the nutrients should not exceed the value of the conserved nutrients. Desirably, the cost of the energy to conserve the nutrients should be considerably less than the value of the conserved nutrients.

Possible topics included in this need are:

a) an analysis of the energy required to conserve the nutrients, when the energy is needed, the form of the energy, and the competition of the energy supply with other energy demands, such as planting or harvesting;

b) storage and timing interrelationships (timing of application) to obtain "best" crop response;

c) comparison of the various techniques to handle, transport, and apply the manure (comparison of energy used to nutrients conserved);

d) amounts of chemical and biological forms of nutrients that can be recovered from all manure handling systems (animal to crop) and their component parts (i.e., animal to collection, collection to storage, etc.);

e) energy use and nutrient concentration at various points in manure handling and storage systems;

f) methods available for enhancing nutrient retention--anaerobic storage, plow-down, injection, etc. Evaluation of energy required to conserve nutrients.

g) availability of manurial nutrients (especially nitrogen) to plants once material is on or in the ground. Nutrient retention during application should be determined; and

h) energy required for system components--for conservation, utilization, and pollution control.

2. Develop/improve equipment for handling of "as-produced" manure (Focus - Production, Educational, Environmental).

There is a need to develop better energy efficient equipment to handle as-produced manure for large and small production units. Such equipment is needed to collect, mix, transport and apply manure.

This equipment should minimize soil compaction, promote more uniform distribution when the manure is applied to the land, and enhance nutrient retention.

Included in this development is the need for better information on the physical properties - size of particles, viscosity, etc. of the manure to be handled. Also included is the feasibility of feed additives and ration balancing to enhance the dry matter content of manure and the ability of handling the manure as a solid.

3. Development management and system specification recommendations so that producers can obtain minimum energy use and maximum nutrient conservation in manure management systems (Focus - Educational).

   Included in this need are techniques to measure actual energy use with available equipment, scheduling of equipment, desirable integration of system components, duration of use, integration into cropping programs, etc. The information should be presented in bulletins and short courses.

Third Priority Group

1. Identify institutional constraints to the adoption of "better" energy and nutrients conservation approaches (Focus - Environmental and Education).

   Even though better conservation approaches may be developed and are shown to be cost effective, they will have little effect until they are adopted. An analysis needs to be made to determine what, if any, institutional constituents may restrain or delay such adoption. When such constraints become known, efforts can be made to reduce or eliminate them. Such constraints may be (1) inadequate transmission of the available information, (2) traditional use of alternative energy or nutrients, (3) inability to use the technology with curcurently sized animal production units, or (4) lack of capital to purchase, install, or modify existing equipment or facilities.

2. Evaluate the environmental impact of volatile compounds and gases lost from animal production systems (Focus - Environmental).

   Large amounts of volatile compounds and gases - such as ammonia, amines, nitrogen oxides - are lost from animal production systems. To date there has been no detailed assessment of the impact these compounds have on the land, crops, water, and animals when they are ultimately deposited, nor on the atmospheric reactions related to smog or ozone depletion. Positive and negative impacts can be speculated. However, the magnitude of the different impacts is not known but needs to be understood to estimate the priority and resources needed to reduce the losses from the environmental standpoint. This research need is apart from the odor implications discussed in Section 8.

3. Develop and evaluate processes for capturing volatilized ammonia (Focus - Environmental and Production).

   Ammonia will volatilize and may result in environmental problems within confined animal production buildings and adjacent to such buildings. The ammonia could be recovered from the off-gases or any liquid wastes and stored for use at an appropriate time in crop production.

4. Assess the energy use and nutrient conservation with "non-traditional" commodities (Focus - Environmental and Educational).

Considerations of energy and nutrient conservation center on beef, dairy, poultry and swine facilities since these are the major animal production commodities. However, there are other animal production operations that also lose nutrients and may be inefficient energy users. An analysis of the nutrient and energy conservation possibilities in these commodities is warranted to place the magnitude of such losses and inefficiencies in national perspective. These "non-traditional" commodities include: horses, sheep, ducks, rabbits, fur-bearing animals.

5. Assess the recovery of fibrous residues for bedding and horticultural use (Focus - Environmental and Production).

In addition to nutrients, there are other resources that can be recovered from animal manures. These include:

a) use of separated or composted solids for bedding, and

b) recovery of separated residues for horticultural use on parks, for plant mulch, or for growing seedlings.

This need would include an assessment of potential markets, possibilities of product uniformity and quality, impact on plant and animal health and environmental quality.

SECTION 7

LAND APPLICATION OF ANIMAL MANURE AND WASTEWATER

The return of animal manures to the land represents the completion of a natural recycling process. The biological, chemical, and physical properties of soil provide an excellent treatment facility for biodegradable wastes.

Methods of application of manure depend on the crop and the type of manure. Solid, slurry, or liquid manure may be spread on the surface and incorporated. Liquid manure may also be applied by irrigation, usually through a big gun-type sprinkler. The method chosen will depend on the nature of the site, the state of the material, and the crop that is being fertilized. For conservation of nitrogen, surface application is not recommended because ammonia is volatilized. Immediate incorporation conserves most of the nitrogen and is recommended where practical.

The quantity and quality of manure available for land application depends on the type and number of animals, ration fed, manure management system and climate. The USDA, Economics, Statistical, and Cooperative Service reports the number of animals, and many publications give estimates of the manure produced by each animal. A recent summary of animal waste utilization on crop and pastureland was prepared by the EPA and USDA (in press).

Generally, animal manure contains the elements essential for plant growth. The rates of manure applied usually are based on its nitrogen and salt content. Therefore, chemical analysis should be obtained because the nutrient and salt content varies with management.

In humid areas where salinity is not a problem, adequate manure may be used to supply the nitrogen required by the crop. However, in areas of low rainfall or irrigated areas, salt concentrations must be considered so that salinity will not become the limiting factor in crop production. In irrigated areas sufficient irrigation water must be applied to move the salt below the root zone.

Phosphorus and potassium are usually in excess when adequate nitrogen is applied. This excess phosphorus and potassium usually does not cause problems because phosphorus is immobilized in the soil and plants do not accumulate toxic quantities of potassium. However, forages grown where nitrogen and potassium are both high may cause nutritional problems (grass tetany) in pregnant or lactating cows. It may be advisable to apply manure according to the phosphorous or potassium needs of the crop and add commercial nitrogen.

The season of manure application is often partially determined by storage facilities and other critical farm operations. Pollution concerns are also involved in timing manure applications with regard to probable periods of frozen ground, intense rainfall, runoff and soil loss. Surface application of manure in the fall or winter usually decreases the amount of runoff and sediment loss. However, the total amount of nutrients lost usually increases.

SCOPE OF PRESENT INFORMATION

Historically, livestock manures were not considered a problem. With increased use of confinement livestock operations, large amounts of manure are concentrated, resulting in environmental problems with water pollution, flies, dust, and odors. Results of research on land application of manure are discussed under the broad topic outlines of soil system, plant system, animal system, and hydrological system.

Soil System

When manures are applied to the soil system, several biological, chemical and physical properties of the soil are affected. Application of wastes is affected by four design criteria: (1) organic loading, (2) nutrient loading, (3) salinity, and (4) soil physical properties.

Organic Loading--

The capacity of the soil (and its microbial population) to decompose large quantities of non-toxic materials, primarily of a polysaccharide nature, is well documented. The carbon/nitrogen ratio (C:N) of the waste material often dictates the rate and extent of decomposition. The rate of waste decomposition is apparently not affected by the amount of organic loading (Mathers and Stewart, 1970). Calculations of probable organic matter losses suggest that soil type and climate affect decomposition rates of organic matter.

If large applications of organic matter are made, depletion of soil oxygen and resulting anaerobic soil conditions are potential considerations. Potential effects of anaerobic soil conditions on the animal waste constituents and the soil are described by Parr (1974).

Nutrient Loading--

Nitrogen--Nitrogen in animal wastes exists in several forms which can be conveniently classified as organic or inorganic nitrogen. The organic forms require mineralization (ammonification and nitrification) before becoming available for crop intake, or for movement from the root zone of crops. The inorganic forms, NH_4-N and NO_3-N, occur in varying quantities in animal wastes and wastewaters.

Mineralization of nitrogen is crucial in ascertaining the effect of animal wastes applied to the soil. When only a part of the manure decays the first year, there is a considerable residual effect. When manure is incorporated into soil at the nitrogen rate needed by the crop, nitrate accumulates in the soil profile and leaching is minimal.

Pratt et al. (1976) in California measured mineralization rates of manure nitrogen at 45 percent in the first year, 10 percent of the residual nitrogen in the second year and 5 percent in the third and fourth years. There are different mineralization rates reported in other research. These differences may be due to the forms of nitrogen in the manure, climate, and/or soils.

Denitrification is another process whereby manure nitrogen is lost from the soil. It occurs when microorganisms utilize nitrate nitrogen as an electron acceptor during their respiration in the absence of molecular oxygen, thus releasing gaseous forms of nitrogen, such as N_2 and N_2O. Favorable conditions for denitrification can be created, when animal wastes are applied on soils with heavy texture and poor drainage. Oxygen depletion and denitrification can occur at micro sites within the soil. Nitrification will not occur in the same sites where denitrification occurs, because the first process functions under aerobic conditions, whereas the latter process functions under anaerobic conditions. In soils treated with animal wastes aerobic and anaerobic conditions can exist, enabling nitrification and denitrification to occur at the same time (Reddy and Patrick, 1975 and 1976). Little work has been done to measure denitrification losses under field conditions in soils treated with animal wastes, possibly because of the difficulty in measuring the gaseous end products under field conditions.

Ammonia volatilization is known to be a significant mechanism for losses of manure nitrogen. It is particularly important in surface applied manures (Lauer et al., 1976). Very little work has been done to estimate the nitrogen losses as a function of climate.

Phosphorus and potassium--Research has been conducted to establish levels of phosphorus and potassium accumulation on manured soils at various depths. Levels of phosphorus and potassium higher than needed for optimum yields have occured but with little downward movement. Lateral movement of phosphorus and potassium occurs with sediment in runoff waters.

Salinity--

In areas of heavy rainfall and natural leaching, salinity is not a problem. However, high rates of manure on soil in areas of low rainfall may cause salt problems that reduce germination and seedling growth. When lagoon water is used for irrigation, dilution with low salt water or limited applications may be necessary. Analysis of lagoon water for salt concentrations is essential to determine the irrigation management necessary to prevent crop damage. Long-term effects of animal manure application rates on soil salinity have not been defined or evaluated.

Soil Physical Properties--

Application of solid wastes usually improves the tilth of soils. However when excess salt is applied with lagoon water, soil structure may be weakened, water intake rates decreased, and crusting problems become severe.

Plant System

Crop yield and quality depends on an adequate but not excessive supply of the essential plant nutrients. A deficiency or excess of one element in a plant will cause a chemical imbalance which generally reduces crop yield.

Manure application rates have been evaluated at several locations in the United States. Research data are conflicting as to what rate gives optimal crop yields and what rate suppresses plant growth and yields. Factors causing these differences are in part due to the location but also to manure management methods. A need exists to coordinate, standardize and integrate ongoing research on this topic.

High application rates of manure nitrogen result in excess nitrate in the soil. Excess nitrate will reduce sugar yields from beets. High ammonia levels in soils with high manure application rates, have been found to inhibit germination and plant growth. Normally, when manure applications were discontinued, seed germination and crop growth returned to normal the second year.

Animal System

The short-term and accumulative effects of animal consuming crops grown on land that has received animal manure are addressed in this section.

Nitrate Toxicity--

Nitrate accumulation in forages in response to high applications of manure is well documented. Experimental results reporting direct nitrate toxicity in animals grazing heavily manured forages is lacking. There are reports of nitrate toxicity on commercial farms, some of which have been confirmed to be nitrate toxicity by veterinarians. It is clear, however, that high rates of manure can help set the stage for environmental stress to precipitate a toxicity problem. An excellent summary of the nitrate problem is presented by the National Research Council (1972).

> "Forage plants may accumulate significant quantities of nitrate when grown under drought conditions in soils rich in nitrogen, and these plants may cause death of livestock. The extent of these losses depends on the level of nitrogen in the soil, the species of plants, the stage of maturity of its plants, the severity of the drought, the prior condition of the exposed animals, and the management practices of the livestock producer."

If the silages are made from crops containing high nitrates, there is also the potential problem of nitrate accumulation and evolution of nitrogen oxides during fermentation. These gases may be released from silage and may cause death to farm workers or to animals confined near the silos (National Research Council, 1972).

Grass Tetany--

Grass tetany is a metabolic disorder of cattle and sheep whose daily consumption of available magnesium is too low. Many factors have been associated or thought to be involved in the occurrence of grass tetany. These include temperature, rainfall, cloudiness, type and availability of forage, soil conditions, nitrogen and potassium fertilization, age, and reproductive status of the cow, and the cow's production level. Reports of cattle losses attributed to grass tetany on cool-season pastures heavily fertilized with poultry litter were confirmed by a grazing study to determine the effect of heavy broiler litter fertilization on the incidence of grass tetany (Stuedemann et al., 1975).

Grass tetany is not known to be a problem with warm season grasses, except in low magnesium corn silages. Silages can be supplemented with magnesium to overcome the problem. Forage analyses for total nitrogen, calcium, potassium, and magnesium can indicate the approximate potential for grass tetany.

Tall Fescue Toxicity--

Tall fescue is grown on about 17 million acres in the mid-south region from Missouri to the Atlantic Ocean. Tall fescue toxicity is known to occur in animals grazing it. Some of the symptoms include lameness in hind quarters, poor appetite and subsequent loss of weight and foot problems. Fat necrosis (hardfat) was recognized as a herd problem of mature cattle grazing tall fescue heavily fertilized with poultry litter in the north Georgia area.

Are there other grasses used or recommended for waste disposal where these or other kinds of problems may be expected in utilization of forage? The combination of excessive and/or unbalanced mineral nutrition and its effects on chemical composition of forages and the grazing of monocultures, may create undesirable accumulative effects on animal performance and health. Short-term studies on digestibility and intake may not reveal these problems but commercial producers may experience them. Nutrient recycling from grazing cattle may also contribute to the problem by permitting differential buildup of plant nutrients such as phosphorus and potassium over that expected from a hay or silage harvest system.

Parasitism and Pathogens--

Research to date indicates some parasitism of animals grazing manure fertilized pastures. This subject requires further investigation.

Several reports indicate a minimal disease potential from animal manure application to land. It is generally accepted that cattle can safely graze disposal areas 2 to 3 weeks after manure application. Much conflicting data exist concerning the survival rates and mobility of pathogens in soils.

Toxic Metals--

Some producers supplement their livestock feeds with trace elements, e.g., copper, arsenic, zinc. It is not expected that problems would arise in using grain grown in soils fertilized with manure from animals fed trace elements at recommended levels. Research to date has not shown manured forages to cause metal toxicity to animals.

Hydrological System

The changes in stream water quality and possible pollution of water supplies have been investigated at several locations in the United States.

Runoff--

Application of wastes to land can affect the quality of subsequent runoff from those lands. This is referred to as non-point pollution. The climate of the area, the soil type, the form of the waste (liquid or solid), and the method of application will affect the quality of the runoff. Increases in BOD, nutrients and coliform count have been substantiated in runoff from manure covered land. Generally, higher application rates gave greater pollution potential.

The season of manure application is partially determined by storage facilities and timing of other critical farm operations. Pollution concerns are involved in the timing of the manure applications with regard to periods of frozen ground, intense rainfall, runoff and soil loss. Fall and winter manure applications are subject to snowmelt runoff in cold climates, which may constitute as much as 60 to 80 percent of the annual runoff. Winter manure applications have been researched with differing conclusions as to quantity of snowmelt and runoff occuring. There is general agreement that winter manure applications give greater losses of nitrogen and phosphorus.

Spring manure applications can have a major impact upon runoff quality and soil losses. Nutrient losses in the spring are usually associated with soil sediment losses.

Because nutrient losses from land disposal areas are so strongly related to sediment transport from watersheds, a method for predicting erosion from watersheds is needed. Perhaps the best known empirical sediment transport model is the Universal Soil Loss Equation (USLE) developed by Wischmeier and Smith. However, it is one-dimensional in nature and does not consider changes in flow direction, land slope, and flow velocity on the watershed. Kuh and Reddell (1977) have recently described a two-dimensional erosion model which predicts the total amount of erosion from a watershed and the areal distribution of erosion and sediment deposition.

Ground Water--

When manure or wastewaters are applied to land the dissolved chemical constituents may be leached into groundwater aquifers. With manure applied to a soil having moderate to rapid internal drainage, nitrates, chlorides and fecal coliform counts have been shown to increase markedly. Under saturated soil conditions, the nitrate level decreased. Continued high applications of manure slurry to the soil can contaminate the shallow groundwater.

RESEARCH NEEDS

First Priority Group

1. Characterize the nitrogen and other nutrient transformations (including mineralization and losses) that take place in manure and soils as they are influenced by handling methods, soil types, crops and climate (Focus - Environmental, Production, and Energy).

   There is a need for a better understanding of what happens to nutrients in manures to be able to estimate the environmental impact from applying manure to the land. Also, the conservation of the nutrients could be enhanced. If the amount of nutrients available to crops from manure could be reliably predicted, a farmer could then use less commercial fertilizer than he would presently use. Part of this research priority should be to develop a predictive model for use by farmers when applying manure to cropland.

2. Evaluate the environmental impact of runoff from manured cropland on receiving waters as influenced by method of application, tillage and soil conservation practices (Focus - Environmental).

   Much of the research to date on this topic has been done on plots and in a few cases on single fields. The same data are needed for watersheds. Also, the data to date have been taken at the edge of the plot or field. This needs to be extended to the receiving water and include an evaluation of the transport mechanisms and the effect of tillage or soil conservation practices, e.g., buffer strips, no-till, etc. Most soil conservation practices are oriented to erosion prevention and need to be evaluated with respect to nutrient transport.

   Part of this research area should be to adapt existing hydro-chemical models to predict effects of runoff from manured land on receiving water quality.

3. Extend models of cost analysis to complete manure systems by regions and by animal species and to include impact on the environ-ment. (Focus - Production, Educational and Environmental).

   The purpose of these models would be to help producers make decisions on manure handling methods in relation to economic returns and quality of the environment. The complete systems referred to would include manure handling methods, time and labor constraints and crop production. The economic benefits of manure on soil should include aspects other than crop yield, e.g., erosion reduction, improved soil tilth, etc.

   The model should consider the relationship between apparent manure nutrient values and actual production yields from commercial fertilizer. The cost/benefit ratio for alternative application systems versus environmental effects should be incorporated into the model. Also, the impact of energy in evaluating the supply/demand relationship of commercial fertilizer and manure should be included.

4. Establish critical application rates of nitrogen, phosphorus, potassium, and micro nutrients in manure in relation to plant uptake of these elements and quality of forage or grain (Focus - Production and Environmental).

   Imbalance of nutrients in manures as related to plant need lead to excess application of certain elements, e.g., applying fertilizer based on nitrogen needs of crop will frequently give excess phosphorus or potassium. The potential effects and management requirements of excessive application of certain elements need to be determined. The organic matter in manure is an excellent chelating agent for some micro nutrients and may restrict their plant uptake, e.g., zinc.

Second Priority Group

1. Determine the impact of increased infiltration due to manure applications on soils and upon the amount and quality of leachate leaving the plant root zone (Focus - Environmental).

   Research had documented that manure covered soils have a greater infiltration rate. Nutrient and salt content of leachate from manured soils are known to increase under certain conditions. There is a need to develop a model(s) to predict the volume, rates and quality of leachate as well as the probability of occurrence.

   In dry and arid regions, salt management by leaching is essential to maintain soil productivity. The nutrient load on these soils is important to irrigation and soil management. An understanding of the interactions between manure nutrients, commercial fertilizers, infiltration of rain or irrigation water will help to minimize the loss of nutrient from the root zone and control ground water pollution.

2. Optimize manure application methods and systems (Focus - Production, Educational and Environmental).

   There is a need to match equipment to manure handling properties and operating conditions to insure uniform application on fields. Manure properties vary due to animal species, housing, bedding regime, and waste handling system (liquid, slurry or solid). Performance evaluation of equipment is needed to establish criteria for development.

   Included in this topic should be evaluation of management options to control odor, e.g., injection or plow-down.

Crop yields should be maximized and nutrient losses minimized through matching how much manure is applied in relation to holding capacity of the soil, the needs of the crop and environmental impact. Cost of alternative unit operations should be considered.

3. Determine the influence of manure on soil properties, in particular physical characteristic and erodability (Focus - Environmental and Production).

   Many soils in the United States with decreasing organic matter content are experiencing reduced water intakes from rain or irrigation. Also, increased compaction problems from use of machinery are occuring. The physical characteristic to be monitored should include at least the following: tilth, structure, water holding capacity, infiltration rate and compaction. There is need to determine how nutrients and manure particles are transported within the soil and attached to soil particles. The effect of organic solids on soil properties needs to be studied as related to erodability.

Third Priority Group

1. Improve sampling and analytical procedures to accurately characterize manure, lagoon wastewaters/sludges and runoff waters used for application to cropland (Focus - Environmental and Production).

   Parameters to be considered are nutrients, metals, and organics.

2. Characterize the fate of pathogens and parasites, toxic substances and complex organic compounds when applied to soil and plant systems (Focus - Environmental).

   Pathogens and parasites have generally not caused problems, but researchers, veterinarians and sanitarians should be able to predict and avoid problem situations. Concerns with the potential for animal disease transmissions from forages or manured soils lessen the demand for manure and/or restrict its application in isolated situations. Some regulatory personnel remain skeptical about the alleged safety of manure from a pathological standpoint.

3. Investigate potential utilization by land application by by-products from other manure uses (Focus - Production).

   An example would be slurries from biogas (methane) digesters.

4. Measure the effect of non-uniform manure applications (distribution) on cropland (Focus - Environmental).

   Local overloading of soils may occur due to poor spread pattern of equipment, improper management decisions on where to spread or transport by runoff. There is a need to evaluate local overloading of soils and the effect upon the soil and crops. This should address solid and liquid application methods.

GENERAL NEEDS FOR IMPLEMENTATION

Implementation programs must include best management practices that are designed to be regional specific. Guidelines should encourage applications of manure to the land in such a manner as to promote maximum nutrient recycling and insure environmental protection.

Education is the primary link between research and user acceptance. Extension teaching programs must center around methods of encouraging the use of periodic soil testing to define supplemental plant nutrient needs and to stress how the nutrients in manure can best be used to meet plant requirements. The importance of an educational program was recently noted in the report, Opportunities for More Effective Use of Animal Manure (Staats, 1976).

Demonstration programs are among the best methods available to promote well founded ideas. Simple and straightforward demonstration projects should be established in key locations that clearly define the value of manure as a source of fertilizer. These demonstration experiments should be kept current with the latest results of research. Tours of the demonstration areas should be conducted periodically to constantly remind users of the benefits of proper manure management practices from an economical and environmental standpoint.

Programs should be designed to encourage an increased working relationship between agricultural extension services, the SCS, soil and water conservation districts, regional planners and industry representatives. Collectively, these groups should make a concerted effort to work closely with individual farmers on proposed methods to encourage efficient use of animal manures. The programs should stress the adoption of best management practices instead of regulatory policy to improve environmental quality.

A current barrier to both the developmental and implementation processes is a need for data banks of known information and a retrieval system that will make this information readily available to those who have need for it. It would require a simple, uniform system of entering information as it becomes available, classifying and cross-referencing it according to specific subject areas, and a simple, uniform retrieval system. This would be extremely valuable for researchers, extension agents, planners and decision makers at all levels of government. It would be useful to public and private organizations in providing direct technical assistance and advice to farmers and feedlot operators.

In order for a practice to be fully accepted by agricultural producers, sound reasons for its necessity must be shown. This approach should include clear, concise, and well documented reasoning as to why a problem exists and how the farmer plays a key role in helping to correct a given problem area.

The development of farm management practices that are known to be instrumental in improving environmental conditions for society, should, if possible, be designed to provide for an economic advantage to the farmer. In order for a practice to be readily accepted, it must clearly show a savings in one or more of the following areas: (1) labor costs, (2) maintenance costs, and (3) purchased commodities (i.e., fertilizer, fuel, feed, etc.).

Additionally, the formulated practices must be designed to fully integrate into existing farm management systems. That is, competition for land, labor, and machinery should be kept to a minimum and the practice should fit the current cropping system as closely as possible.

SECTION 8

ODORS: CAUSE AND ABATEMENT IN ANIMAL PRODUCTION

Large quantities of manure are deposited within confinement livestock and poultry operations. Under typical moisture and temperature conditions this manure is subject to anaerobic decomposition processes. Volatiles released cause odor problems. Under dry conditions dusts may be generated which contribute to nuisance conditions.

Odor nuisance is the primary complaint received by the confinement livestock and poultry producer. While the total number of people offended by livestock odors is relatively small, the potential repercussions are great. A few odor nuisances or air quality violations can easily be transformed into odor regulations which place physical and financial restrictions on all producers in a region or state.

Court decisions based on nuisance statutes or specific air quality control regulations threaten livestock or poultry producers. These decisions require costly changes in the operation which can force the operation out of business.

Four specific types of facilities or areas associated with livestock production have been identified as sources of odor: (1) open feedlots, (2) buildings in which animals are confined, (3) lagoons, storage pits, basins and ponds, and (4) land used for application of accumulated manure. Individual livestock facilities may require specific odor control recommendations based on the species of animal, the period of odor release, the intensity of the odors at any one time or other site factors such as topography and weather patterns.

In addition to the nuisance aspect of odors associated with livestock and poultry production, there is logical concern with the health and safety implications of the gases, dusts and aerosols emitted. Many of the identified volatile components are known to be acutely toxic at higher concentrations than normally encountered. Under certain management conditions, e.g., agitating a manure pit, livestock deaths have occurred. However, little is currently known of the effects of long-term exposure to lower concentrations. Dusts are of concern as respiratory irritants and carriers of more harmful constituents. Aerosols from manure treatment and handling processes are known carriers of potentially pathogenic organisms, yet little direct evidence of health impact has been documented. Reports of increased respiratory sensitivity and allergenic reactions to livestock environments are of concern.

Significant quantities of ammonia and amines volatilize from confined animal and poultry areas and waste management areas. These compounds are absorbed by surface waters increasing the nitrogen content of the waters. There is evidence that, in addition to eutrophication, amines can influence the flora and fauna of surface waters. Information about the quantities and kinds of nitrogen compounds that may be absorbed by surface waters from animal feeding activities is lacking.

Economic and energy conservation considerations are important aspects of research needs associated with odor management. These considerations must be applied to the entire animal enterprise since more fragmented appraisals would be misleading.

SCOPE OF PRESENT INFORMATION

Measuring and Evaluating the Nature of the Problem

Measurement Techniques--

Odor evaluation and odorant measurement have been used to study air pollution from livestock and poultry production units. Odor evaluation has been based on olfactory measurements by odor panels with investigation of odor strength and odor acceptability. Analytical measurements of the concentrations of the odorous gases, e.g., ammonia and hydrogen sulphide, have been made.

Olfactory evaluations have inherent variability due to sampling problems and difference in individuals' assessment. Techniques such as rating, ranking, forced choice and dilution have been used. Since these techniques were adopted from the food industry their application to the evaluation of odors from livestock production units has had limited success. Variations of techniques introduced by experimenters to meet specific needs have led to no standard method being used. This, in turn, has led to the inability to compare experimental results between researchers. Statistical analysis of data is part of the basic requirement for olfactory evaluations. Differences in the extent of its use has further confounded the problem.

Gas liquid chromotography (GLC) has been the primary method for identification of odorants. The technique has led to the isolation of approximately sixty odorous compounds in the gases emitted from livestock production units. The procedure has limited sensitivity. Minimum detectable levels of five ppm hydrogen sulphide are 10,000 times greater than that sensed by the human nose. Consequently, gas collection and concentration methods are required prior to analysis. The inadequacies of selective concentration and the inability to specify and agree on indicator odorants have restricted the use of this technique.

The value of standardized odorant measurement would be realized if it were correlated with standard olfactory odor evaluations. These correlations would eliminate the need for expensive, tedious and time consuming odor panels in evaluating odor control alternatives. Little work has been reported in this area and its usefulness will be limited until the correlations can be based on repeatable, standardized procedures.

Background Information--

Needed background information from livestock production units are odorant evolution rates and acceptable odor levels measured by standardized techniques. Ammonia evolution rates from cattle feedlots have been measured. Evolution data for other major odorants from waste management regimes and livestock species are not available. This information is required if studies on the health and safety of operators and evaluation of odorant removal systems are to have widespread significance.

Acceptable odor levels at specified distances from livestock operations have not been established. If regulations are to be established for the protection of the producer and the public and comparisons made between the effectiveness of various waste management systems, this background information is needed.

Transport and Duration--

Transport and duration of odors have been recorded in isolated and uncontrolled conditions when complaints have been lodged against producers. The influence of climatological factors, the impact of vegetative screens and the influence of particulate matter (dust) on odor transmission are not well documented.

Theoretical estimates of climatological effects such as temperature, humidity, wind speed and direction may be made from the technology currently available in other industries. Similar estimates may be made on the role of particulate matter in the transmission of odors. However, the specific relationships of these factors to livestock odor problems and the interaction of vegetative screens is required.

Developments in Odor Control Technology

Completed research dealing with odor control technology includes a broad range of chemical treatment, biological processes, physical conditions and management techniques. Primarily, open feedlot and confinement housing odor control techniques deal with the chemical and physical properties of the waste. A number of "deodorants" have been tested on feedlots and, almost without exception, no satisfactory, reproducible results have been obtained. The primary reason is that weather conditions and waste characteristics vary greatly.

Confinement housing usually involves liquid waste handling although some scrape-haul solid handling systems exist. For liquid systems, pH control, aeration and temperature control all have been demonstrated technically effective. Economic considerations have not been well documented. Again, the solid systems, because of the usually low moisture content, have shown considerable advantage in relation to odor control.

Control of odors from lagoons and storage pits, basins, ponds or tanks has been difficult in the past. Proper design and management techniques offer only effective odor control at present, especially for anaerobic lagoons and storage units. Disinfectants have proved of little value. Enzyme treatment and modification of feed additives have shown mixed results with type of waste being the most important variable. Management techniques, including emptying pits and loading lagoons at optimum times, are affected by climatological conditions.

The management of land application practices offers an effective means of odor control. Land application usually comes after treatment in lagoons or storage in ponds, pits, basins, or tanks. Odor potential is great. Monitoring climatological conditions and making waste management decisions minimize odor problems. Applying manure or wastewater when wind conditions promote dilution or carry odors away from neighbors, will reduce odor problems. Immediate soil incorporation through a tillage operation or injection has avoided odor problems.

Health Impact of Odors and Odorants

Data exist which indicate the lethal and inhibitory concentrations of various gases for man and livestock species. Similarly, there are dust levels which have proven hazardous to human health. Data do not exist which define the human health or livestock performance inhibition due to combinations of dust and mixtures of gases at concentrations below those known to be toxic. The frequent experience of persons working in confinement livestock and to poultry buildings is one of increased respiratory sensitivity and allergenic type reactions. Research is needed to define these health impacts and suggest the appropriate safety measures whether they be dust filters or more elaborate forms of human protection. Alarms and other warning devices would also be indicated if the necessary relationships were established.

Although there are little definitive data currently available, the physical and mental health of persons living immediately adjacent and downwind of animal facilities is of concern. Such persons may be exposed to low levels of toxic gases, airborne dusts, aerosols and odors on a nearly continuous basis. Aerosols and dusts have been documented to concentrate odorants and microorganisms indicative of fecal contamination. Complaints of agrieved persons have included headaches, nausea, and respiratory irritation. If these symptoms are validated, the use of air scrubbers, particle filters or other devices may be indicated.

Effects of Odorants on Water Quality

Recent studies have initiated concern for water quality in the vicinity of large animal feedlots. Volatilization of nitrogen and its transport in the atmosphere to water bodies has been verified. Eutrophication is a threat, and continued study of this facet of feedlot operation is important. Technology for the control of nitrogen emissions from feedlots, is, at lease in part, available.

RESEARCH NEEDS

First Priority Group

1. Locate all foreign and domestic research on odor identification, measurement and control for all odor sources so that successful techniques may be adapted or altered for use with animal manure odors (Focus - Environmental, Educational and Production).

2. Standardize the measurement and evaluation of odor (Focus - Environmental).

   This research priority needs to address three aspects:

   a) Measurement techniques: standardized organoleptic odor evaluation, standardized objective measurement methods for indicator odorants and correlation of odor evaluation and odorant measurement results;

   b) Background odor information: measure odor and odorant evolution rates and establish acceptable livestock production unit odor emission levels; and

   c) Odor transport and duration: measure the effect of climate, screens and barriers, particulate matter (dusts), and odor/odorant transport, frequency and durations.

Second Priority Group

1. Develop and evaluate effective odor control technologies (Focus - Environmental and Production).

   The development of odor control technology for new and existing livestock production facilities should consider the four principal odor production areas of livestock facilities: (1) open feedlots, (2) confinement housing, (3) treatment lagoons and storage pits, ponds, basins or tanks, and (4) land application sites. Possible physical, chemical and biological control strategies to consider in developing control technologies should include control of moisture and temperature in manures, absorption and adsorption of odorants, dilution with water, containment of wastes, gas scrubbing, aeration of wastewaters, pit ventilation control, oxidants, deodorants, disinfectants, bacterial cultures and enzymes, feed additives, feed modification, and filters.

2. Establish the physiological and psychological impact(s) of odors and odorants in or from production units (Focus - Environmental and Production).

   There is a need to define the interactions between the toxic gases, odorants, dust and aerosols with livestock and poultry production and the short-term and chronic effects on animal performance and employee health and safety. The impacts of fugitive gases, dusts and aerosols on the exposed general population in the vicinity of intensive livestock production and manure treatment-disposal sites should be evaluated.

Third Priority Group

1. Assess the impact of airborne volatiles on water quality (Focus - Environmental).

    This would involve measuring the aerial nitrogen contributions of different types from confined animal and poultry units to nearby surface waters. Also, the effects of volatiles, e.g., amines, on flora and fauna should be assessed.

General Considerations

Economic and energy considerations are very important in all odor management research and must be given a high priority. These considerations must not, however, be allowed to dictate the disposition of a facet of odor control methodology since all alternatives may be applicable in certain constrained situations.

Odor control technology for the livestock and poultry industries must be developed to allow appropriate growth and continued operation of the industries in response to consumer demand. Effective odor control will permit the greatest flexibility in the utility of land resources as bases for agricultural, industrial and municipal development.

Uncontrolled odors raise the fear of psychological and physiological limitations for the animals concerned, the operator and workers and nearby residents. It might be that one or two highly publicized odor problems in one locality can be interpreted to be a general problem of livestock production. The anticipated result is an odor control regulation which places needless constraints on the entire industry of an area, state or region.

ESTABLISHMENT OF AGRICULTURAL ODOR RESEARCH CENTERS

Odor control has been a difficult and unyielding research problem. There are large knowledge gaps in our understanding and management of odors and odorants. A research approach that would give a high probability of success would be the establishment of two or more odor research centers in the United States. The permanent staff should consist of at least two odor scientists with support personnel adequate for several scientists. Scientists interested in and qualified for animal waste odor work would be attracted to these centers and could work there on a sabbatical leave and temporary assignments basis. These team efforts should include agricultural and environmental engineers, animal scientists, chemists, and microbiologists. Sites should be located so that the combined programs would cover major areas of beef, dairy, poultry and swine production in the United States.

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16. ABSTRACT

The purpose of this report is to identify and assess research needs for livestock manure management as related to environmental quality. Needs identified are prioritized and assigned to one or more function areas, such as, environmental quality, demonstration, livestock production, education, and energy.

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