Approved: 3-11-99
Date

MINUTES OF THE HOUSE COMMITTEE ON ENVIRONMENT.

The meeting was called to order by Chairperson Joann Freeborn at 3:30 p.m. on February 11, 1999 in Room 423-S of the Capitol.

All members were present except: Rep. Tom Sloan - excused
Rep. Henry Helgerson - excused

Committee staff present: Raney Gilliland, Legislative Research Department
Mary Torrence, Revisor of Statutes
Mary Ann Graham, Committee Secretary

Conferees appearing before the committee: Dr. Bill Hargrove, Director, KS Center for Agricultural Resources & Environment, KS State University, 044 Waters Hall, Manhattan, KS 66506
Dr. Jay Ham, Assoc. Professor, Agronomy Dept., KS State University, Throckmorton Hall, Manhattan, KS 66506
Dr. Alan Schlegel, Professor, Southwest Research-Extension Center, KS State University, Umberger Hall, Manhattan, KS 66506
Dr. Pat Murphy, Professor, Dept. of Biological & Agricultural Engineering, KS State University, Durland Hall, Manhattan, KS 66506

Others attending: See attached list

Chairperson Joann Freeborn called the meeting to order at 3:30 p.m. She reviewed next week's agenda. Tuesday, February 16 there will be possible action on **HB2124**, and hearings on **HB2289** and **HB2291**. Thursday, February 18, a hearing on **HB2264** and possible action on bills previously heard.

The Chairperson welcomed Dr. Bill Hargrove, Director of Kansas Center for Agricultural Resources and the Environment, to the committee. He presented the committee with a packet of material, (See attachment 1) an Update and Summary of Animal Waste Management and Utilization by Kansas State University. He briefed the committee on the Executive Summary, K-State Research and Extension Response to **1998 HB2950**: An Animal Waste Management Research and Extension Initiative. In response to KS **1998 HB2950** he identified nine tasks for K-State Research and Extension in meeting their obligations and in responding to legislative, state agency, and citizen concerns over the issues related to swine waste management and application to land. Questions and discussion followed.

Dr. Pat Murphy, Department of Biological and Agricultural Engineering, reviewed a schedule of training sessions dealing with New Kansas Swine Environment Laws: Implementing Them on Your Farm. (See attachment 2)

The Chairperson welcomed Dr. Jay Ham, Associate Professor of Agronomy Department, KS State University. He briefed the committee on Seepage Losses and Nitrogen Export from Animal Waste Lagoons, (See attachment 1) with the use of slides. Questions and discussion followed.

The Chairperson welcomed Dr. Alan Schlegel, Professor, Southwest Research-Extension Center, to the committee. The briefed the committee (See attachment 1) on the Environmental Impact of Land Application of Animal Waste and the Impact of Land Application of Animal Wastes on Soil Chemical, Biological and Physical Properties, with the use of overhead views. Questions and discussion followed.

The Chairperson thanked the guests for their presentation.

The meeting adjourned at 5:15 p.m. The next meeting is scheduled for February 16, 1999.

# HOUSE ENVIRONMENT COMMITTEE GUEST LIST

DATE: February 11, 1999

| NAME | REPRESENTING |
|---|---|
| Alan Schlegel | Kansas State Univ. |
| Bill Hargrove | KCARE/ K-State |
| Kerri Ebert | KS Dairy Association |
| Steven Graham | K-State Research + Extension |
| Jay Ham | " " |
| David Bruchmann | Rep Douglas Johnston |
| MARC JOHNSON | K-state Research & Extn. |
| Tom Bruno | Allen & Assoc |
| Jim Allen | Seaboard. |
| John Bottenberg | KPPC |
| Rose Flora | |
| Dave Travis | KDHE |
| GREG FOLEY | KDHE |
| Garry Keeler | KDA |
| Dale Lambley | KDA |
| Kristine Meyer | KS Society of Professional Engineers |
| CORA Schloetzer | League of Women Voters - KS |
| Mark Lawlor | Rep. Palmer |
| Pat Murphy | KSU - |

# HOUSE ENVIRONMENT COMMITTEE GUEST LIST

DATE: February 11, 1999

| NAME | REPRESENTING |
|---|---|
| Karl Mueldener | |
| Charles Benjamin | KNRC/KS Sierra Club |
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**REPORT TO THE ENVIRONMENT COMMITTEE,
KANSAS HOUSE OF REPRESENTATIVES**

*11 February, 1999*

# Update and Summary of Animal Waste Management and Utilization by Kansas State University

**Marc A. Johnson, Dean and Director**
**Steven M. Graham, Assistant to the Dean**

*Presenters*
**Bill Hargrove, Director of KCARE**
**Jay Ham, Associate Professor of Agronomy Department**
**Alan Schlegel, Professor, Southwest Research-Extension Center**
**Pat Murphy, Professor, Department of Biological and Agricultural Engineering**

**Kansas Center for Agricultural Resources and the Environment**
**K-State Research and Extension**
Kansas State University
(785) 532-7103 <kcare@ksu.edu>

House Environment
2-11-99
Attachment 1

*Animal Waste Management and Utilization - 1999*

# Table of Contents

# I. EXECUTIVE SUMMARY

*K-State Research & Extension Response to HB2950:*
*An Animal Waste Management Research & Extension Initiative*

**Bill Hargrove, Director of the Kansas Center for Agricultural Resources and the Environment (KCARE)**

In response to Kansas HB2950, we have identified the following tasks for K-State Research and Extension in meeting our obligations and in responding to legislative, state agency, and citizen concerns over the issues related to swine waste management and application to land:

1. Conduct a literature review on land application of animal wastes focused on Kansas and similar environments, and prepare a summary of technical information on land application of animal wastes, especially related to the potential for contamination of groundwater.

2. Assist KDA in developing guidelines for nutrient utilization plans and related regulations through meetings and providing technical information and review, as requested by KDA.

3. Assist KDHE in designing a training/certification program for waste managers and personnel applying animal waste to land.

4. Conduct the necessary lab/field research to support the guidelines for "agronomically appropriate application rates" and conduct an educational program on land application of animal wastes.

5. Investigate wastewater recycling through irrigation systems.

6. Conduct "deep sampling" on fields where swine waste has been applied in order to determine the potential for groundwater contamination.

7. In ongoing lagoon evaluations, focus on determining the amount and fate of chemicals "seeping" from lagoons. This should include direct measurement of concentrations of solutes below lagoon liners by deep coring and modeling the fate of water and solutes leaving lagoons.

8. Design and evaluate "best management practices" for closing facilities and associated lagoons in environmentally safe ways.

9. Expand our educational efforts in odor management and control.

Of these tasks, #1,2,3, and 6 are more short-term in nature and #4,5,7, 8, and 9 are more long-term in nature. We have developed a unified Plan of Work that describes our objectives and plans for accomplishing the above tasks. It is presented as Attachment I. We summarize in the following pages our progress and key findings in several important areas over the past 12 months.

**Seepage Losses and Nitrogen Export from Animal-Waste Lagoons - Dr. Jay Ham, Leader**

We have now measured seepage rates on a total of nine lagoons (7 swine and 2 cattle). The seepage rates for the nine lagoons ranged from <0.01 to 0.10 inch/day with a mean of 0.05 inch/day (the KDHE maximum is 0.25 inch/day). Sludge that accumulates on the bottom of the lagoon plays a role in reducing the permeability of the liner and reducing the seepage rate at least over the first year of initial use. Most of the nitrogen leaving the lagoons via seepage is in the ammonium form, a relatively immobile form in soil. Though the total amounts of N leaving lagoons as ammonium can be large (1 to 6 tons of ammonium-N/yr), we hypothesize that most of this ammonium will be held by soil below the lagoon liner as long as the soil texture is medium to fine (silt loam to clay). Results from coring beneath a lagoon show this to be the case. Most of the ammonium is held by the soil to a depth of about 10 feet below the clay liner. When a facility is closed or a lagoon is no longer in use, exposure of the ammonium-saturated soil to air will result in conversion of the ammonium to nitrate, posing a significant environmental risk. For more information, see Attachment III.

### Assistance to KDHE and KDA in Developing Regulations, and Nutrient Management Planning - Prof. Pat Murphy and Dr. Dave Whitney, Leaders

We provided technical information and input to new regulations drafted by KDHE and KDA as required by HB2950. The requirements for nutrient management plans can be found in Attachment IV. We are in the process of developing and planning the certification training program in collaboration with KDHE. The plan is to begin offering those training sessions in summer, 1999. We have also developed an educational program in nutrient management planning; a brochure is attached, outlining the program and identifying the dates and venues for the programs. See Attachment IV.

### Literature Review: Environmental Impact of Land Application of Animal Wastes - Dr. Alan Schlegel, Leader

Over 100 scientific journal articles from around the country and relating to all livestock manure, not just swine, were reviewed. The important environmental issues related to land application of animal waste include: nitrate leaching, phosphorus in surface runoff, salt accumulation and leaching, and heavy metal accumulation, especially zinc and copper.

There has been no reported research from Kansas that evaluates application of swine waste with respect to nitrate leaching. However, there have been several reported studies of beef cattle waste application and nitrate leaching. From research around the country and on a variety of types of animal manure, the risk of significant amounts of nitrate leaching is a function of the rate of manure application, regardless of manure type. Applications that result in nitrogen amounts exceeding the crop requirement result in nitrate leaching. When manure applications are limited to the crop N requirement, there is no indication of nitrate leaching or a threat to groundwater, regardless of manure type.

With respect to phosphorus losses in runoff, not only is rate of application important, as with Nitrogen, but also the timing of manure applications is very important. The major portion of P loss in runoff generally results from one or two intense storms. Thus, the length of time between manure applications and the first runoff-causing storm is important. Phosphorus loss can be minimized by incorporation of manure through tillage or injection. Data from Oklahoma shows that soil test P levels of 200 ppm resulted in 1ppm P in runoff, while results from Arkansas showed soil test levels of 100 ppm resulted in 1ppm P in runoff. Applying manure based on crop N requirements alone results in P accumulation in the soil. Thus, most states are using P as the basis for manure application.

Salt content of manure or wastewater can sometimes be high enough to cause crop damage when applied to land. However, no reports of a human health threat or environmental damage other than crop injury were found. There are published reports of plant injury form Zn or Cu in situations where municipal sludge have been applied to cropland, but no reports of damage from animal waste.

The complete literature review is presented as Attachment V.

### Impact of Land Application of Animal Wastes on Soil Chemical, Biological, and Physical Properties - Dr. Alan Schlegel, Leader

Soil chemical properties were measured in irrigated fields in western Kansas with a history of animal waste applications. The fields varied in the type of waste applied (solid cattle manure or effluent water from swine or cattle wastewater lagoons) and the duration of application (from 3 to 30 years). At most sites, soil phosphorus (P) levels were increased (up to 150 ppm) by waste applications, indicating that application rates exceeded crop P demands. The highest P concentration was 200 ppm Bray-1 P in the surface soil (0 to 6 inch depth), which is the maximum level established for continued application of swine waste. Soil nitrate levels were also increased (as much as 100 ppm) by waste applications. At some sites, considerable nitrate (30 to 50 ppm) had leached past the crop root zone to a depth of at least 10 feet. To determine the extent of nitrate movement, deeper soil cores (up to 50 ft) will be taken at selected sites. Soil chloride (Cl) was higher following manure application but, in most instances, Cl content was less than 35 ppm and would not be considered a problem (the drinking water standard is 250 ppm Cl). Extractable copper was about 2 ppm in fields receiving swine waste compared to about 1 ppm in non-manured fields. Extractable zinc was less than 2 ppm at sites receiving swine wastes compared to less than 1 ppm in the non-manured sites. The complete report is presented as Attachment VI.

### Use of Subsurface Drip Irrigation with Lagoon Wastewater - Dr. Freddie Lamm and Dr. Todd Trooien, Leaders

Use of subsurface drip irrigation (SDI) with water from animal waste lagoons has many potential advantages, including less human contact with wastewater, no runoff, no surface accumulation of immobile nutrients like phosphorus, greater application uniformity, fewer climatic application constraints, and less irrigation system corrosion. A pilot study was conducted by K-State Research and Extension at Midwest Feeders, Ingalls, KS, to measure the performance of a filtering system and five different dripline types for delivering beef feedlot runoff lagoon water to a cornfield. Of the five dripline types tested, the three largest emitter sizes (0.4, 0.6, and 0.92 gal/hr/emitter) showed little sign of clogging. The two smaller emitter sizes (0.15 and 0.24 gal/hr/emitter) showed some signs of emitter clogging. The disk filter and automated backflush controller operated well in 1998. These results show that SDI has potential for use with lagoon wastewater. It appears that the smaller emitter sizes normally used with groundwater in western Kansas may not be appropriate for use with lagoon wastewater. These smaller emitter sizes may be prone to clogging when used with wastewater. The results of this study, while very encouraging, should be considered preliminary. A full report is presented as Attachment VII.

### Future Work: Issues that Need Expanded Efforts - Prepared by Bill Hargrove

Three topics need expanded efforts and are identified for future work. These include: 1) Modeling transport of water and solutes from animal waste lagoons; 2) Odor control and air quality; and 3) Facility closure protocols. We present proposed ideas for work on modeling and odor control in Attachment VIII. We plan to work with KDHE to develop some plans for evaluating remediation of abandoned lagoon sites and closure protocols.

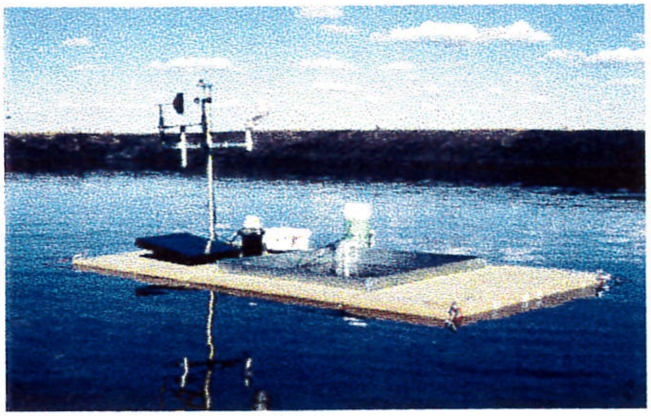
**98/99 BUDGET - Special Appropriations for Animal Waste Management**

| | Personnel | Equipment | Total |
|---|---|---|---|
| **Allocations** | **$237,225** | **$237,500** | **$474,725** |
| | | | |
| **Obligations To Date** | ----- | ----- | ----- |
| Land Application | ----- | ----- | ----- |
| Lit Review | $6,054 | $0 | $6,054 |
| Survey Sampling | $12,750 | $26,775 | $39,525 |
| Rates of Application | $27,625 | $20,000 | $47,625 |
| Lagoon Evaluation | ----- | ----- | ----- |
| Modeling | $51,484 | $19,794 | $71,278 |
| Seepage & Contaminant Loading | $37,714 | $170,931 | $208,645 |
| Facility Closure | $27,000 | $0 | $27,000 |
| **Total** | **$162,627** | **$237,500** | **$400,127** |
| **Non-Obligated** | **$74,598** | **$0** | **$74,598** |

## Proposed Budget 1999/2000 - Animal Waste Management Initiative

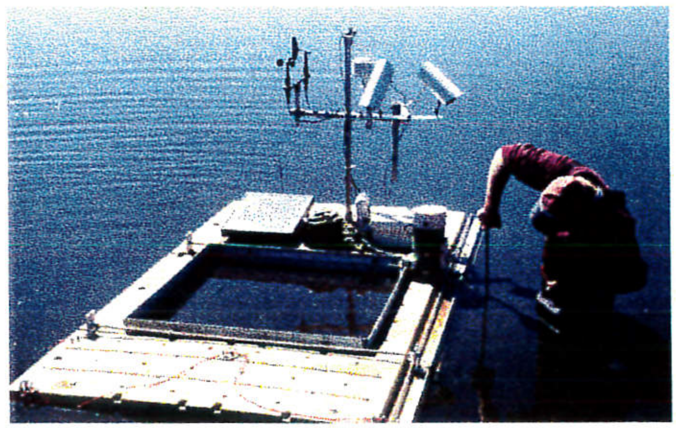
| | Personnel | Operating | Total |
|---|---|---|---|
| **Proposed Allocation** | **$189,780** | **$47,445** | **$237,225** |
| | | | |
| Waste Lagoon Evaluation | ----- | ----- | ----- |
| (1) Research Assistant<br>(.5) Lab Assistant<br>(1) Grad Student<br>(1) Technician | $93,750 | $20,000 | $113,750 |
| Land Application of Manure | ----- | ----- | ----- |
| (1) Field Assistant<br>(.5) Lab Assistant<br>(1) Grad Student | $69,030 | $27,445 | $96,475 |
| Facility Closure | $27,000 | ----- | $27,000 |
| **Total** | **$189,780** | **$47,445** | **$237,225** |

# Animal Waste Lagoons



Left: A floating lysimeter and meteorlogical station used to measure evaporation from lagoons

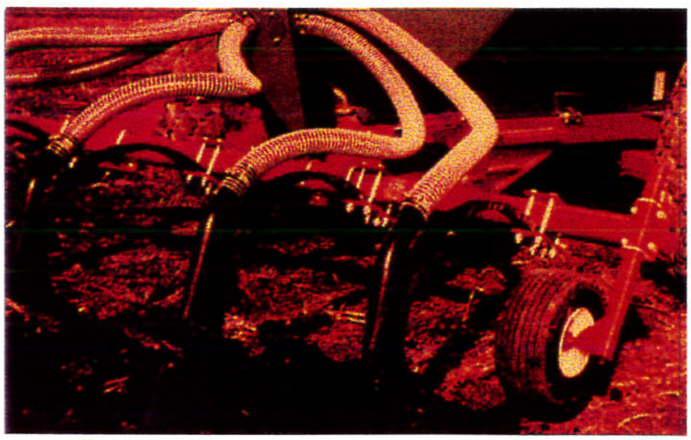
Below: A research assistant adjusts instrumentation to measure subsurface water temperatures.



Above: Organic sludge layer that has been deposited along the sides and bottom of a cattle feedlot runoff lagoon. Photo taken when lagoon was emptied for cleaning.

Right: Collecting soil cores from an 11-year-old lagoon using a direct-push soil probe. The lagoon had been dried and sludge removed prior to sampling.

# Applying Animal Waste to Land



Above: Tractor applying liquid manure through a rubber hose to underground injectors.

Left: Tank wagon with soil injectors for liquid manure.

Right: A tractor pulls a traditional manure spreader.

# Use of Subsurface Drip Irrigation with Lagoon Water

The experiment site as viewed from across the lagoon. Electrical controls are located on the reverse side of the mounted white panels. The floating pump is shown in the lagoon. Water is pumped up the hose on the left. A booster pump adds pressure. Excess wastewater volume returns to the lagoon in the middle hose. The hose on the right is also return flow to the lagoon and is used only for testing. After wastewater passes through the disk filter (red), it enters a manifold and is directed to individual corn plots in the background. The blue and white injection pumps and tanks for acid and chlorine are shown on the right.

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## Grazing Land Water Quality Education Program

Project Leaders: Paul D. Ohlenbusch, Agronomy
Rodney D. Jones, Agricultural Economics

The first phase of K-State's "Grazingland Water Quality Education Program" is nearly complete for 1997. Program leaders are Paul Ohlenbusch, Extension Agronomy range and pasture management specialist, and Rodney Jones, Extension Agricultural Economics livestock production specialist. Joe Harner, Extension Agricultural Engineer, is cooperating. Erek Fuchs, Extension Assistant in Agronomy, is working directly on the program with Ohlenbusch.

In its first year, the program leaders are cooperating with five grazingland managers in a three-county area. The area involves Marshall, Nemaha, and Pottawatomie Counties.

The overall goal of the multi-year program is to develop an education program so that producers and professionals can evaluate the water quality status of grazinglands, and develop potential solutions when necessary. Grazinglands are potential sources of suspended solids, bacteria, nitrogen, phosphorus, and biological oxygen demand (BOD).

During this summer and fall, the team has been completing the first phase of the project. This first phase basically consisted of taking a resource inventory of the grazinglands of the five cooperating producers. Fuchs and Ohlenbusch now have physically surveyed the fields, and have a detailed record of the soil types, vegetation, outcroppings, draws, fences, livestock watering sources, streams, wells (including abandoned wells), eroded areas, structures, dumps, and anything else potentially relevant to water quality and livestock management.

This information is recorded on paper and drawn onto aerial maps from the Natural Resources Conservation Services or Farm Services Agency. This information is in the process of being put into Geographical Information Systems digital maps through the use of Global Positioning System reference points.

Once the resource inventory is complete, the next phase will be to analyze the producers' current management practices and strategies. After the analysis of potential water quality concerns and current management practices, alternative management strategies will be developed for consideration with the producer. Together with the producer, the team will decide which conditions need attention and which are better off left alone, from the perspective of water quality.

For more information, contact Paul Ohlenbusch (785) 532-5776.

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**Demonstration of BMPs to Avoid Groundwater Pollution from Application of Manure to Cropland**

Project Leader: Dr. Mahbub Alam, Irrigation Extension Specialist, SW Res. Ext. Center

Collaborators:
Curtis Thompson, Extension Agronomist
Todd Trooien, Research Agriculture Engineer
Stacy Campbell, County Ext. Agent, Morton Cty.
Darl Henson, County Ext. Agent, Grant Cty.
Gary Gold, County Ext. Agent, Stevens Cty.
Alan Schlegel, Research Agronomist
Troy Dumler, Extension Economist
Frank Swan, County Ext. Agent, Stanton Cty.
Clay Simons, County Ext. Agent, Ford Cty.

There is a growing concern regarding the effect of continuous application of confined animal waste of beef feedlots and swine lagoons to crop land, especially its impact on groundwater. The demonstration project is aimed at evaluating the current application practices and develop or confirm best management practices. (BMPs) K-State Research and Extension is working with producers and industry starting this fall. Individual cooperating producers will provide the land and facility for the demonstration.

The main focus is to evaluate benefits and impacts of land application of manure. In the process, baseline nutrient status of deep soil profile will be established prior to application and progressive changes will be tracked for five years. Residual build up or leaching of nutrients, especially nitrate-nitrogen, under irrigated conditions will be monitored for different application rates. This will help develop best management practices for using livestock waste as a fertilizer amendment. The program will also provide opportunity to conduct educational and informational programs on proper use of livestock manure.

This is a cooperative project between KDHE and Kansas State University.

Funding source: Section 319 Grant fund for Nonpoint Source Pollution Control Project - Kansas Department of Health and the Environment.

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## Performance Evaluation of Vegetative Filter Strip Systems Below Livestock Confinement Area

Project Leaders: Prasanta K. Kalita, Biological and Agricultural Engineering
Steven K. Starrett, Civil Engineering

Vegetative filter strips are strips of land covered with various grasses or other types of vegetation. These have been recognized as Best Management Practices for sediment control. A good vegetation cover reduces runoff velocity, increases the infiltration time, and utilizes nutrients for its growth. Feedlot runoff contributes significant nutrients to the receiving water bodies (lake, stream, reservoir); however, if such runoff passes through a vegetative filter strip, its quality can be improved. Two vegetative filter strips have been installed below livestock confinement areas: one in the Cheney Lake Watershed near Wichita and the other one in the Herington Lake Watershed near Herington, Kansas. Runoff passes through the filter strips and enters streams draining to the reservoirs. Automatic water samplers have been installed at the entrance and exit of each filter strip to collect periodic runoff samples and the water samples are analyzed for nitrogen, phosphorus, and sediment concentrations. Soil and vegetation samples are collected to analyze for nutrient leaching in the soil and utilization by vegetation. The filter strips will be evaluated on the basis of their effectiveness in reducing nutrients in surface runoff.

Funding source: Kansas Department of Health and Environment.

For more information contact: Prasanta Kalita (785) 532-6819.

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## Fecal Coliform Contamination in Kansas River Basins: Monitoring and Development of Best Management Practices

Project Leaders: Charles W. Rice, Agronomy
George Marchin, Biology
Joe Harner, Bio and Agricultural Engineering
Prasanta Kalita, Bio and Agricultural Engineering
Rodney Jones, Agricultural Economics

Fecal coliform bacteria often are present in surface waters of Kansas. Potential sources of coliform include runoff from animal feedlots, livestock grazing lands, wildlife and waterfowl excrement, home septic systems and other waste handling systems. Because of the widespread nature of the contaminant, research is needed to identify levels of contamination to develop Best Management Practices (BMPs) to reduce levels of fecal bacteria in the surface waters of Kansas. The objectives of this study are to:

1. To monitor water quality at several locations in the state to determine
   - A. Levels and potential sources of contamination
   - B. When contamination occurs
   - C. Survival of fecal bacteria in soil and sediment.
2. To evaluate the effectiveness of grass filter strips and other BMPs in reducing fecal coliform contamination of surface waters.
3. To identify adoption risks economic costs associated with implementation of BMPs.

This is a multi-year project that will be fully implemented this year. Preliminary sampling during 1997 in northeast Kansas indicated fecal coliform levels are highest in late spring and early summer after major runoff events. In the watersheds that were monitored, animal operations appear to be the primary contributor. It is likely filter strips and other practices can be implemented to reduce contamination.

Funding sources: Kansas Department of Agriculture, Kansas State Conservation Commission, Kansas Water Office.

For more information contact: Charles Rice (785) 532-7217.

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**Use of the Analysis of Antibiotic Resistance of Fecal Streptococci as a Means of Tracking Source of Fecal Contamination**

Project Leader: George L. Marchin, Biology

The extent of fecal contamination of waterways can only be reduced if appropriate analytical techniques are employed to ascertain the source of such contamination. Three probable sources of contamination come to mind: wild animal populations, animals utilized in the agricultural industry, and the human population. Two readily employed measures of fecal contamination are fecal coliforms and fecal streptococci. The difficulty is that all three of these sources can excrete these organisms. We are faced with the problem, therefore, that fecal contamination can be quantified without precisely identifying the component population that is the most serious contributor.

One approach described in the scientific literature utilizes the fact that fecal streptococci derived from these three diverse sources have different levels of antibiotic resistance. This is due primarily to their origins in wild animals, domestic animals and humans, that have distinct and different exposures to antimicrobial compounds. The agricultural producer, therefore, that uses a suite of antibiotics to promote the growth of livestock is selecting for an enteric population of microbes with distinct antimicrobial characteristics. These distinct characteristics do not quickly change when those organisms are placed in the environment. Further, their antimicrobial "fingerprint" can be used to identify them and ultimately identify source.

Antibiotic resistance of fecal streptococci as means of tracing the sources of fecal contamination has several other advantages. The methods are economical. Fecal streptococci are relatively long-lived in the environment. Under natural environmental conditions and in the short term fecal streptococci do not readily transfer genetic information. Finally, bacteriological selection procedures are straightforward.

For more information contact: George Marchin (785) 532-6635.

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## Sextro Dairy Parlor Wetland Cell Demonstration Project

Project Leaders: Joseph P. Harner, Biological & Agricultural Engineering
David Key, County Extension Agent, Nemaha County

Collaborators:
Kansas Department of Health and Environment
Kansas State Conservation Commission
Natural Resource and Conservation Service
Kansas Forestry Department
Kansas State University
Nemaha River Dairy

Objective: Demonstrate the utilization of a wetland cell for treating milk parlor wash water. The wetland cell will be planted to cattails. The minimum retention time of the effluent in the wetland is 14 days. Monitoring of the inflow and outflow will follow plant establishment and will evaluate the systems performance and design guidelines.

Accomplishments: The dairy installed during 1997 a concrete basin to provide 120 days storage of the manure prior to land application and a vegetative filter planted to grass and trees for removing nutrients from the lot runoff. This project expands the waste management system to include a wetland cell for treating the milk parlor water prior to the tree planting area. The wetland cell is located in series with the concrete basin and vegetative filter. The wetland cell was designed during fall, 1997. Construction of the cell will occur in early 1998 as weather permits.

Potential Impact: The project will help evaluate an alternative to using holding ponds or lagoons for controlling milk parlor effluent. Current guidelines assume 10 to 15 gallons per day per cow are used for sanitation of equipment and cleaning of the milk parlor. A wetland cell for reducing nutrient loading from livestock operations performs better with a daily loading of nutrients. This is in comparison to infrequent heavy nutrient loads created during a rainfall event of runoff from an open lot. Milk parlor effluent provides a uniform daily nutrient loading rate. Milk parlor effluent will have nitrogen and potassium loading rates of 150-200 ppm, phosphorus rates of 100-150 ppm.

Funding Source: Kansas Nonpoint Source Pollution Control Program - Kansas Department of Health & Environment.

For more information contact: Joseph Harner (785) 532-5813.

## Nichols Dairy Ecological Pollution Control Demonstration

Project Leaders: Joseph P. Harner, Biological & Agricultural Engineering
K. Mankin, Biological & Agricultural Engineering
P. Kalita, Biological & Agricultural Engineering
J. Zimmermann, Biology

Collaborators:
Kansas Department of Health and Environment
Kansas State Conservation Commission
Natural Resource and Conservation Service
Kansas Forestry Department
Carl Nichols Dairy
Kansas Department of Agriculture
Kansas Parks and Wildlife
US Fish and Game

Objective: An ecological pollution control project is currently under development in Anderson County for a 200-cow dairy. The nutrients are removed from the milk parlor effluent and loafing areas (barn yard) using three wetland cells and three vegetative filters. A holding pond is used to control the release of the runoff into the wetland cells. The project includes 1.25 acres of wetland cells and 1.5 acres of grass filters. The grass filters average 60 feet wide and a total length of more than 1,000 feet.

Accomplishments: Funding for installation of the project was obtained in 1997. KSU completed the design work in summer, 1997. Input was obtained from KDHE, NRCS, and the producer. The tentative date for completing construction is scheduled for March,1998. The site has been prepared for the contractor to begin work immediately as weather permits.

Potential Impact: The project will provide information on the nutrient removal rates of an ecological system which utilizes wetland cells and vegetative filters. The nutrients removed by the plants will be harvested as forages for feed. Future system performance data will provide understanding of developing livestock pollution control practices with controlled release rates. This enables the producers to install control practices which do not require investments in irrigation equipment for periodic pumping of lagoons.

Funding Source: Kansas Nonpoint Source Pollution Control Program - Kansas Department of Health & Environment.

For more information contact: Joseph Harner (785) 532-5813.

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## Black Vermillion Watershed Dairy Environmental Cooperative

Project Leaders: Joseph P. Harner, Biological & Agricultural Engineering
David Key, County Extension Agent, Nemeha County
Michael Vogt, County Extension Agent, Nemeha County
Dave Whitney, Agronomy
Kevin Dhuyvetter. Agricultural Economics

Collaborators:
Kansas Department of Health and Environment
Kansas State Conservation Commission
Natural Resource and Conservation Service
Kansas Forestry Department
Kansas Department of Agriculture
Nemaha and Marshall County Dairies

Objective: The dairy environmental cooperative mission is to control to manure and effluent nutrients leaving a farmstead and to effectively manage controlled nutrients with cropping practices. The objective is to reduce the runoff of nutrients, fecal coliform and sediment from dairies in the Black Vermillion watershed. The specific objectives are:

A. Develop and install demonstration systems for storage of dairy manure and effluent leading to reduced nutrient, fecal coliform and sediment in runoff.

B. Develop and deliver educational programs to dairy farmers to assist them in implementing best management practices for on-farm utilization of stored nutrients in lagoons or solids storage basins.

C. Develop local dairy environmental cooperatives to assist dairy farmers to design and in complete waste management systems and understand the management of the system.

Accomplishments: The implementation of the project will begin in January 1998. The county extension agents have promoted the project and received inquiries. The project goal is to bring the equivalent of 1,000 dairy cows into compliance during a three year period. Inquiries about the project have resulted in producers wanting to bring dairies milking over 500 cows in compliance.

Potential Impact: Annual nutrients in manure from a 100 cow dairy is approximately 21,000 pounds of nitrogen, 8,600 pounds of phosphorus and 17,000 pounds of potassium. A portion of these nutrients leave a dairy if left uncontrolled. Therefore, developing best management practices to help producers store these nutrients until they can be applied and used by crops will lead to improvements in water quality. Anticipated improvements will also occur because producers will not have to applied manure to frozen or saturated cropland. Nutrients potentially leave a field during snow melts if the ground is frozen. Applications of manure to saturated ground increases soil compaction within a field and has a negative impact on soil quality.

Funding Source: Kansas Nonpoint Source Pollution Control Program - Kansas Department of Health & Environment.

For more information contact: Joe Harner (785) 532-[illegible]

**Kansas Center for Agricultural Resources and the Environment**

**K-State Research and Extension**

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KCARE

# Fecal Coliform in Kansas Surface Waters

A Research and Extension Progress Report by Kansas State University

**Principal Investigator**

*Charles W. Rice, Department of Agronomy*

## Executive Summary

Microbial contamination of water resources has become a high priority concern. Bacteria contamination is one of the primary or secondary contaminants in the majority of the twelve major river basins in Kansas. Microbial contamination of water resources results in impaired use due to the increased risks to humans and the degradation of recreational and drinking water quality. Other regions around the United States have indicated similar instances of microbial contamination of reservoirs, streams, and estuarine waters.

Fecal coliform (FC) limits in surface water vary depending on the intended use. For recreational primary contact, e.g. swimming, the maximal allowable standard for FCs is 200 colony forming units (CFU)/ 100 mL water. For secondary contact, e.g. boating and fishing the standard is 2000 CFU /100 mL water. For finished drinking water the standard for fecal coliform (FC) is <1CFU/100mL. Bacterial numbers can vary dramatically with time of year, environmental conditions, and distance from source. Sources of coliform bacteria include runoff from animal feedlots, livestock grazing lands, wildlife, and other waste handling systems.

There is a paucity of studies on fecal coliform movement below septic leach lines. Studies examining movement of fecal coliforms and coliphages near septic lateral lines showed that transport are regulated by hydraulic gradient, slope and soil conductivity. Considerable work is needed to better understand movement and survival of FCs in soil and sediment from all sources.

Differentiation of the sources of fecal pollution of surface and groundwater is a difficult task. The traditional indicator of fecal pollution has been determination of fecal coliforms. Source identification, i.e. human, agricultural animal or domestic-wild animal has been more problematic.

The initial attempts at source identification relied upon measurement of both fecal coliform and fecal streptococci concentrations. More recent data, however, suggest that for many reasons the fecal streptococci numbers vary in response to a wide variety of environmental and physiological parameters. Thus, the fecal coliform to fecal streptococci ratio is not recommended. Newer technologies hold promise for source of fecal pollution identification. Three basic approaches can be identified in recent literature. One method utilizes patterns of antibiotic resistance in both fecal coliforms and fecal streptococci to track source. Other newer techniques employ molecular techniques generally based upon nucleic acid technologies. While ratios of fecal coliforms to fecal streptococci have limited value they still are indices of fecal pollution and can yield indications of source if they are from untreated surface water and are freshly collected. Antibiotic resistance markers have additional value and have been demonstrated to be reliable. Among DNA based technology, discrimination runs from ribotyping to AFLP to PFGE. In these latter techniques, the more discriminatory the technology, the higher the price.

Research has been conducted for controlling sediment, fertilizers, pesticides, nitrogen, and phosphorus in runoff water at many locations. Lagoons, vegetative filter strips, and land application of wastes have proved useful in reducing contaminant loadings in drinking water sources. However, there has been little research conducted on management practices that control microorganisms in drinking water sources.

In 1998, Kansas State University develop a study in collaboration with state agencies to:

1)Monitor water quality at several locations to determine: a) level and pattern of bacterial contamination in Kansas waters; b) potential sources of contamination; and c) survival in soil

and sediment.

2)Determine effectiveness of best management practices particularly vegetative filter strips.

To monitor water quality in terms of numbers of fecal organisms in flowing water, key sites were obtained to observe inputs from human, livestock and wildlife components. Four of the sites around the St. John, Kansas area represent grazing livestock inputs, with varied grazing patterns and a nearby municipal waste stabilization facility. To assess the wildlife inputs on fecal coliform and fecal streptococcus numbers, Konza Prairie Natural Research Area, Quivera National Wildlife Area and Cheyenne Bottoms were selected. Five septic filter fields have been selected for study by January 1999. Results to date are only preliminary and indicate highly variable levels as expected. Values ranged up to 3,000 CFU/ 100 mL. A database is being developed to help determine the source of the bacteria.

In addition, four vegetative filter strips were chosen for this study to investigate fecal coliform transport in storm runoff from beef feedlots. The feedlots have similar drainage area and stocking density. The design procedures and filter strip areas, however, are very different. The vegetative filter strips are located near Cheney Lake, Herington Lake, Hillsdale Lake, and the town of Gypsum. The outflow from the filter strip is reducing the number of fecal coliform bacteria flowing into surface water sources from feedlots. Five runoff events have been analyzed to date. Percent reduction in fecal bacteria ranged from 18% to 100%. Water at one runoff event was completely contained within the filter strip. The reduction in fecal bacteria leaving the site is due to the volume of water leaving the site and not due to specific retention of the fecal bacteria.

Research will continue during this year to:

1) develop the seasonal pattern of fecal bacteria in Kansas surface waters

2) evaluate methods for determining the sources of bacteria

3) evaluate the effectiveness of filter strips and other management practices to reduce bacteria in runoff from feedlots.

# II. K-State Research and Extension Response to HB2950: Plan of Work

## Introduction:

The 1998 Kansas State Legislature enacted a law providing for environmental regulations and restrictions on large swine production facilities in Kansas (HB2950). The law requires Kansas State University to provide technical information, educational programs, and research data on several aspects of swine waste management. Through discussions amongst faculty over the past few weeks/months, we have identified the following tasks for K-State Research and Extension in meeting our obligations and in responding to legislative, state agency, and citizen concerns over the issues related to swine waste management and application to land:

1.) Conduct a literature review on land application of animal wastes focused on Kansas and similar environments, and prepare a summary of technical information on land application of animal wastes, especially related to the potential for contamination of groundwater.

2.) Assist KDA in developing guidelines for nutrient utilization plans and related regulations through meetings and providing technical information and review, as requested by KDA.

3.) Assist KDHE in designing a training/certification program for waste managers and personnel applying animal waste to land.

4.) Conduct the necessary lab/field research to support the guidelines for "agronomically appropriate application rates" and conduct an educational program on land application of animal wastes.

5.) Investigate wastewater recycling through irrigation systems.

6.) Conduct "deep sampling" on fields where swine waste has been applied in order to determine the potential for groundwater contamination.

7.) In ongoing lagoon evaluations, focus on determining the amount and fate of chemicals "seeping" from lagoons. This should include direct measurement of concentrations of solutes below lagoon liners by deep coring and modeling the fate of water and solutes leaving lagoons.

8.) Design and evaluate "best management practices" for closing facilities and associated lagoons in environmentally safe ways.

9.) Expand our educational efforts in odor management and control.

Of these tasks, #1,2,3 and 6 are more short-term in nature and #4,5,8 and 9 are more long-term in nature. We have identified key faculty to work on these various tasks; and we have organized small teams to begin the work. Furthermore, we have identified key short-term personnel that could help us achieve our short- and long-term obligations, and have begun the process of recruiting. These positions will be funded from a combination of resources on hand plus state resources made available through HB2950. We have completed the literature review and are in the process of deep sampling soils where manure has been applied. We have been working with KDA and KDHE in providing technical input to the regulations that have been developed.

For our long-term efforts, we have developed a unified plan of work that describes our objectives and plans. The following pages describe this plan of work; it will serve as our "roadmap" for the future. The plan of work is presented in four parts:

I. Impact of Land Application of Animal Waste on Soil Chemical and Biological Properties

II. Utilization of Livestock Wastewater through Irrigation

III. Modeling Water and Solute Transport to Assess the Impact of Animal Waste Containment on Groundwater Quality

IV. Sampling and Analysis of Soil Cores Collected Beneath Animal Waste Lagoons

**Impact of Land Application of Animal Waste on Soil Chemical, Biological and Physical Properties**
**FY 98-99**

## Principal Investigators

*Dr. Alan Schlegel, Professor, Southwest Research-Extension Center*
*Dr. Chuck Rice, Professor, Agronomy Department*
*Dr. Gary Pierzynski, Associate Professor, Agronomy Department*
*Dr. Mahbub Alam, Assistant Professor, Southwest Area Extension*

## Introduction

Application of animal wastes can enhance soil chemical and biological properties and serve as a valuable nutrient source for crop production. In areas where manure is available in sufficient quantities, it can supply a significant proportion of crop nutrient requirements. However, ineffective use of manure results in waste of valuable nutrients and can adversely affect the environment. Two environmental concerns from land applications of manure are surface runoff from manured fields causing eutrophication of surface water and leaching of nitrates through the soil profile into the groundwater. With an increase in the number of large confined animal feeding operations, there is a perception of increased risk to the environment from animal wastes. The purpose of this study is to sample fields that have received land application of animal wastes (swine, beef, dairy or poultry) and compare the soil chemical and biological properties to similar fields that have not received manure applications. The results of this study will be used to evaluate the impact of past manure applications on soil properties and to guide future research needs of land application of animal wastes.

## Objectives

Determine the impact of land application of animal wastes on:

1.) Soil chemical properties to include levels of
- a. Phosphorus (soil test P, total P, and organic P)
- b. Nitrogen (inorganic [(NO3) and (NH4)] and organic N)
- c. Chloride (Cl)
- d. DTPA-extractable zinc (Zn) and copper (Cu) [for soils that have received swine or poultry manure]
- e. Carbon (organic C and soluble organic C)
- f. Soluble salts

2.) Soil biological properties to include
- a. Total bacteria counts
- b. Microbial biomass C and N
- c. Denitrifier counts and activity
- d. Nitrifier counts and activity
- e. Mineralizable C and N

## Approach and Methods

Fields with a known history of land application of animal wastes will be identified as sampling sites along with adjacent similar fields that have not received manure applications. It is anticipated 6 to 10 fields representing a range of manure application practices in diverse geographic regions will be identified for soil sampling. The criteria for site identification will include a.) known history of animal waste application including estimates of manure nutrient content, application rates, and duration of application; b.) soils that represent geographic regions that routinely receive land application of animal wastes; c.) soils that are common to large parts of the state; and d.) availability of adjacent fields with similar soil characteristics that have not received manure applications.

Each field site will be divided into several subfields to account for variability within each field caused by inherent differences in soils within a field. Four cores will be taken from each subfield and composited for analyses. Soil cores will be collected to a depth of 10 feet (at most locations) with a hydraulic soil probe. The surface foot of soil will be divided into 0-2 inch, 2-4 inch, 4-6 inch, 6-8 inch, and 8-12 inch samples. The deeper soil samples (1 to 10 ft. depths) will be divided into 12-inch increments. In addition, sites with a long history of manure application may be sampled to a depth of up to 50 ft.

Soil samples will be collected in September and October 1998. Personnel from Kansas State University will conduct most of the sampling; however, ServiTech (Dodge City) may conduct some of the deeper soil samples. The chemical and biological analyses will be performed at KSU. The results of the analyses should be completed by December and made available to the cooperators. The results of the study will be used to evaluate the impact of animal waste applications on soil chemical and biological properties and to guide future research efforts in land application of animal wastes. When using or reporting the results of the research, the sampling sites will be identified by soil type and county location and not by the name of the cooperator or landowner. The cooperation of land owner/operators is essential to the project and their names will be kept confidential.

## Utilization of Livestock Wastewater Through Irrigation
## FY 98-99

### Principal Investigators

*Freddie Lamm, Irrigation Engineer, Northwest Research-Extension Center*
*Todd Trooien, Irrigation Engineer, Southwest Research-Extension Center*
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The pilot project evaluating the potential for livestock wastewater use through SDI at Midwest Feeders Inc., Ingalls, Kansas will be continued through the fall of 1998. This project is evaluating 5 different dripline emitter flow rates under replication conditions. This project is funded through special funds from the legislature and USDA. It is not funded by HB2950.

It is proposed that the next project entail evaluating the SDI filtration system requirements for different types of livestock wastewater. Although the equivalent mesh or particle size handled by the filtration system is dictated by the dripline characteristics, there are still many unknowns about the required filter area and backflush cycles for different types of wastewater. We propose to conduct the test on 15 lagoons (8 swine, 5 beef feedlots and 2 dairies). Water samples will be taken before and after the filtration system. The samples will be analyzed for N, P, K, Calcium, Calcium Carbonate, Sodium and other salts, TDS, and Total Suspended Solids. A test filtration system will be constructed to allow the simultaneous evaluation of three different filtration mesh sizes when pumping livestock wastewater. Differential pressure across each of the three filters will be recorded with a data logger from test initiation until plugging or until a predetermined differential pressure is attained. Water will be discharged back to the lagoon and will not be utilized through a SDI system in this study. The study will result in information about sizing of SDI filtration systems for typical wastewater. Additionally, more information will be gained on the composition of typical livestock wastewater in lagoons in Kansas.

**Modeling Water and Solute Transport to Assess the Impact of Animal Waste Containment on Groundwater Quality**
**FY 98-99**

## Principal Investigators

Lakshmi Reddi, Civil Engineering
David Steward, Civil Engineering

## Problem Statement

Containment of animal waste in lined lagoons has become a topic of intense debate at state, regional, and national levels. Public awareness of this practice is very high in several states including Kansas, Texas and North Carolina. The leachates from animal waste lagoons pose a potential health risk since they will migrate from the lagoon to the underlying drinking water supplies. To protect groundwater resources underlying the lagoons, various states regulate the seepage quantities from lagoon liners. The maximum allowable seepage rate varies from 1/56 inch/day (Minnesota and Missouri) to 1/4 inch/day (Nebraska and Kansas). The wide range of regulated seepage rates reflects the degree of uncertainty in the current state of knowledge on fate and transport of animal waste through the lagoon liners and the underlying natural soils. Some regulatory agencies are inclined to allow higher seepage rates in anticipation of the time-dependent liner clogging/sealing and the subsequent attenuation of contaminant concentrations.

The impact of animal waste storage on groundwater quality is dependent not only on the integrity of lagoon liners but also on the regional hydrogeology. Some of the important parameters governing this impact are:

1.) Quality of leachate from the containment system (in addition to the quantity which is mandated by regulatory agencies)

2.) Time-dependent rate at which the leachate is released from the liner bottom

3.) Mass transfer (physicochemical and biological) and transport (advection and diffusion)

4.) Characteristics of soils underlying the lagoon

5.) Depth to the groundwater table

The problem requires an interdisciplinary approach involving both science and engineering perspectives. In response to the need expressed by the Kansas Department of Health and Environment (KDHE) and the Kansas Water Office, some preliminary studies have been conducted thus far on the transport of animal waste in porous media. These studies were restricted to experimental studies involving site-dependent conditions. The proposed work plan will broaden the scope of these studies to address the problem in a comprehensive manner.

## Objectives

The broad objective of the proposed study is to develop methods needed to assess the impact of animal waste containment on groundwater quality. Specific objectives are:

1.) To determine the fate and transport of animal waste in an engineered liner system typical of a lagoon bottom

2.) To determine the fate and transport of animal waste in the natural soils underlying the liner sides and the bottom

3.) To assess the impact of animal storage on groundwater quality for a wide range of operating conditions of the lagoon and hydrogeological scenarios

## Method

The first two objectives will be fulfilled by setting up mathematical models. To fulfill the first objective, and Advection-Dispersion-Reaction (ADR) type equation will be solved analytically to determine the fate and transport through the liner. A unique feature that differentiates this task from other ADR solutions available for compacted liners will be the incorporation of liner sealing mechanisms (which cause reductions in porosity and advective velocity). The experimental data gathered from previous studies on the breakthrough curves of Nitrate, Chlorine, and Phosphorous through liner samples showed evidence of time-dependent pore occlusion. The mathematical model will be validated using the experimental data. Composite liners (consisting of compacted clays and geosynthetics) and alternative liners (often constructed using natural soils amended with bentonite or animal manure) will also be studied. Recent trends indicate increasing use of such liners in animal waste management practices. The model will be used to determine the extent by which such liners inhibit seepage. The model will be capable of predicting pore occlusion as a result of physicochemical and biological clogging of the liner. This feature will be useful in the second task (described below) where the bacterial constituents in leachate from the liner may tend to occlude the pores of the natural soils underlying the liner and overlying the water table.

The second objective will involve numerical solution of reactive and decaying solute transport equations in the unsaturated regime. Time-dependent flux from the first model will form boundary conditions for this model. The problem will be addressed using two different computer programs that simulate contaminant transport in unsaturated flow. The first computer program will consist of a one-dimensional implementation of the governing equations. The Richards equation will be used to simulate the advection, longitudinal dispersion, and decay of contaminants in the unsaturated zone. This program will be run over a range of parameters (e.g., depth of water table, rate of leaching yielded by the first model, decay coefficients, etc..) to obtain estimates of the contaminant concentrations that reach groundwater tables under diverse scenarios. The boundaries for the domain of study will be groundwater tables at the bottom and the lagoon liner profile at the top. The lagoon liner profile may require three-dimensional treatment of the problem. Analytical techniques for treatment of three-dimensional saturated flow are available in the literature. These techniques will be used to treat the three-dimensional problem under the lagoon assuming that the hydraulic conductivity of the unsaturated soils is piece-wise constant and using panel-doublets in the flow domain. The resulting three-dimensional model will allow accurate predictions of streamlines in the unsaturated zone. Fate and transport will be simulated using the flow rates along these streamlines coupled with terms representing advection, longitudinal dispersion, mass transfer and decay.

The models will be validated using the field data available on nitrate levels in groundwater wells monitored in close proximity of lagoons in Southwest Kansas. A survey of the data was conducted recently in an ongoing KDHE investigation. After due validation with the available experimental and field data, the mathematical models will be used to simulate a number of hypothetical scenarios, thus fulfilling the third objective.

It is expected that the computer models developed in this project will be useful in other related problems. In particular, these models could be used to quantify the rates of nitrate that reach the saturated groundwater table due to the application of animal wastes in fields. Terms could also be incorporated in this model to reproduce the sink that occurs due to plants removing phytoremediation to contain nitrate in abandoned feedlot lagoons.

## Deliverables

Results from the proposed study will be disseminated in two ways. First, it is conceivable to develop a nomogram which can be used in an inverse manner to obtain design and operating conditions of the lagoon such that the groundwater quality is not impacted beyond a specified value (based on risk assessment). This will be useful for both practitioners and regulators in minimizing the impact of animal waste storage on groundwater quality. Second, the results will be used to generate a siting map to delineate the regions vulnerable to animal waste contamination (and therefore not suitable for lagoon placement). Such a map will be useful in site selection for lagoon construction and design.

## Logistics and Resources

The work outlined above will be conducted as a cooperative effort between Civil Engineering and Agronomy faculty. Faculty members in the Agronomy department working in the areas of Soil Chemistry and Soil Microbiology will be contacted for input on mass transfer and decay mechanisms, which need to be incorporated into the models. The funding required to carry out this work plan is in the following categories: i) personnel (one-month salaries for two faculty during summer), ii) salaries for a post-doctoral research associate and a doctoral graduate student, iii) two Pentium/workstations, and iv) nominal funds for travel, communication, and duplication.

The first modeling task (fate and transport through lagoon liner) outlined in the preceding sections is currently in progress; it is one of the tasks being performed in the active project funded by Kansas Water Office. A Post-Doc (Dr. Bonala) was hired to initiate the modeling tasks. Funds are requested from this project to sustain support for Dr. Bonala until at least the middle of 1999 by which time the first objective will be fulfilled.

## Sampling and Analysis of Soil Cores Collected Beneath Animal Waste Lagoons FY 98-99

### Principal Investigators

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*G. M. Pierzynski, Department of Agronomy*
*C. W. Rice, Department of Agronomy*
*J. P. Murphy, Department of Biological and Agricultural Engineering*

### Introduction

Anaerobic lagoons are used to contain and treat livestock waste at many concentrated animal operations (CAOs). Lagoon effluent often contains high concentrations of nitrogen and other nutrients. Most of these compounds are applied to nearby farmland as fertilizer or are lost to the atmosphere from the lagoon surface. However, in earthen-lined lagoons, a small portion of the effluent seeps through the bottom and sides of the basin and into the soil beneath the facility. Determining the fate and transport of this leachate is critical for assessing the impact of waste lagoons on local groundwater quality. Of particular interest is the movement of ammonium- and nitrate-nitrogen.

Water balance studies of five animal waste lagoons in Kansas showed that seepage losses (whole-lagoon infiltration rates) were small, ranging from 0.5 to 2.5 mm/d (Ham et al., 1998). However, the concentrations of ammonium in the swine lagoons were quite high, averaging 678 mg/L. Sample calculations show that chemical fluxes from the lagoons ranged from 1,297 to 5,784 kg $NH_4$-N/ha/y. Thus, for a 2.5 ha lagoon, nitrogen export over 20 years of operation could exceed 289,200 kg $NH_4$-N. Determining the factors affecting the absorption, transformation, and transport of this mass of nitrogen is a critical aspect of evaluating lagoons and performing risk assessments.

Our approach for investigating chemical transport from a lagoon is analysis of soil cores collected beneath the soil liner. Miller et al. (1976) evaluated soil nutrient profiles beneath four swine lagoons that had been operated for two, eight and ten years. The 2-year old lagoons on fine textured soil had high ammonium concentrations of 300 to 900 mg/g, concentrated in a 0 to 8 inch layer directly below the lagoons. Concentrations returned to background levels by 0.4 m under the liner. However, older lagoons in medium to course-textured soil, had high ammonium concentration that persisted down to the maximum sampling depth of 4 m. Similar results were obtained by Culley and Phillips (1989) who found ammonium concentrations between 600 and 1400 mg/kg in a distinct, 0-8 m soil zone below earthen pits that had been used to contain dairy waste for three years. Negligible traces of nitrate were found in both studies.

The objective of the proposed research is to collect and analyze soil cores collected beneath animal waste lagoons in Kansas. This data will be evaluated in combination with water balance and modeling studies to help predict the fate and transport of effluent that infiltrates in the soil under earthen lagoons.

### Materials and Methods

Sampling Procedures

Soil cores will be obtained from swine, cattle-feedlot, and dairy waste lagoons when access to a suitable site is permitted. There are two sampling options that might prove useful. First, lagoons are sometimes emptied and dried to allow the removal of sediments and organic sludge. If a lagoon can be identified that is scheduled for cleaning, then soil cores could be collected from the bottom of the lagoon when only a slurry remained in the basin. It is imperative that cores be collected before the liner dries in order to obtain representative samples of the $NH_4$ and $NO_3$ profiles. Bore holes could be filled and recompacted with a soil-bentonite mixture and/or a grout formulated for filling soil cavities. A second option would be to collect vertical cores along the perimeter of a functioning lagoon near the shoreline. Effluent depth is sometimes low as the result of waste removal for irrigation. Thus, coring straight down under these conditions may provide an indication of horizontal nutrient transport at the lagoon periphery. One advantage of this approach is that cores could be collected periodically over the life of the lagoon. The bore holes could be filled and plugged as mentioned earlier.

Soil samples will be collected using a combination of hand and mechanical sampling. Deep cores will be collected with Geoprobe Model 540M Probing Machine (Geoprobe Systems, Salina KS). The Geoprobe System uses direct-push, pneumatic-hammer technology that allows core sampling with minimal static machine weight and no contamination from the sides of the probe hole. Soil cores will be collected using the Geoprobe large-bore or macro-bore tool string to depths of 10 to 15 m when conditions are suitable. Bore samplers will be equipped with polymer liners to improve data integrity. Each push of the tool string (incremental samples) will obtain a core approximately 3.8 cm in diameter and 75 cm in length. If necessary, the bore hole will be filled with a cement-bentonite grout using a high-solids injector pump designed for use on the 540M (GS1000, Grout Machine, Geoprobe Systems). Details of the soil sampling plan (number of samples, depth, etc..) Will be customized once a lagoon has been selected.

Waste samples from the lagoon being sampled (or a nearby lagoon at the same CAO) will be obtained at multiple depths using a 1.2 L Kemmerer sampler. Samples will be chilled to near
0C ° and transported to a laboratory for analysis.

The sampling project hinges on obtaining permission from cooperators with an acceptable lagoon. Assuring cooperators that the soil coring procedures will not compromise lagoon performance (i.e., create a leak in the soil liner) is critical.

### Soil Analysis

A limited amount of data is available for the complete chemical characterization of lagoon water. One such analysis shows the cation composition of the water to be dominated by $NH_4^+$ followed by K, Na, Ca, and Mg. On a charge basis the $NH_4^+$ to K and the $NH_4^+$ to Na ratios are 4:1 while the $NH_4^+$ to Ca ratio is 11:1 and the $NH_4^+$ to Mg ratio is 33:1. Total cation concentrations sum to 80 meq/liter. Assuming a soil cation exchange capacity of 10 meq/100g and bulk density of 1.35 g/cm$^3$, the depth of soil required to absorb all the cations is considerably less than the depth of soil that would be saturated for a given rate of seepage from a lagoon. These estimations suggest that the water at the leading edge of the wetting front would have much lower cation concentration than the original leachate from the lagoon, assuming that all of the cations in the water had the opportunity to interact with the cation exchange sites in the soil. Conversely, the water has fairly high $Cl^-$ concentrations and $Cl^-$ may be useful as a tracer to estimate the approximate depth of leaching. However, uncertainty in the soil moisture profile will make predicting leachate movement difficult. Large differences in hydraulic conductivity between the compacted-soil liner and the underlying soil may result in the formation of an unsaturated zone in or immediately below the liner. The soil moisture profile will also be measured from the core samples.

The lagoon water has low $NO_3$-N concentrations and high $NH_4^+$-N concentrations, in agreement with other observations (Miller et al., 1976), and indicative of the anaerobic environment in the lagoon and the potential for $NO_3$-N problems should the soil beneath the lagoon ever become aerobic. The high biological and chemical oxygen demands of the water suggest high concentrations of dissolved organic C, which may be another useful tracer for estimating the approximate depth of leaching. Phosphorus concentrations are also quite high although the potential environmental problems from this are not certain. The distribution of the P into inorganic and organic forms will have an influence on the relative mobility of the P in the soil. It is likely that the majority of the P will be in inorganic forms with a low mobility. No information is available on metals at this time. The primary metals of concern would be Cu and Zn, which are added to the swine rations. It is not likely that the metals would move very far in the soil although this would have to be confirmed with soil analysis. Given the composition of the lagoon water and the anticipated chemical and microbial processes in soil, the following analyses will be conducted on soil samples collected from beneath the waste lagoons:

Total P
Bray P1-extractable P
Water soluble P
Organic P
KC1-extractable $NH_4^+$-N and $NO_3$-N
Ammonium acetate-extractable Ca, Mg, K and Na
Soluble salts
Soil texture
Cation exchange capacity
Total organic carbon
Total Cu

Aerobic Bacteria
Anaerobic Bacteria
Fecal Coliform
E. Coli
Denitrifying Bacteria
Nitrifying Bacteria
Microbial Activity
Total Zn
Soluble C

Analysis of the liquid waste (lagoon liquor) will include: $NO_3$-N,$NH_4$-N, total N, organic N, pH, total P, Cl, Mg, Ca, Na, K, biological oxygen demand, chemical oxygen demand, total suspended solids, and electrical conductivity.

### Time Line:

Analysis of at least one lagoon before December 31, 1998.

### Assignment of Responsibility:

| | |
|---|---|
| J.M. Ham and Pat Murphy: | Identification of Cooperators; Collection of Soil Cores; Waste Sample Collection |
| Gary Pierzynski and Chuck Rice: | Analysis of Soil and Waste Samples |

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# III. Seepage Losses from Animal Waste Lagoons: Potential Impacts On Groundwater Quality

*Research Update: February 11, 1999*


### Principal Investigator

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### Introduction

Anaerobic lagoons are an integral part of the waste management system at many concentrated animal operations (CAOs). Lagoon waste contains high concentrations of nitrogen, phosphorus, salts, and other nutrients that are eventually applied to farmland as liquid fertilizer. However, while the waste is being stored and treated in the lagoon, subsurface seepage losses may affect soil and water quality near the facility. Of particular concern is the movement of nitrates into local drinking water supplies. Kansas State University is conducting research to determine how construction methods, soil type, local geology, and other factors affect the relationship between the lagoon use and groundwater quality. Components of the research project include: (1) measurement of seepage and subsurface nitrogen losses from commercial lagoons, (2) a laboratory evaluation of soil used to construct compacted liners, (3) a survey of water chemistry in wells located adjacent to CAOs, (4) computer modeling of nitrogen movement in the soil under lagoons, and (5) developing best management practices for land application of waste. This report provides an abbreviated update on measurement of seepage and nitrogen movement from lagoons in Kansas. Results represent progress to date and are not final conclusions. More detailed results are provided elsewhere (see references). Additional reports are planned for April and December, 1999.

### Whole-lagoon Seepage Rates

Regulations in Kansas stipulate that soil-lined lagoons used for animal waste should be constructed so that seepage is less than 1/4 or 1/8 inch per day, depending on where and when the facility was built. Kansas State University developed instrumentation to measure whole-lagoon seepage rates using water balance methods. New research by Ham (1999) shows that this technique can measure seepage to within ± 0.02 inch per day. To date, these methods have been used to collect data from seven swine waste lagoons and two cattle feedlot lagoons. Seepage rates from the Kansas lagoons ranged from 0.01 to 0.10 inch per day; thus, seepage was below the 1/4 and 1/8 inch standards in all cases (Table 1). Data suggest that, when proper soils and clays are used to construct the liner, it is feasible to build soil-lined lagoons that will keep seepage rates below 1/16 inch per day, even when waste depths are near 20 feet and sandy soils exist beneath the compacted liner. Ham and DeSutter (1999) found that organic sludge on the bottom of the lagoon apparently reduced the permeability of soil liners, especially in medium- and coarse-textured soils. However, there was also evidence that seepage may have been more pronounced along the side embankments (shoreline) where erosion and other processes compromised the integrity of the liner. Because of side seepage, it may be impractical to build soil-lined lagoons that have seepage rates less than 1/32 inch per day. In summary, seepage losses from many earthen lagoons in Kansas are probably less than 1/10 inch per day. However, seepage rates from soil-lined lagoons are not zero, and questions remain regarding the movement of nitrogen that does penetrate the liner and move into the subsoil surrounding the facility. The implications of this process will be discussed in later sections.

### Waste Chemistry

The potential impact of a lagoon on groundwater quality is not directly governed by the seepage rate, but is dependent on nitrogen input loading and the vulnerability of the local aquifer. For waste lagoons, input loading represents the rate at which ammonium, nitrate, and other soluble compounds flow from the reservoir of liquid waste into the underlying soil. Thus, the nitrogen export rate from a lagoon is essentially the seepage rate times the concentration of nitrogen in the waste. Table 2 shows the average chemical properties of lagoon waste collected from swine and cattle-feedlot operations in Kansas (DeSutter and Ham, 1999). Almost all the nitrogen in the lagoon is in the form of ammonium (NH4+). There are only traces of nitrate (NO3-) in the liquid, which would be expected under anaerobic conditions. The most notable finding was that nitrogen concentrations in swine-waste lagoons were, on average, seven times higher than in cattle-feedlot lagoons. Waste in cattle feedlot-lagoons is diluted because it is primarily runoff from precipitation that falls on the open-air pens. Conversely, liquid in swine lagoons is waste that was collected in pits beneath the animal barns and then flushed into the lagoon (no dilution). In summary, there are differences in the nitrogen content of lagoon effluent from swine and cattle-feedlot operations. If a swine-waste lagoon and a cattle-feedlot lagoon were seeping at the same rate, the amount of nitrogen deposited into the underlying subsoil would be significantly higher at the swine site. This does not mean that swine lagoons are hazardous and cattle lagoons are not. Our data simply show that these differences exist.

### Subsurface Nitrogen Losses Into Soil Under Lagoons

The movement of effluent-nitrogen into the soil surrounding the lagoon is not only dependent on the seepage rate and the nitrogen concentration, but also is affected by the chemical and physical properties of the soil. Ammonium has a positive charge, while clay particles in soil are negatively charged. Objects with opposite charge attract; thus, NH4+ ions that leak from a lagoon are often strongly adsorbed onto the surface of clay particles in the soil profile. Conversely, negatively charges ions, such as chloride, are not attracted to soil particles and tend to move through the soil profile unimpeded. The ability of a soil to adsorb positively charged ions is described by the Cation Exchange Capacity (CEC). Soils with high clay contents have CECs near 30 meq/100 g and very sandy soils have CECs near 5 meq/100 g. If two lagoons were seeping at the same rate, but one was built above a sandy soil and the other above a clayey soil, one might expect the NH4+ to travel 6 times farther from the lagoon built at the sandy site. This is not exactly what happens in the field because other factors affect solute transport, but it does demonstrate the importance of soil CEC. To gain a better understanding of subsurface nitrogen dynamics, Kansas State University plans to sample and analyze the soil beneath lagoons. Figure 1 shows the average $NH_4^+$ concentration from four soil cores collected at an 11-year old cattle-feedlot lagoon in southwestern Kansas. The lagoon had been dried and the organic sludge removed prior to sampling. Ammonium concentrations were near 400 ppm near the original bottom of the lagoon and then decreased rapidly to about 30 ppm at 16 feet. The shape of the concentration curve demonstrates how $NH_4^+$ was adsorbed in the soil profile. There were essentially no nitrates in any of the soil samples. Thus, almost all the nitrogen that had been lost from the lagoon was still in the $NH_4^+$ form and about 90% of that nitrogen was still within 10 feet of the soil liner. However, in one area of the lagoon the subsoil was very sandy, and $NH_4^+$ concentrations were 66 ppm at 16 feet. This shows how a lower CEC allowed nitrogen to move to lower depths. Ammonium could potentially move directly into the groundwater at sites built above shallow aquifers in sandy soils. In summary, preliminary data suggest that nitrogen losses through a lagoon liner will, in many cases, be deposited as $NH_4^+$ in a rather shallow soil zone near the periphery of the lagoon liner. The amount of nitrogen and size of the deposit will be dependent on the seepage rate, concentrations of nitrogen in the waste, CEC of the underlying soil, local geology, and lagoon age.

### Lagoon Closure

Field measurements have shown that seepage losses from many lagoons occur very slowly. However, over 20 to 40 years of operation, even a low seepage rate can deposit a large mass of nitrogen beneath a lagoon. For example, Ham and Desutter (1999) showed that the total nitrogen deposited in soil beneath a 5-acre swine lagoon could potentially exceed 250,000 lbs. over a 20 year period. When a lagoon is eventually emptied and closed, the nutrient-laden zone of soil under the lagoon will tend to become dry and aerobic , especially in western Kansas where potential evaporation is much greater than precipitation. Under dry soil conditions the $NH_4^+$ may convert to $NO_3^-$, which is very mobile in the soil (Figure 2). Over time, seasonal precipitation and intermittent water movement (drainage) through the soil profile could transport this newly formed $NO_3^-$ toward the groundwater. However, a fraction of the nitrogen may be converted to harmless $N_2$ gas and released into the atmosphere (denitrification). It is difficult to predict the ultimate fate of nitrogen in the $NH_4$-laden soil surrounding lagoons. It may be feasible to phytoremediate the soil profile with plants. Salt tolerant crops like barley or perhaps constructed wetlands might be capable of absorbing large portions of the nitrogen and also stimulate denitrification. Furthermore, it is not clear if the nutrient-laden soil under a lagoon poses a significant risk to the groundwater, especially when the depth to groundwater is large (e.g., 100 ft). Much of the nitrogen may be lost to the atmosphere even without a phytoremediation plan. In summary, older lagoons that are closed and abandoned will initially have a deposit of $NH_4^+$nitrogen in the soil under the facility. Additional research is needed to determine if this nitrogen will affect groundwater quality, and how the risk of contamination is affected by soil and geologic conditions. Best management practices for lagoon closure should be explored.

### Future Research

The Kansas State University research team will continue the study of animal waste lagoons in 1999. Research priorities include: (1) measuring whole-lagoon seepage in different regions of Kansas to evaluate the effect of soil type and geology on lagoon performance; (2) periodically measuring whole-lagoon seepage at new facilities to document the change in seepage over time; (3) collecting soil cores beneath older lagoons to document the extent of side seepage and size of the NH4-laden soil zone; (4) modeling nitrogen movement in the soil and groundwater surrounding lagoons using computer simulation; (5) formulating strategies for lagoon closure and remediation; and (6) measuring the movement of ammonia and other odorous gases emitted from the surface of lagoons.

### References

DeSutter T.M., and J.M. Ham. Survey of waste chemistry in anaerobic lagoons at swine units and cattle feedlots. Technical Report. Department of Agronomy, Kansas State University, Manhattan, KS 66506.

Ham, J.M. 1999. Measuring evaporation and seepage losses from lagoons used to contain animal waste. KAES no. 99-326-J. Trans. ASAE (submitted)

Ham, J.M. 1999. Seepage losses and nitrogen export from animal waste lagoons: A water balance study. KAES no. 99-138-J. J. Environ. Qual. (in press)

Ham, J.M., L. Reddi, C.W. Rice and J.P. Murphy. 1998. Evaluation of lagoons for the containment of animal waste. A report submitted to the Kansas Department of Health and the Environment. Kansas Center for Agric. Resources and the Environment. Kansas State University, Manhattan, KS 66506.

Reddi, L.N., and H. Davalos. 1999. Animal waste containment in anaerobic lagoons lined with compacted clays. J. Geotech. and Geoeviron. Eng. (submitted)

**Table 1. Whole-lagoon seepage rates from lagoons in Kansas.**

| Facility | | Seepage Rate | mm/day | in./day |
|---|---|---|---|---|
| Swine, Nursery* | 1.1 | 0.04 | | |
| Swine, Finish | 0.4 | 0.02 | | |
| Swine, Finish* | 0.8 | 0.03 | | |
| Swine, Sow* | 1.1 | 0.04 | | |
| Swine, Sow* | 1.5 | 0.06 | | |
| Swine, Sow* | 2.0 | 0.08 | | |
| Swine, Sow* | 2.3 | 0.09 | | |
| Cattle | 2.5 | 0.10 | | |
| Cattle | 0.2 | <0.01 | | |

* waste depth was near maximum capacity

**Table 2. Average chemical characteristics of lagoon waste from swine units and cattle feedlots.**

| Measured Parameters (mg L-1) | Swine | Cattle |
|---|---|---|
| NO3--N | 1.0 | 0.5 |
| NH4++NH3-N | 672.8 | 98.3 |
| Total N | 792.4 | 184.2 |
| Organic N | 118.8 | 85.6 |
| Calcium | 79.8 | 144.9 |
| Magnesium | 19.3 | 87.8 |
| Potassium | 647.0 | 551.9 |
| Sodium | 270.3 | 147.7 |
| Total P | 42.5 | 47.5 |
| Chloride | 275.6 | 568.8 |

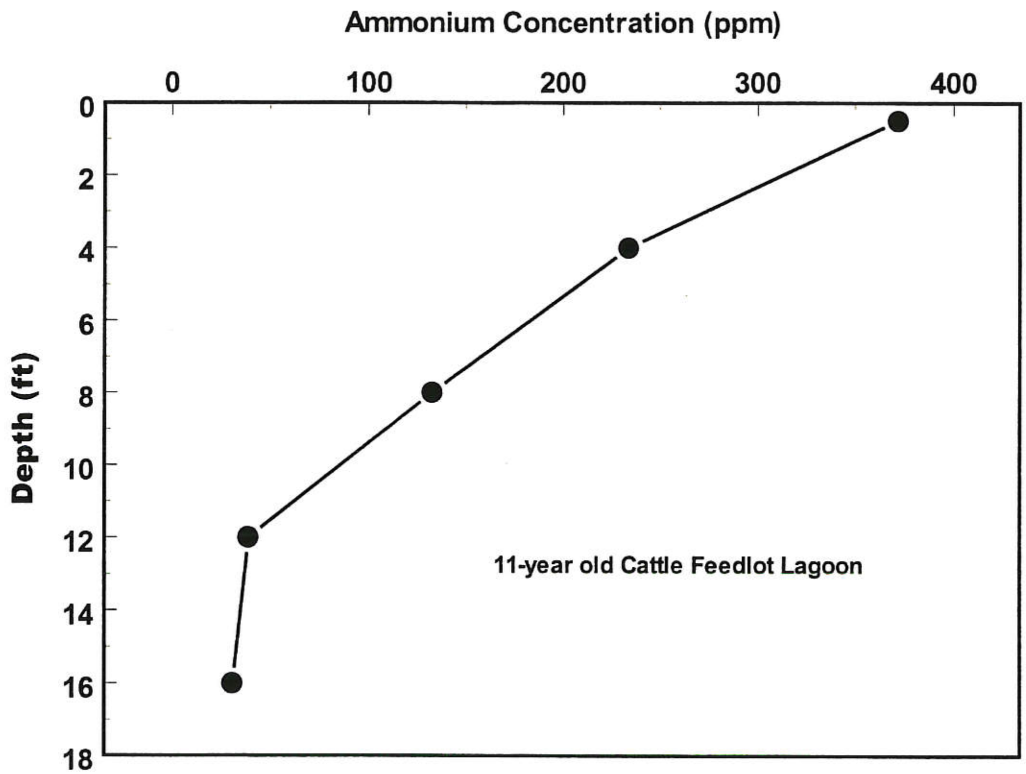



Figure 1. Ammonium-nitrogen profile in soil beneath an 11-year-old cattle feedlot lagoon.

**Lagoon Closure Issues**

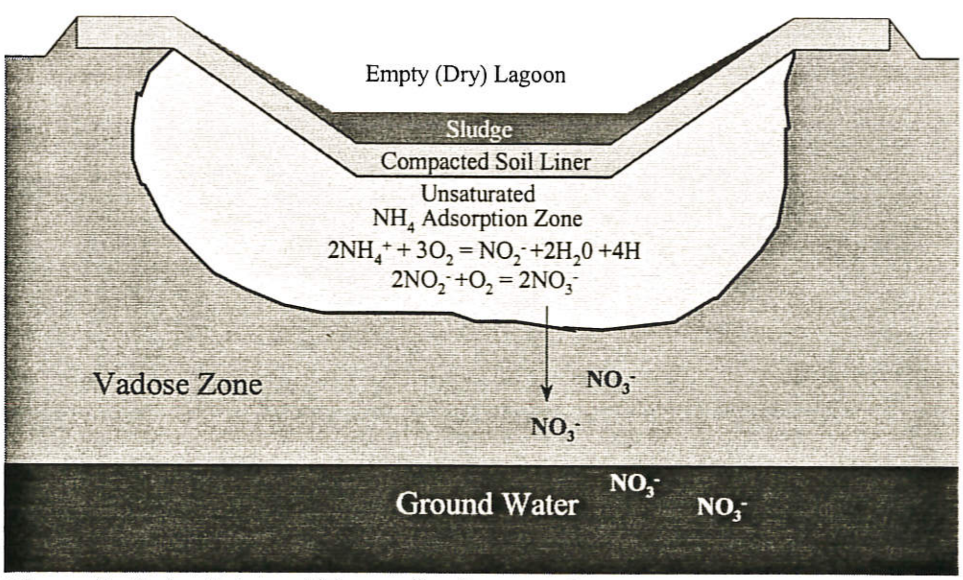



Figure 2. Potential conditions after lagoon closure.

# Seepage Losses and Nitrogen Export From Animal-Waste Lagoons

Jay M. Ham
Department of Agronomy
Kansas State University

## K-State Research Effort

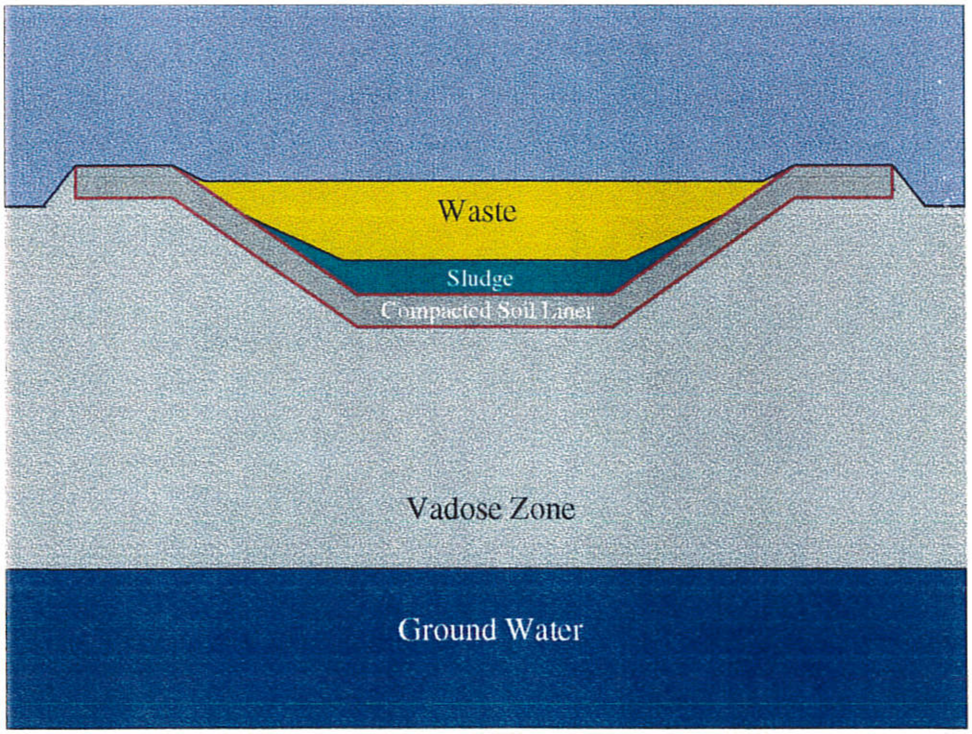
* Field Measurements at Existing Lagoons
* Laboratory Studies of Soil Liners
* Water Quality Survey
* Literature Review
* Land Application of Waste
* Modeling contaminant Transport

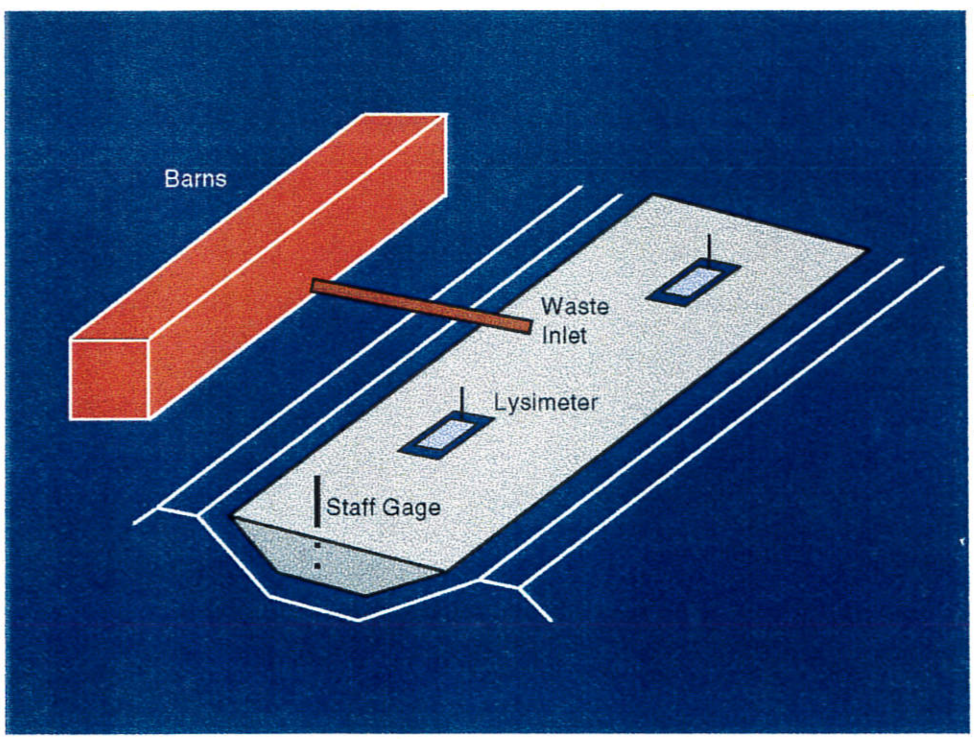
## Waste Lagoons and Ground Water Quality

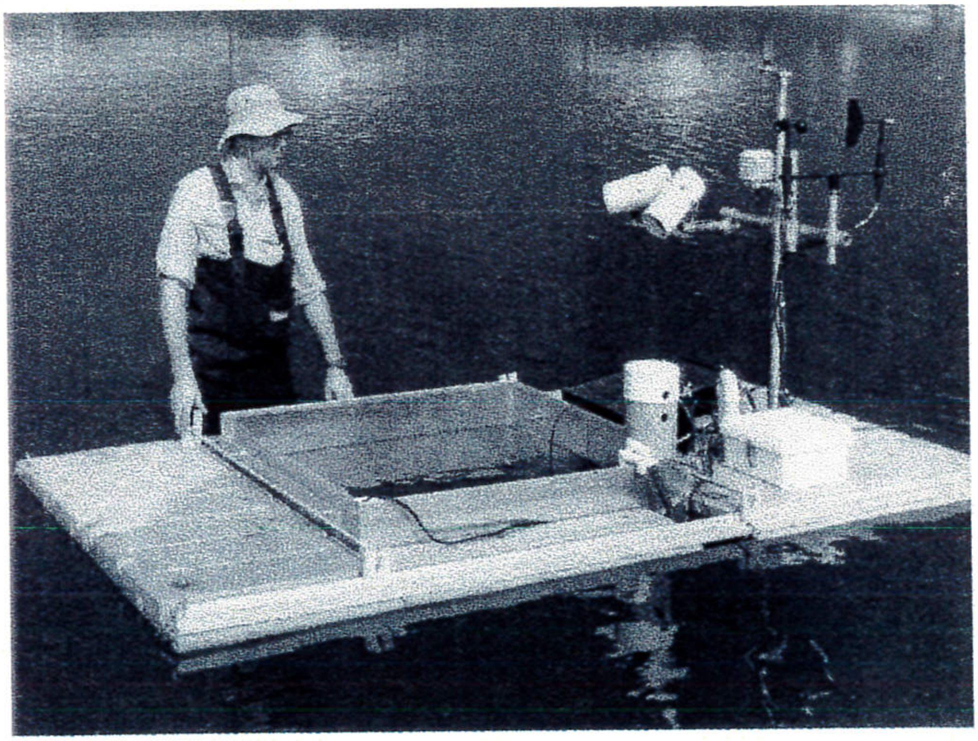
* Nitrogen Export
* Aquifer Vulnerability

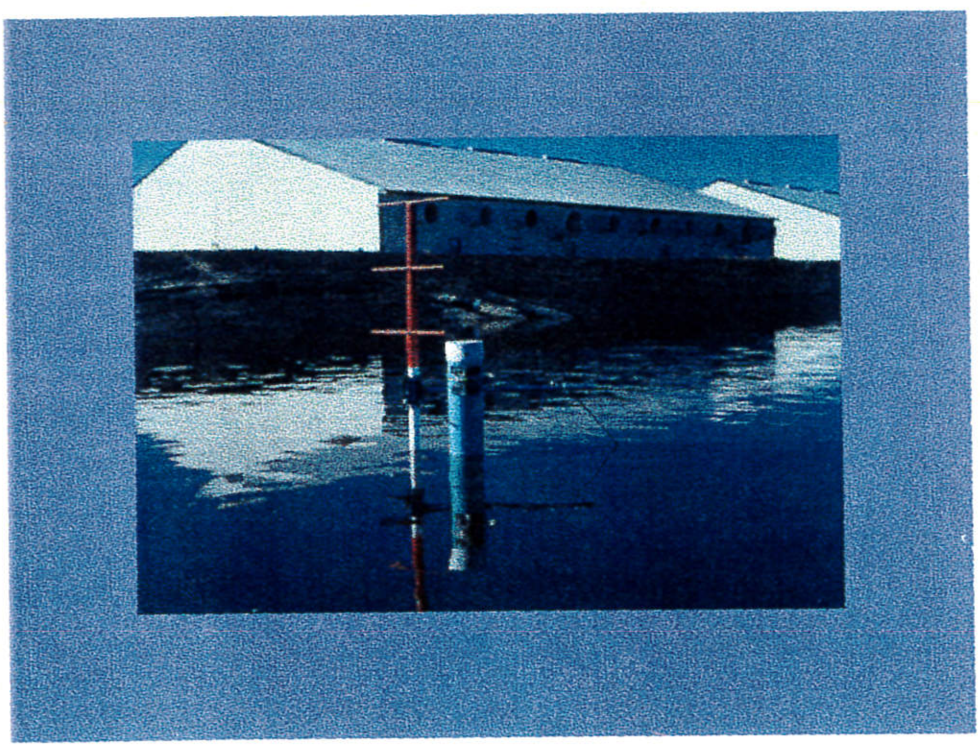
## Methods

* Whole-Lagoon Water Balance
  Seepage = Change in Depth - Evaporation
* Soil Coring Beneath Existing Lagoons


Waste
Sludge
Compacted Soil Liner
Vadose Zone
Ground Water


Barns
Waste
Inlet
Lysimeter
Staff Gage

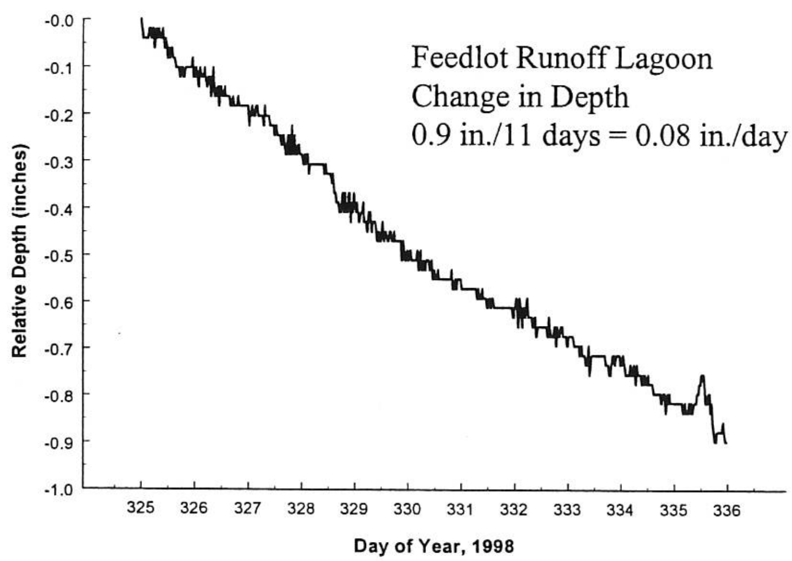


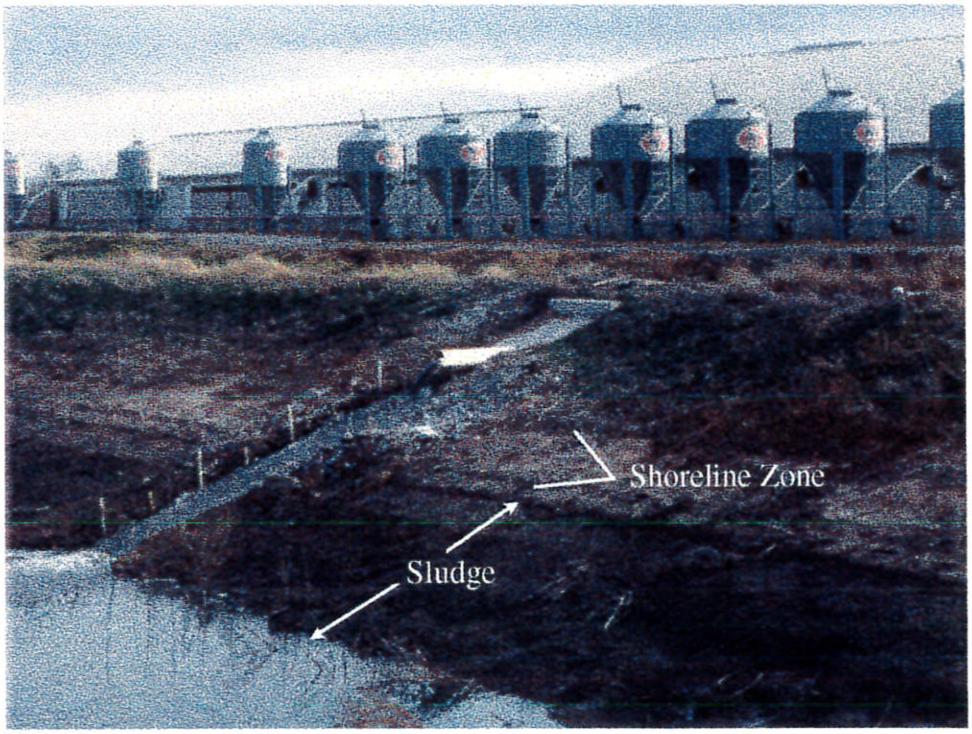


# Seepage Losses From Waste Lagoons

| Facility | Seepage Rate mm/day | m/day |
|---|---|---|
| Swine, Nursery* | 1.1 | 0.04 |
| Swine, Finish | 0.4 | 0.02 |
| Swine, Finish* | 0.8 | 0.03 |
| Swine, Sow* | 1.1 | 0.04 |
| Swine, Sow* | 1.5 | 0.06 |
| Swine, Sow* | 2.0 | 0.08 |
| Swine, Sow* | 2.3 | 0.09 |
| Cattle | 2.5 | 0.10 |
| Cattle | 0.2 | <0.01 |

* near maximum depth



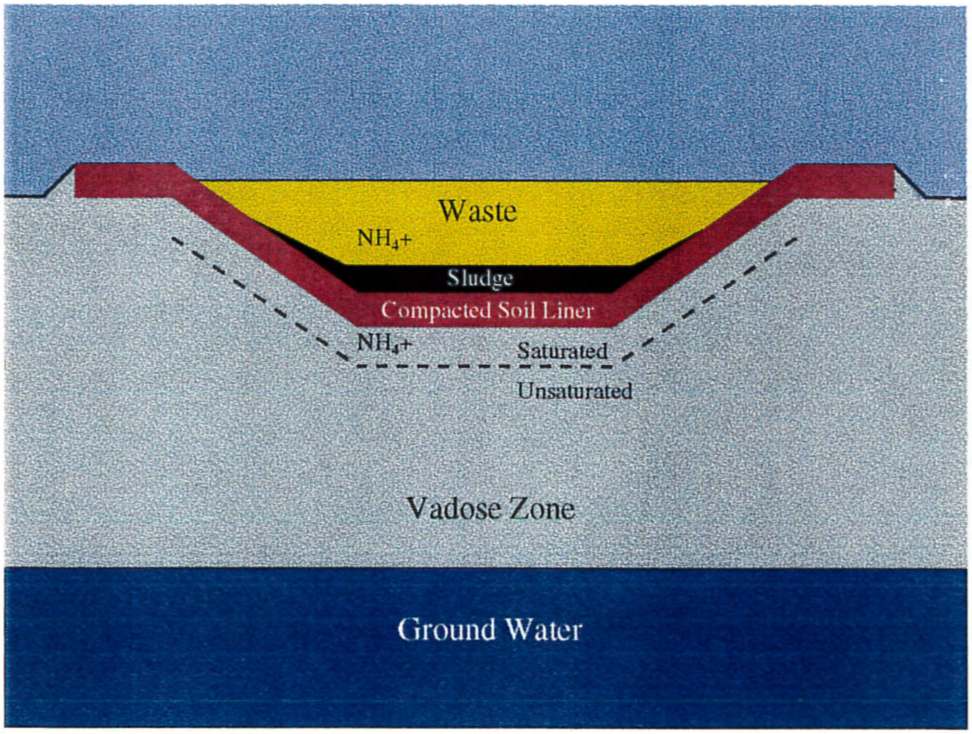

Shoreline Zone
Sludge

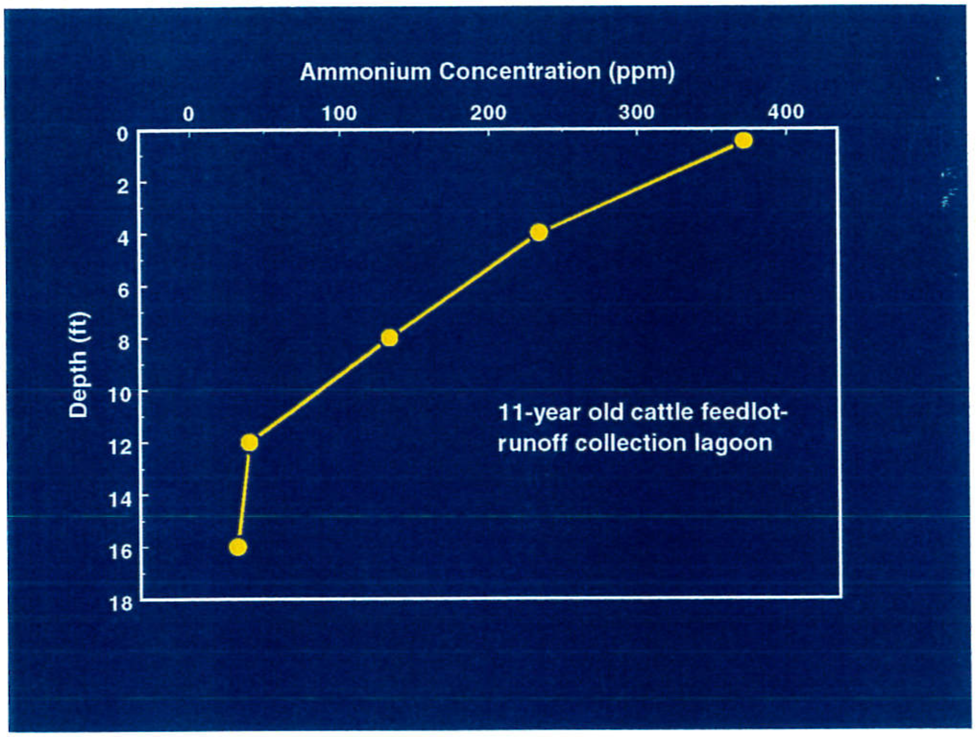
# Nitrogen in Lagoon Waste

| Compound (mg/L) | Swine-Waste Lagoons | Cattle Feed yard Runoff Lagoons |
|---|---|---|
| Nitrate | 1.5 | 1 |
| Ammonium | 657 | 84 |
| Total N | 771 | 160 |
| Organic N | 114 | 76 |

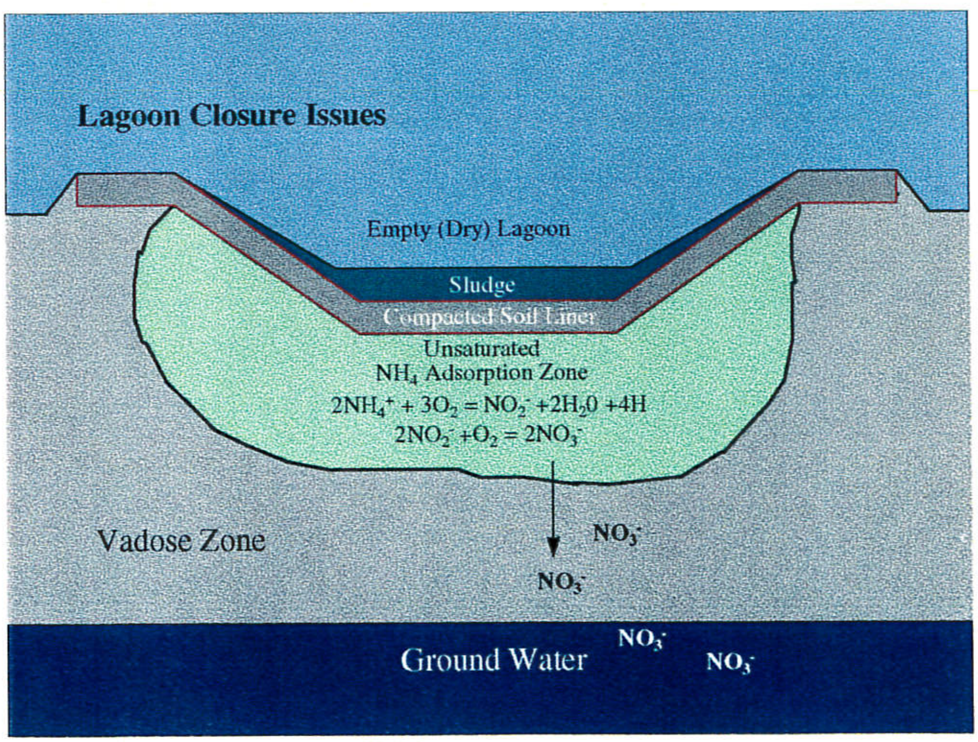
# Nitrogen Export From Swine-Waste Lagoons

| Lagoon | Ammonium-N Export (lbs/yr) | (lbs/20-yr) |
|---|---|---|
| A | 3,612 | 72,240 |
| B | 12,535 | 250,700 |
| C | 10,344 | 206,858 |


Waste
$NH_4+$
Sludge
Compacted Soil Liner
$NH_4+$
Saturated
Unsaturated
Vadose Zone
Ground Water



Ammonium Concentration (ppm)
0
100
200
300
400
0
2
4
6
8
10
12
14
16
18
Depth (ft)
11-year old cattle feedlot-runoff collection lagoon

Lagoon Closure Issues
Empty (Dry) Lagoon
Sludge
Compacted Soil Liner
Unsaturated
NH4 Adsorption Zone
2NH4+ + 3O2 = NO2- +2H20 +4H
2NO2- +O2 = 2NO3-
Vadose Zone
NO3-
NO3-
Ground Water
NO3-
NO3-

# Summary

* Seepage rates are low (<0.1 inch per day)
* Sludge does reduce permeability of liner
* Some nitrogen does move into the subsoil
* In many cases, much of this nitrogen will remain close to the lagoon
* The storehouse of nitrogen under the lagoon could become mobile and move toward the groundwater when the lagoon is emptied and dried (closure)

# Research Plan

* Continue seepage studies and soil coring
* Perfect and simplify methods for measuring seepage
* Modeling movement of chemicals beneath the lagoon (Site-Specific Risk Analysis)
* Test new system for measuring gas emissions (odor) from the lagoon surface

# Possible Products

* Geographic maps of optimal lagoon locations
* Site-specific lagoon designs
* Improved lagoon construction strategies
* Best management for lagoon closure (accounting for the long-term fate of nitrogen)
* Improved rationale for setback distances (odor and air quality)

# IV. House Bill 2950 - KDHE and KDA Environmental Regulations

**Team Leader**
*James P. Murphy, Biological and Agricultural Engineering*

House Bill 2950 (HB2950), passed during the 1998 legislative session, defines environmental regulations for large Kansas swine producers. During the legislative session, technical, best management practices, and general swine production information were delivered to various environmental committees, which were crafting the bill. The objective of the effort was to supply technical information to the legislature without influencing the outcome of the bill. The Kansas Center for Agricultural Resources and the Environment (KCARE) coordinated specialists from civil engineering, biological and agricultural engineering, animal science and industry, and agronomy departments to supply the information. The information supplied dealt with swine manure storage, lagoon seepage, odors, dead pig disposal, facility closure, and application of manure to land.

The delivery of the information made the legislative committees more aware of the role, function, and capabilities of Kansas State University. Most of the information was also utilized by other state agencies such as the Kansas Department of Health and Environment and the Kansas Department of Agriculture. Other interested groups included commodity and environmental organizations.

HB2950 specifies K-State involvement to meet the new regulations. Approximately 150 Kansas producers will be required to meet the new regulations. A manure application plan along with six hours of instruction will be required for certification of swine producers to apply manure to their land. Other plans included in HB2950 are dead animal disposal, odor, closure, emergency response, lagoon seepage, and manure storage. Extension programs in cooperation with KDA and KDHE will be developed next year to educate swine producers about HB2950 requirements.

# Kansas Department of Agriculture

Nutrient Utilization Plan Form

Published by the Kansas Secretary of Agriculture December 15, 1998

This form is required by House Bill 2950 (1998 Session) and the Kansas Chemigation Safety Law, K.S.A. 2-3302 et seq. You must complete this form if:

1. you have an animal unit capacity of 1000 or more hogs; and
2. manure or wastewater (swine waste) from your swine facility is applied to land by any means or process.

This completed form together with all attachments must be approved by the Kansas Secretary of Agriculture BEFORE a permit for your swine facility will be considered for renewal or issuance.

**For KDA Office use only:**

Date form Received by Secretary of Agriculture: ____________ ______, _____.
month day year

Date plan approved by secretary (effective date of plan): ____________ ______, _____.
month day year

Plan expires on: __________ ______, _____.
month day year

KDHE application number ________.

KDHE permit number ________.

The goal of nutrient utilization is to protect all ground and surface water and the soils and public health of this state from impairment from swine facilities. To that end, all application of swine waste must be in accordance with agronomic application rates determined by the Kansas secretary of agriculture. This form will be used to address site-specific conditions for land application of manure, wastewater and other nutrient sources and must comply with Section 6 of House Bill 2950.

Please complete the following form. PLEASE PRINT OR TYPE.

1. Name, address, and telephone number of the facility that plans to supply swine waste to be applied to land.

______________________________________________________Name

____________________________________Address ______________Zip

_________________________________County ________________Phone

___________________________________animal unit capacity for facility



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2. Please identify all land areas to which swine waste may be applied. (Attach additional pages as needed to identify all land areas.)

_______________Section_____________Township__________Range

_______________Section_____________Township__________Range

_______________Section_____________Township__________Range

_______________Section_____________Township__________Range

_______________Section_____________Township__________Range

_______________Section_____________Township__________Range

_______________Section_____________Township__________Range

_______________Section_____________Township__________Range

_______________Section_____________Township__________Range

_______________Section_____________Township__________Range

3. Is the swine facility the owner of the land to which swine waste will be applied?
__________yes _________no

4. If you answered no above, who is the owner of the land?
__________________________________________Name
________________________________________Address
__________________County ______________Phone

5. Please provide a detailed description of the method of the application of swine waste to land:

___________________________________________________________

___________________________________________________________

___________________________________________________________

___________________________________________________________

6. Does your method of application include mixing swine waste with irrigation water?
____________yes ________no

7. If you answered yes to number six, do you have a valid chemigation permit?
____________yes ________no



1-50

8. Do you agree not to apply swine waste to frozen or saturated soil except where soil conservation practices to control runoff are followed?

_____________yes _________no

9. Do you agree not to apply swine waste to highly erodible land except in accordance with a conservation plan that complies with the federal food security act of 1985?

_____________yes ________no

10. Do you agree to incorporate swine waste into soil within 24 hours after applying to bare ground if the application is within 1,000 feet of any habitable structure, wildlife refuge or city, county, state or federal park?

_____________yes ________no

11. If you answered no to number 10 above, please identify whether you have a KDHE approved odor reduction plan, a KDHE approved innovative treatment plan, or have been provided with a written waiver by the owner of the habitable structure?

______________________________________________________________

______________________________________________________________

12. Do you agree not to apply swine waste during a rain storm unless soil conservation practices to control erosion and runoff are employed?

_____________yes _______no

13. Name, address and telephone number of individual who ensures that the correct agronomic application rate is used.

______________________________________________________________

______________________________________________________________

______________________________________________________________

**AMENDMENTS**

Any changes to this form between the effective date of the plan and the expiration date of the plan must be attached as an Amendment. Each Amendment must clearly specify which section of the form it amends.

**REQUIRED ATTACHMENTS:**

A. A site map for the intended location of waste application

B. Copies of all written agreements with parties involved in the application of waste.

C. Description of crop rotations on all land to which swine waste is applied

D. Baseline and annual records of soil tests for each successive year. Each baseline and annual sampling event shall include a completed chain of custody form and laboratory report. Each chain of custody form must include, the date of sampling, a description of each sample collected, including the location, requested analytical method(s), the signature of the person who conducted the sampling, and all other relevant or appropriate information. Each laboratory report shall include the date of analysis, a sample identification that can be matched with the chain of custody, the analytical method(s) used, the result and corresponding units, the signature of the person conduction the analysis, and all other relevant or appropriate information.

E. Baseline and annual records of manure nutrient analysis for the two years following approval of the plan. Each baseline and annual sampling event shall include a laboratory report. Each laboratory report shall include the date of analysis, the analytical method(s) used, the result and corresponding units, the signature of the person conducting the analysis, and all other relevant or appropriate information. If book values are used, cite the publication from which the values were derived.

F. Calculations comparing manure nutrient analysis with soil test results to calculate needed fertility and application rates for pasture production and crop target yields (completed work sheet.)

G. Rates, methods, frequency and timing of application of manure, wastewater and other nutrient sources

H. Amounts of nitrogen and phosphorus applied.

I. Precipitation records and amounts of irrigation and other water applied.

J. Inspection and maintenance records.

K. Training records.

L. Conservation plans for each field applicable to numbers 8, 9 and 12 of this plan.

# Nutrient Utilization Plan Worksheet (One per field)

1-53

Year: ______

New ☐

Amended ☐

**Producer/Farm Name:** ______________________ **County:** ____________

**Estimated Annual Swine Waste Application (Tons or Gallons):** ____________________

| KDHE Permit or Application No: ______ | Field ID: ______ Category: ______ | Acreage: ______ Maximum P Soil Test Level (ppm P): ______ |
|---|---|---|

| Col A | Col B | Col C | Col D | Col E | Col F | Col G | Col H | Col I | Col J | Col K |
|---|---|---|---|---|---|---|---|---|---|---|
| Year | Crop/Veg | Expected Yield **Units/acre** | Estimated N Removal **lbs/acre** | Estimated $P_2O_5$ Removal **lbs/acre** | Soil Test P (ppm P) **Bray-1 Mehlich-3 Olsen** | Basis of Application Rate **N or $P_2O_5$** | Allowable N or $P_2O_5$ Application **lbs/acre** | Swine Waste Application Rate **Solids tons/ac Lq 1000 gal/ac** | Net Addition (loss) $P_2O_5$ **lbs $P_2O_5$/ac** | Total Swine Waste Applied **Solids - Tons Lq - 1000 gal** |
| | | | N Factor (Table 2, page 9) x Col C | $P_2O_5$ Factor (Table 2, page 9) x Col C | **Circle Above** From lab Analysis | Table 3, page 10 | Instructions Page 7 | **Circle Above** Col H / Factor (Table 4, page 11) | Col I X $P_2O_5$ Factor(Table 4, page 11)-Col E | **Circle Above** Col I x Acres |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |

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# ructions For Nutrient Utilization Plan Worksheet

**I. TITLE BOX OF WORKSHEET:**

1. **KDHE Permit or Application No:**
   Enter the appropriate number if it is available

2. **Field ID and Acres:**
   Use a name or number to identify the field and record the number of acres in the field.

3. **Category and Maximum P soil test level (ppm P): Bray-1; Mehlich-3 or Olsen equivalent.**
   This is the category and soil test P level above which no swine waste should be applied.

   **Reference: Table 1, page 8**

**COLUMN A: Year**

Enter the year(s) for which you are estimating the nutrient application and removal.

**COLUMN B: Crop/Veg**

Enter the crop(s) to be grown for the year listed in Col A.

**COLUMN C: Expected Yield**

Enter the expected yield of the crop listed in Col B.

**COLUMN D: Estimated N Removal**
(If using $P_2O_5$ removal, use Col E).

**Reference: Table 2, page 9**
Select the crop and N removal per unit of crop and multiply the N factor by Col C.

**COLUMN E: Estimated $P_2O_5$ Removal**
(If using N removal, use Col D).

**Reference: Table 2, page 9**
Select the crop and $P_2O_5$ removal per unit of crop and multiply the $P_2O_5$ factor by Col C.

**COLUMN F: Soil Test P (ppm P)**
Enter beginning Soil Test P Level (ppm P) from soil test analysis for the first year **(Circle the test used)**.
For subsequent years, refer to Column F on page 2.

**COLUMN G: Basis of Application Rate**

**Reference: Table 3, page 10**
Enter the basis for the optimum swine waste application rate.

**COLUMN H: Allowable N or $P_2O_5$ application**

4. If Col G is based on N recommendation use A (below)
5. If Col G is based on $P_2O_5$ recommendation use B (next column)

**A. N Rec = (YG x Factor x STA) - PCA - PYM - PNST**

N Rec = Nitrogen recommended in Lbs/A.

YG = Yield Goal (Col C)

Factor = From Table 5, page 11 (attached) depending on the crop.
If the crop is a legume go to B (next column).

STA = Soil Texture Adjustment:
**1.1** for sandy soil
**1.0** for medium & fine textured soil.

PCA = Previous Crop Adjustment
**100 lbs/A** for Alfalfa or Sweet Clover
**50 lbs/A** for Red Clover
**30 lbs/A** for Soybeans
**20 lbs/A** for Fallow
**0 lbs/A** for all other crops

PYM = Previous Year's swine waste
**50 lbs** for last year
**20 lbs** for 2 years ago
**0 lbs** for no swine waste history

PNST = Profile Nitrogen Soil Test Results
(For the required 24 inch sampling depth)
Where:
Surface: ppm N x .3 x depth (inches) = lbs/A
Subsoil: ppm N x .3 x depth (inches) = lbs/A
Total: = Surface + Subsoil in lbs/A

**Example:** If the crop is corn and the expected yield is 140 Bu/A, soil texture is silt loam, previous crop is corn, no previous swine waste and the soil test results are 12 ppm for the surface and 6 ppm for the subsoil.
Then: PNST is (12 ppm N x .3 x 6 inches) +
(6 ppm N x .3 x 18 inches) = 54 lbs/A

**N Rec =** (YG x Factor x STA) - PCA - PYM - PNST
(140 x 1.35 x 1.0) - 0 - 0 - 54
(189 - 54) = **135 lbs/A**

**B. If the swine waste application basis is Soil Test P:**

1. Col E (x) Col G
2. If the Soil Test P Level is below 50 ppm P, use **1.5 times $P_2O_5$ removal rate** for a perennial legume crop, or **1 times agronomic N rate** for an annual legume crop or previous to establishment of a perennial legume crop.

**COLUMN I: Swine Waste Application (tons/acre or 1000 gal/acre).**

1. If Col G is N basis, then Col H divided by N Factor (Table 4, page 11)
2. If Col G is P basis, then Col H divided by $P_2O_5$ Factor (Table 4, page 11)

**COLUMN J: Net Addition (loss) of $P_2O_5$**

1. If Col G is N basis, then Col I x $P_2O_5$ Factor (Table 4, page 6) - Col E
2. If Col G is P basis, then (Col H - Col E)

**COLUMN F: For the following year:** ***(estimated)***

**Bray-1 or Mehlich-3:** (Col J divided by 11.5 + current year Col F).

**Olsen:** (Col J divided by 30.0 + current year Col F).

**COLUMN K: Total Swine Waste Applied(tons or 1000 gal)**
(Col I x Acres in field)



1-55

## Table 1: Maximum P Soil Test Level (ppm P)

**Enter in the top section of the Nutrient Utilization Plan Worksheet**

A. **Category Number**

B. **Maximum P level** (The Soil Test P level above which no Swine Waste should be applied)

<table>
<tr><th></th><th colspan="3">Average Annual Rainfall</th></tr>
<tr><th>Land slope in Percent</th><th>Less than 22 inches</th><th>22 to 30 inches:</th><th>Greater than 30 inches</th></tr>
<tr><td>0 to 5 %</td><td>Category 1<br>Lowest Vulnerability for Runoff<br><br>Maximum P level<br>Bray-1: 200<br>Mehlich-3: 200<br>Olsen: 76</td><td>Category 2<br>Intermediate Vulnerability for Runoff<br><br>Maximum P level<br>Bray-1: 150<br>Mehlich-3: 150<br>Olsen: 57</td><td rowspan="2">Category 3<br>Greatest Vulnerability for Runoff<br><br>Maximum P level<br>Bray-1: 100<br>Mehlich-3: 100<br>Olsen: 38</td></tr>
<tr><td>Greater than 5 %</td><td>Category 2<br>Intermediate Vulnerability for Runoff<br><br>Maximum P level<br>Bray-1: 150<br>Mehlich-3: 150<br>Olsen: 57</td><td>Category 3<br>Greatest Vulnerability for Runoff<br><br>Maximum P level<br>Bray-1: 100<br>Mehlich-3: 100<br>Olsen: 38</td></tr>
</table>

1-57

# Table 2. Nitrogen & $P_2O_5$ Removed in Harvested Crop

| Crop | Unit | N | $P_2O_5$ |
|---|---|---|---|
| **Feed Grains:** | | | |
| Corn | lbs/bu | .80 | .39 |
| Grain Sorghum | lbs/cwt | 1.50 | .76 |
| Grain Sorghum | lbs/bu | .84 | .41 |
| **Forages:** | | | |
| Bermudagrass (hybrid) | lbs/ton | 46.00 | 12.00 |
| Bromegrass | lbs/ton | 36.00 | 13.01 |
| Corn Silage | lbs/ton | 8.30 | 3.45 |
| Fescue, Tall | lbs/ton | 38.00 | 18.00 |
| Sorghum/Sudangrass | lbs/ton | 40.00 | 15.00 |
| Wheat Silage | lbs/ton | | |
| **Legumes:** | | | |
| Alfalfa | lbs/ton | 56.00 | 15.00 |
| Clover, Red | lbs/ton | 40.00 | 10.08 |
| Soybeans | lbs/bu | 4.00 | .80 |

| Crop | Unit | N | $P_2O_5$ |
|---|---|---|---|
| **Small Grains:** | | | |
| Barley, Spring | lbs/bu | 1.10 | .39 |
| Oats | lbs/bu | .80 | .25 |
| Rye | lbs/bu | 1.17 | .34 |
| Triticale | lbs/bu | 1.17 | .34 |
| Wheat | lbs/bu | 1.40 | .50 |
| **Specialty Crops:** | | | |
| Canola | lbs/bu | 1.88 | .92 |
| Cotton | lbs/bale | 31.00 | 12.09 |
| Flax | lbs/bu | 2.00 | .85 |
| Potatoes | lbs/cwt | .35 | .16 |
| Sugar Beets | lbs/ton | 4.20 | 1.49 |
| Sunflowers | lbs/cwt | 3.60 | 1.69 |

From: Plant Food Uptake (PFU) for Great Plains Crops, Potash & Phosphate Institute.

1-58

# Table 3: Basis for Swine Waste Application Rate

**Enter in Column G:**

| Soil Test Phosphorus Level (ppm P) | | Runoff Vulnerability Category from Table 1 | | |
|---|---|---|---|---|
| Bray-1 or Mehlich-3 | Olsen | Category 1 | Category 2 | Category 3 |
| | | For legumes: (alfalfa, soybeans, clover, etc) | | |
| 0 - 50 | 0 - 19 | Use 1.0 x Agronomic N Require: Annual legumes or prior to establishment of perennial legume.<br>Use 1.5 x $P_2O_5$ removal rate: Perennial legume crops. | | |
| | | For all other crops | | |
| 0 - 50 | 0 - 19 | Use 1.0 x Agron N Require. | Use 1.0 x Agron N Require. | Use 1.0 x Agron N Require. |
| 51 - 75 | 20 - 29 | Use 1.5 times $P_2O_5$ removal | Use 1.5 times $P_2O_5$ removal | Use 1.5 times $P_2O_5$ removal |
| 76 - 100 | 30 - 38 | Use 1.5 times $P_2O_5$ removal | Use 1.5 times $P_2O_5$ removal | Use 1.0 times $P_2O_5$ removal |
| 101 - 150 | 39 - 57 | Use 1.5 times $P_2O_5$ removal | Use 1.0 times $P_2O_5$ removal | Use No Swine Waste |
| 151 - 200 | 58 - 76 | Use 1.0 times $P_2O_5$ removal | Use No Swine Waste | Use No Swine Waste |
| Over 200 | Over 76 | Use No Swine Waste | Use No Swine Waste | Use No Swine Waste |

## ble 4. Available N & P From Swine Manure

| Solid Handling System | N | $P_2O_5$ |
|---|---|---|
| **Without Bedding:** | **lbs/ton** | **lbs/ton** |
| Incorporated | 5.8 | 9.2 |
| Surface Applied | 2.8 | 9.2 |
| **With Bedding:** | | |
| Incorporated | 4.7 | 7.1 |
| Surface Applied | 2.2 | 7.1 |
| **Liquid Handling System** | **lbs/1000 gal.** | **lbs/1000 gal.** |
| **Liquid Pit:** | | |
| Incorporated | 94.6 | 113.1 |
| Surface Applied | 40.7 | 113.1 |
| **Lagoon:** | | |
| Incorporated | 10.8 | 8.6 |
| Surface Applied | 4.6 | 8.6 |

Conversion factor: 27,154 gallons = 1 acre-inch

From: Ohio State Bulletin AGF-208-95

Assumptions: 25% of $NH_4$-N available when surface applied
75% of $NH_4$-N available when incorporated
33% of organic N available the first year

## Table 5. Factors for Calculating Nitrogen Requirement of Different Crops Based on Expected Yield

| Crop | Yield in Units | Factor |
|---|---|---|
| Barley, grain | bu/acre | 1.05 |
| Bermuda grass | tons/acre | 40.00 |
| Brome grass | tons/acre | 40.00 |
| Corn, grain | bu/acre | 1.35 |
| Corn, silage | tons/acre | 9.00 |
| Fescue, hay | tons/acre | 40.00 |
| Grain Sorghum, grain | bu/acre | 1.25 |
| Grain Sorghum, silage | tons/acre | 9.00 |
| Oats, grain | bu/acre | 1.05 |
| Sunflowers | cwt/acre | 5.00 |
| Wheat, grain | bu/acre | 1.75 |

For any crop not listed, consult the KS Dept. Of Agriculture

1-59

# V. Environmental Impact of Land Application of Animal Wastes


## Team Leader

*Alan Schlegel, Professor, Southwest Research-Extension Center*


## Summary


Animal wastes have been successfully used as agricultural soil amendments and nutrient sources for centuries. The potential for animal wastes to recycle nutrients, build soil quality, and maintain crop productivity is well established. A growing concern is that changes in livestock production systems, larger and more concentrated operations, may create potential environmental problems because of excessive amounts of animal wastes in localized areas.

The number of swine in Kansas was more than 2 million hogs and pigs in 1989 compared to about 1.6 million head in 1998. The number of swine producers has decreased by about 50% since 1993 although the size of operations has increased. The concentration of animal feeding is not limited to the swine industry since about 90% of the fed cattle in Kansas are marketed by large feedlots (more than 8000 head capacity). Daily manure production has been estimated to be about 1 million pounds (dry matter) from finishing swine and more than 10 million pounds from feedlot cattle.

The only viable alternative, in most instances, for disposal of animal wastes is land application. There is been growing public concern that land application of animal wastes may adversely affect the environment. Two particular concerns are nitrate leaching into the groundwater and phosphorus running off into surface waters. Nitrates in groundwater are a human health concern while phosphorus in surface water increases eutrophication, which decreases the waters use for drinking, wildlife, and recreation. Since animal wastes are bulky and expensive to transport, there is an economic incentive to dispose of them as near as possible to the feeding facilities. With increases in large confined feeding operations, there is increased concern for excessive application of manure causing environmental degradation.

Nitrate is a mobile form of nitrogen (not adsorbed to soil particles) and will move freely in water. Therefore, whenever water moves through soil it will pick up and transport nitrate (nitrate leaching). Nitrate leaching will pose greater problems in well-drained soils (such as sands) that receive abundant N applications (either from manure or commercial fertilizer) in areas with high rainfall (or irrigation) and with shallow depths to groundwater.

In Kansas, there has been no reported research evaluating application of swine waste on nitrate leaching; however, there have been several studies that examined the impact of beef wastes on nitrate movement. In a study near Pratt, four years of beef manure applications at high rates (300 ton/year) caused nitrate movement to a depth of about 7 feet, but little indication of deeper movement. This high rate of manure depressed crop growth and contained more than 5,000 lb N/acre or about 20 times the amount needed for crop growth. Application of manure at a rate that corresponded to crop requirements (about 12 ton/acre) or even several times greater increased crop growth with little or no nitrate accumulation below the crop root zone. Similar results were reported in Texas where 10 ton/acre of cattle manure was the optimum rate for corn and sorghum production (Mathers and Stewart, 1974). Application of effluent water from a beef lagoon at a rate of 6 inch/yr produced maximum corn forage yield in Kansas without nitrate accumulation in the soil (Wallingford et al., 1974). The rate of effluent water that could be safely applied would vary because of differences in N concentration in effluent water. For instance, N concentrations in lagoons sampled in Kansas ranged from 16 to 543 ppm, with 90% in the ammonium form (Murphy et al., 1973).

The amount of nitrate leaching is a function of N applied rather than type of manure. Nitrate movement was found to be similar for beef and swine manure when compared at similar N rates (Evans et al., 1977). In Oklahoma, Sharpley et al. (1991) found minimal nitrate leaching following long-term (up to 15 years) application of poultry and swine manure at moderate rates (100 to 275 lb N/acre).

Land application of animal wastes at rates greatly exceeding crop requirements increased the potential for nitrate leaching. However, when manure applications were limited to the crop N requirements, there was little indication that nitrate leaching was a threat to groundwater from any manure source. This indicates that land application of animal manures using a 'utilization' approach rather than as

a disposal mechanism will minimize potential nitrate leaching problems.

Another environmental concern associated with animal manures is phosphorus runoff into surface waters. Unlike nitrate, phosphorus loss from soil is not a human health concern. Instead, the concern is that P increases eutrophication of fresh water streams and lakes. The problems are most severe where water movement from soil to surface water is greatest and where soil P levels are highest.

Surface water runoff is the major cause of P loss from soil, although P losses are generally less than 5% of applied P. Surface water runoff contains both particulate and dissolved P. Particulate P is the P associated with soil particles and P loss is part of soil erosion during runoff events. As erosion increases, the particulate P concentration of runoff increases. From cultivated fields, particulate P in sediments constitutes 60 to 90% of the P loss. In grasslands, with little soil erosion, dissolved P is the major form of P loss. Dissolved P can also be the major loss mechanism in no-till systems.

The timing of P applications affects P loss in runoff. The major portion of P loss in runoff generally results from one or two intense storms. When P applications are made during the time of the year when intense storms are most likely, then the potential for greater P loss is increased (Edwards et al., 1992). Another factor that influences P loss from manure is the length of time between manure application and the first storm. Westerman and Overcash (1980) found a 90% reduction in P loss from poultry and swine manure applications when simulated rainfall was delayed from 1 hour to 3 days after manure application

Phosphorus loss from agricultural land can be minimized by controlling runoff and erosion. Phosphorus loss in runoff can be 5 times greater with surface applications of manure than with injection or incorporation. Conservation tillage can reduce erosion and runoff; however, soluble P losses can be greater from no-till than conventional tillage systems. Additional measures to control runoff include buffer strips, riparian zones, terraces, contour tillage, and cover crops. These practices are generally more efficient in controlling particulate than dissolved P loss

Loss of dissolved P is dependent on the soil P content of the surface soil. Sharpley et al. (1996) showed a highly significant linear relationship between dissolved P concentration in runoff and soil P content of the surface soil (0 to 2-inch depth). They showed that 1 ppm dissolved P concentration in runoff would be associated with a soil test P (Mehlich 3) of about 200 ppm. This soil test value is about four times greater than needed to produce optimal crop growth.

Applying manure based on crop N requirements increases P accumulation in the soil. The N:P ratio of fresh manure is about 3:1 for swine and beef and about 2:1 for poultry. However, the N:P requirement of grain crops is about 8:1. So, even if all of the nutrients in fresh manure were available for crop growth (and for N, generally less than 50% is available the first year), manure applied at rates to meet crop N requirements would result in P rates several times greater than crop needs. A compounding problem is that manure N is much more subject to loss in storage and application than is manure P. The magnitude of N losses in storage have been reported to be 30-90% for aerated systems, 10-75% for anaerobic systems, and 25-99% from feedlot surfaces (Vanderholm, 1975). Also, surface applications of manure without incorporation may result in N losses up to 90% compared to less than 15% with disk incorporation.

The most direct method for reducing P accumulation in soil is to apply lower rates of manure. Basing manure application rates on crop P rather than N requirements reduce application rates several-fold, which prevents excessive P accumulation and reduces the risk of nitrate leaching. However, this approach requires more land area for manure application and increases handling and transportation costs.

Soluble salts and sodium from animal wastes can cause problems for crop growth and soil tilth when excessive levels accumulate in the soil. The salt content of the soil should be routinely monitored when applying animal wastes. However, salinity problems can generally be avoided by limiting application of animal manures to rates that meet, but don't exceed, crop nutrient requirements.

Land application of animal manures may also impact the heavy metal status of soils. Copper (Cu) and zinc (Zn) are added to swine feed to improve animal performance, which increases the concentration in the waste. However, the use of animal wastes generally poses less of a problem with heavy metal contamination than the use of municipal wastes. Toxicity problems from Cu and Zn can be avoided by limiting their use as feed additives and avoiding excessive rates of manure application.

## Introduction

Animal wastes have been successfully used as agricultural soil amendments and nutrient sources for centuries. For almost 2,000 years, until the advent of chemical fertilizers in the 1940's, animal wastes were one of the primary sources of plant nutrients for the world's agriculture (Sims, 1995). The potential for animal wastes to recycle nutrients, build soil quality, and maintain crop productivity is well established. A growing concern is that changes in livestock production systems may create potential environmental problems because of excessive amounts of animal wastes in localized areas. The trend in animal production is towards confined feeding operations concentrated in specific geographic regions.

The number of hogs and pigs in the U.S. increased 7% from 1996 (56 million head) to 1997 (about 60 million head) [Kansas Agricultural Statistics 1997]. However, this increase was not uniform across the country. Of the 17 major swine producing states, the number of hogs and pigs increased 15% in Iowa and 24% in Oklahoma, in contrast to a decrease of 10% in Georgia and 9% in Wisconsin.

The number of swine in Kansas declined from more than 2 million hogs and pigs in 1989 to about 1.2 million head in 1995 (Kansas Agricultural Statistics, 1990, 1996). Since then, the number of hogs and pigs has increased to about 1.4 million in 1996 and 1.59 million in 1998 (Dec. 1) [Kansas Agricultural Statistics, 1998]. However, the number of swine producers has steadily decreased. There were about 5,300 swine operations in Kansas in 1993 compared to about 2,600 in 1998. This decrease occurred for all size groups, except for those in excess of 5,000 head. The number of small operations (less than 500 head) has decreased from 4,700 in 1993 to about 2,200 in 1998. These small operations accounted for about 35% of the swine inventory in 1993 compared to only 14% in 1998. In contrast, operations having more than 2,000 hogs and pigs accounted for 36% of the inventory in 1993 compared to 71% of the hog and pig inventory in 1998. The swine operations that are increasing in number are those with more than 5,000 hogs and pigs, while few in number (30), they accounted for 49% of the hog and pig inventory in Kansas in 1997.

The number of cattle in Kansas has also increased during the past five years. In 1993, there were 5.9 million cattle compared to over 6.5 million in 1997. An area that has seen greater growth is the number of fed cattle marketed which increased from 4.2 million in 1993 to 5.2 million in 1997. In fact, the concentration of cattle feeding in large operations is more pronounced than with swine. Cattle feedlots with capacities greater than 8,000 head market about 90% of the fed cattle in Kansas.

With the large numbers of livestock in Kansas, there are considerable amounts of manure produced. Daily manure production (wet weight) from various animals is about 65 lb/animal unit (1,000 lb live weight basis) for growing swine, 60 lb for beef cattle, 82 lb for dairy cattle, and 300 lb for poultry (Midwest Plan Service, 1985). Livestock manures are about 10 to 15% dry matter. The N content of fresh manure is about the same (10 to 14 lb/ton wet weight) for swine, beef and dairy cattle, and poultry. For perspective, 80 finishing pigs, 18 feedlot steers, 12 dairy cows, or 2,400 broilers produce one ton of manure-N/year. Phosphorus content is more variable with about 1.7 lb/ton (wet weight basis) for dairy manure, 3 lb/ton for beef cattle and poultry wastes, and 4.8 lb/ton for swine manure. Manure production in Kansas has been estimated to be about 1 million pounds (dry matter) from finishing swine and more than 10 million pounds from feedlot cattle daily. Another consideration is that not all of the nutrients in manure are readily available for plant growth. For instance, most of the N in manure is organic N, which must be mineralized to inorganic N before being taken up by plants. In a study in western Kansas, Herron and Erhart (1965) found that less than half of the N in beef feedlot manure was available for plant growth the first year after application (11 out of 31 lb N/ton). But they also reported a residual benefit from manure lasting up to four years.

### Land application of animal wastes

The only viable alternative, in most instances, for disposal of animal wastes is land application. During the past decade, there has been growing public concern that land application of animal wastes may adversely affect the environment. Two concerns in particular involve water contamination, either groundwater contamination by nitrate that has leached through the soil or contamination of surface water by phosphorus that has been transported from manured fields by surface runoff. This has been exacerbated by the continued concentration of animal production in large operations in localized areas. Animal wastes are bulky, heterogeneous, and relatively low analysis fertilizer materials. This creates tremendous logistical problems to store, handle, transport, and apply animal wastes in an economic manner regardless of environmental concerns. Therefore, there is an economic incentive to apply animal wastes as near as possible to the feeding operation at high rates, in effect a disposal approach. Since excessive applications of animal wastes can cause environmental degradation, the potential for environmental degradation is greater for large confined animal feeding operations. Following is a review of the literature (emphasizing research conducted in Kansas) as it pertains to the impact of land application of animal waste on the environment. The particular focus was the impact of swine waste on environmental quality.

## Potential Environmental Problems

### Nitrate leaching

Nitrate-N in water can cause a public health risk (methemoglobinemia) associated with consumption of water containing high nitrate-N by infants. The public health standard for nitrate-N in drinking water is 10 mg/L (ppm). Nitrate is a mobile form of nitrogen (not adsorbed to soil particles) and will move freely in water. When water moves through soil it will pick up and transport (leach) nitrate if it is present. This becomes a problem when the downward movement of nitrate exceeds the crop rooting depth. Therefore, nitrate leaching will pose greater problems in well-drained soils (such as sands) that receive abundant N applications (either as commercial fertilizer or animal wastes) in areas with high rainfall (or irrigation) and with shallow depths to groundwater. Numerous studies have evaluated the potential for accumulation and movement of nitrate through the soil profile caused by application of animal manures. A few specific studies are described below to illustrate the potential impact of land application of animal wastes on nitrate leaching.

In Kansas, there has been no reported research evaluating application of swine waste on nitrate leaching; however, there have been several studies that examined the impact of beef wastes on nitrate movement. Beginning in 1969, beef feedlot waste was applied to a silty clay loam soil at rates that after 4 years ranged from 114 to 2750 metric tons/ha (50 to 1230 tons/acre) near Pratt, KS (Wallingford et al., 1975). The objectives of the study were to determine the impact of disposal of beef feedlot manure on irrigated corn and soil chemical properties. The manure was either applied annually at rates of about 28 to 688 metric tons/ha (12.5 to 307 tons/acre) or a single application of 123 to 590 metric tons/ha (55 to 263 tons/acre) applied at the start of the study. Average N concentration of the manure was 0.92%, which would have supplied a total of 1050 to 25,000 kg N/ha (or 940 to 22,500 lb N/acre). All treatments except the lowest one supplied N in excess of what could be removed by the corn forage and the excess N was subject to leaching. After three years of annual applications, all treatments except the lowest one showed evidence of nitrate movement to 160 cm (64 inches). The higher rates of annual manure application also showed nitrate movement to 190 cm (76 inches), but little indication of leaching to lower depths. Significant nitrate leaching was also observed from a single manure application. Nitrate analysis taken 3 years after a single manure application of 230 metric tons/ha (103 tons/acre) found increased nitrate at the 160 to 200 cm (64 to 80 inches) depth under plots that had received 481 metric tons/ha (215 tons/acre). The nitrate concentration was over 20 ppm at the 200 cm (80 inches) depth for the 481 metric tons/ha (215 tons/acre) rate compared to less than 5 ppm for the control. There was also some indication of elevated nitrate levels to 300 cm (120 inches). With respect to crop response, corn forage yield was enhanced by annual manure rates of 28 to 68 metric tons/ha (12.5 to 30 tons/acre) and depressed by higher rates.

In a companion study in the same area, Wallingford et al. (1974) also evaluated the effect of lagoon water from a beef feedlot on corn forage and soil chemical properties. Lagoon water at rates of 0, 8, 15, 26, and 46 cm/yr (0, 3, 6, 10, and 18 inches/yr) were applied for 2 years. The N concentration of the lagoon water averaged 59 ppm ammonium and 16 ppm nitrate-N. However, they noted considerable variability in N concentration of the lagoon water used during the study with ammonium concentrations ranging from 4 to 179 ppm and nitrate concentrations ranging from 1 to 63 ppm. To determine if this amount of variation was typical, they sampled lagoons at 12 other locations and found similar variation in composition from one year to the next and between lagoons. Total inorganic N (ammonium plus nitrate) in the other lagoons ranged from 16 to 543 ppm with over 90% in the ammonium form (Murphy et al., 1973). After 1 year of application, all plots that received lagoon water had higher nitrate-N concentrations at the 10 and 30 cm (4 to 12 inches) depths than did the control plots, although there was no indication of nitrate leaching past 30 cm (12 inches). After 2 years, soil nitrate was increased to a depth of 50 cm (20 inches) for all rates of application. The 26 and 46 cm/yr (10 and 18 inches/yr) rates caused particularly high nitrate concentrations at 10 and 30 cm (4 to 12 inch) depths (above 20 ppm). A nitrate peak (above 10 ppm) was also observed at 100 cm (40 inch) under the plots that received 46 cm/yr (18 inch/yr) and a less well defined peak at 240 cm (96 inches). They concluded that disposal rates of 26 cm/yr (10 inches/yr) or more caused significant accumulation of nitrate in the soil profile and that maximum yield of corn forage was obtained with a rate of 15 cm/yr (6 inches/yr).

In a later study in Kansas, Schlegel (1992) evaluated the effect of composted beef feedlot manure on sorghum growth and soil chemical properties. The application rates in this study were much lower than the previous studies to better evaluate utilization rather than disposal of manure. Composted manure was applied annually at rates up to 16 metric tons/ha (7.2 tons/acre) alone or with commercial N fertilizer at rates up to 180 kg/ha (160 lb/acre) to a furrow-irrigated silt loam soil near Tribune, KS. The compost had a N content of about 1.4%, which corresponded to an annual N rate of about 225 kg N/ha (200 lb/acre) for the highest compost rate. Soil nitrate measurements taken after four years of annual application found no increase in soil nitrate at any depth to 300 cm (120 inches) from compost applications. However, increases in soil nitrate below 150 cm (60 inches) were observed after 4 years from application of commercial N fertilizer at the 180 kg/ha (160 lb/acre) rate. Sutton et al. (1978) reported similar results when comparing liquid swine waste to inorganic fertilizer in Indiana. They found greater downward movement of nitrate from inorganic fertilizer than from liquid swine manure even though the N application rate of the swine manure was over twice the amount in the inorganic fertilizer. Although in both instances the amount of nitrate movement was relatively small and not considered detrimental.

Researchers in other states have also evaluated the effect of manure disposal from beef feedlots on nitrate leaching. Mathers and Stewart (1974) applied beef feedlot manure at rates 0, 22, 45, 112, and 224 metric tons/yr (0, 10, 20, 50, and 100 tons/acre) annually for 3 successive years to irrigated corn in western Texas. The N content of the manure ranged from 1.0 to 1.8% with an average of 1.37%. The total amount of N added in manure in the 3 years was 900 to 9000 kg/ha (800 to 8000 lb/acre). The 22 and 45 metric tons/ha (10 and 20 tons/acre) rate maintained soil nitrate at a fairly constant level over the 3-yr period, but higher rates caused large accumulations of nitrate in the soil profile. Accumulations of soil nitrate were small the first year but increased markedly each successive year. After 3 years of applying 224 metric tons/ha (100 tons/acre) , there was over 1300 kg/ha (1160 lb/acre) of nitrate in the top 180 cm (72 inches) of soil compared to about 200 kg/ha (180 lb/acre) at the start of the study. For the 112 metric ton/ha (50 tons/acre) rate, soil nitrate was over 900 kg/ha (800 lb/acre) in the top 180 cm (72 inches) of soil. They noted a peak of nitrate concentration at a depth of about 45 cm (18 inches) of 60 and 85 ppm nitrate-N for the 112 and 224 metric ton/ha (50 and 100 tons/acre) rates, respectively; and significant nitrate accumulation below 180 cm (72 inches) to a depth of 360 cm (144 inches). Nitrate concentrations were above 10 ppm at the 360 cm (144 inches) depth for the 112 and 224 metric tons/ha (50 and 100 tons/acre) application rates. Only small differences in nitrate levels were observed below 360 cm (144 inches) to a depth of 600 cm (240 inches) indicating that only small amounts of nitrate had leached below 360 cm (144 inches). Total nitrate in the soil from 30 to 360 cm (12 to 144 inches) was 1260 kg/ha (1125 lb/acre) for the 112 metric ton/ha (50 tons/acre) rate and 1730 kg/ha (1550 lb/acre) for the 224 metric ton/ha (100 tons/acre) rate. This represented about 28 and 19% of the total N added by the two application rates, respectively. With respect to corn response, the optimum rate of manure was 22 metric tons/ha (10 tons/acre). A companion study was conducted at the same location using grain sorghum instead of corn as the test crop and similar results were reported (Mathers et al., 1972).

In the study described above (Mathers and Stewart, 1974), manure was also applied at rates of 448 and 896 metric tons/ha (200 and 400 tons/acre) for 2 years which added a total amount of N of 12,500 and 25,000 kg/ha (11,200 and 22,400 lb/acre) , respectively. For application rates of 224 metric tons/ha (100 tons/acre) or less, soil nitrate increased with increased application rates. However, this trend did not continue when manure was applied at higher rates. The authors concluded that application rates could be so great as to inhibit nitrification, thereby preventing mineralization of ammonium to nitrate. After two applications of 896 metric tons/ha (400 tons/acre), they found 65 ppm nitrate-N in the top 30 cm (12 inches) of soil. However, in the next 150 cm (60 inches) of soil, the nitrate-N concentration averaged only 2.5 ppm. After one season without manure application, the nitrate-N increased to 118 ppm in the top 120 cm (48 inches) of soil and considerable nitrate was found to 360 cm (144 inches). They suggested that denitrification occurs when very large applications of manure are made each year and that when applications stop the large residual N supply is nitrified causing nitrate accumulation and movement in the soil.

In a more recent study in Colorado, Davis et al. (1997) examined soil properties from 41 fields in the South Platte River Basin that had a history of beef feedlot manure applications. They categorized the fields by soil type, either sandy soils (22 fields) or clay soils (19 fields). The manure application rates were 40 to 66 metric tons/ha (18 to 30 tons/acre) for the sandy soils and 44 to 77 metric tons/ha (20 to 34 tons/acre) on the clay soils. Consequently, they found greater residual nitrate-N in the clayey than the sandy soils. However, the N content of the irrigation water was considerably greater for the sandy than clay soils (23 vs. 7 ppm nitrate-N). So when considering both residual soil N and irrigation water N, the sandy soils had N in excess of crop needs of 521 kg/ha (465 lb/acre) compared to 292 kg/ha (260 lb/acre) for the clay soils. They concluded that soil nitrate was excessive and susceptible to leaching losses.

In a higher rainfall area, Evans et al. (1977) compared the effect of disposal of beef (liquid and solid) and swine (liquid) manures to a silt loam soil in Minnesota. The annual application rates (wet weight basis) were 224 metric tons/ha (100 tons/acre) for the solid beef manure and 636 metric tons/ha (284 tons/acre) for the liquid beef and swine manures. Total N content averaged 3.2% for the solid beef manure, 7.7% for the liquid beef, and 9.8% for the liquid swine manure (dry weight basis). Because of the difference in N content and total solids in the wet manures, the total amount of N applied was considerably greater with the liquid beef manure than the other two. The total amount of N in the manure applications each year was about 2150 kg/ha (1920 lb/acre) for solid beef, 5170 kg/ha (4616 lb/acre) for liquid beef, and 2390 kg/ha (2134 lb/acre) for liquid swine (far exceeding any crop N requirement indicating manure disposal rather than utilization was the priority). After one year of manure application, the nitrate-N levels in the top 90 cm (36 inches) of soil were increased by liquid beef and liquid swine manures. A peak in soil nitrate concentration was observed at a depth of 45 cm (18 inches) with about 100 ppm nitrate-N for liquid swine and nearly 200 ppm nitrate-N for liquid beef reflecting the greater amount of N applied in the liquid beef manure treatment. Little movement of nitrate past 90 cm (36 inches) was reported. After two years of application, nitrate-N levels were increased to a depth of 240 cm (96 inches) by application of liquid beef manure. The nitrate levels following application of solid beef and liquid swine manures were similar to each other but lower than liquid beef, but still nitrate-N levels were increased to a depth of 210 cm (84 inches) compared to a non-manure treatment that received the recommended amount of inorganic fertilizer. One year after manure applications were stopped, nitrate-N levels to depths of 360 cm (144 inches) were higher in plots receiving liquid beef manure than from all other treatments. Nitrate levels in solid beef and liquid swine manure treatments were higher to depths of 240 cm (96 inches) compared to the inorganic fertilizer treatment. The total amount of N applied in solid beef manure and liquid swine manure was about the same and nitrate accumulation in the soil profile were similar in most instances. This indicates that nitrate leaching is a function of total N applied rather than type of manure. They concluded that the application rates were excessive for all manures, resulting in significant nitrate movement below the rooting depth of corn, usually about 150 cm (60 inches). Greatest nitrate movement occurred in years with above normal precipitation.

Further north, Gangbazo et al. (1995) evaluated water contamination by swine manure and commercial fertilizer in Quebec, Canada. Swine manure was applied at twice the crop N requirement in the fall, spring, or split between the fall and spring. The manure treatments also received the recommended amount of N as commercial fertilizer, 180 kg N/ha (160 lb/acre) for corn, so the total N applied was 540 kg/ha (480 lb/acre) for all manure treatments (3 times the recommended rate). They found that 98% of nitrate-N loss was by leaching, while 85 to 90% of ammonium-N loss was by runoff. However, total ammonium-N losses were minimal and never exceeded 4 kg/ha (3.6 lb/acre) annually. In contrast, nitrate-N losses were very substantial. During the second year, fall application of swine manure produced a total annual loss (runoff plus drainage) of 161 kg nitrate-N/ha (144 lb/acre) or about 40 mg/L (ppm) compared to 95 kg nitrate-N/ha (85 lb/acre) or about 24 mg/L (ppm) for fertilizer alone. Nitrate-N losses from spring manure applications were 176 kg /ha (157 lb/acre) and the highest nitrate-N loss of 196 kg/ha (175 lb/acre) were with the split application. The amount of nitrate-N loss, in excess of that from fertilizer alone, represented 18 to 28% of the N contained in the manure. In this study, nitrate loss was considerable for all treatments, even when fertilizer was applied without manure at the recommended rate, and application of manure at twice the recommended N rate only increased the problem.

The potential for nitrate leaching was also reported from excessive applications of swine lagoon effluent to a loamy sand soil in North Carolina (King et al., 1990). Lagoon effluent was applied weekly throughout the growing season by sprinkler irrigation to Coastal bermudagrass at rates to supply approximately 335, 670, and 1340 kg N/ha/yr (300, 600, and 1200 lb/acre/yr) or approximately 1, 2, and 4 times the recommended N rate for Coastal bermudagrass. After 11 years of application, nitrate-N was significantly increased in the 60 to 210 cm (24 to 84 inches) depth by the high application rate of effluent indicating excessive effluent application. From a crop perspective, the high effluent rate was also a problem. Nitrate-N content in the forage at the end of the study from plots receiving the high effluent rate approached or exceeded the toxic threshold level for feeding to some ruminant animals (Burns et al., 1990). In the treatments receiving low and medium rates of effluent, the soil nitrate-N levels were below 5 ppm and similar to those of the control treatment (no effluent applied). However, earlier in the study, soil nitrate-N levels ranged up to 20 ppm with the medium effluent rate indicating that this rate of application may also be excessive (King et al., 1985). The low rate of effluent application (335 kg N/ha/yr or 300 lb/acre/yr) was not considered to be a risk for groundwater pollution and also produced acceptable forage yields (Burns et al., 1985).

In the same study, Westerman et al. (1985) reported that the amount of N loss by rainfall runoff was low. The amount of nitrate-N in rainfall runoff averaged only 2 kg/ha/yr (2 lb/acre/yr) at the highest effluent rate; therefore rainfall runoff of N was not a serious concern for surface water pollution. They found similar results when swine manure slurry and lagoon effluent was applied to tall fescue with less than 2% of applied N loss in runoff (Westerman et al., 1987). As a component of the effluent application to 'Coastal' bermudagrass study, Evans et al. (1984) reported on subsurface drainage after 5 years of effluent application. In this region a surface soil (sandy) with high infiltration rate overlays a less permeable clay layer. Most rainfall (or irrigation water) rapidly infiltrates the surface soil (less than 1% surface runoff) but downward movement is restricted by the underlying clay layer causing lateral movement as shallow subsurface flow (about 25% of water input) along the surface of the clay layer. Subsurface flow tends to establish stream flow or leaches to the groundwater. They found that the concentration of nitrate-N in subsurface flow was 6, 18, and 27 mg/L for effluent rates supplying 325, 650, and 1300 kg N/ha/yr (290, 580, and 1160 lb/acre/yr), respectively. The low effluent rate (representing the recommended rate of N application for coastal bermudagrass) maintained the subsurface soil-water quality to within the 10 mg/L standard. They concluded that effluent rates in excess of crop N requirements were excessive and greatly increased the potential for contamination of streams and groundwater.

In a study closer to Kansas (Sharpley et al., 1991) examined the effect of long-term (up to 15 years) poultry and swine manure application to three Oklahoma silt loam soils. The sites selected were producers fields with a history of manure applications and were representative of soils in northeast Oklahoma. Swine manure had been applied at all three sites. The amount of N applied annually averaged 111, 241, and 308 kg/ha (100, 215, and 275 lb/acre) at the three sites. They found no consistent effect of swine manure application on N content of any soil. Although some nitrate-N (about 10 ppm) was found below 150 cm (60 inches) in one soil. Poultry manure was applied to one soil at 5.6 metric tons/ha/yr (2.5 tons/acre/yr). The total amount of N applied annually in the poultry manure was 256 kg/ha (230 lb/acre) and the producer also applied an additional 200 kg/ha (180 lb/acre) of fertilizer N (the crop was fescue pasture). This was the highest loading rate of N and nitrate accumulated in the soil with 25 ppm nitrate-N in the 168 to188 cm (67 to 75 inches) depth and 13 ppm in the 188 to 221 cm (75 to 88 inches) depth compared to 6 ppm or less in the same soil without manure. In general, they concluded that the potential contribution of N from the manures to groundwater was minimal but that a greater concern would be surface water runoff of N and P.

The potential for nitrate leaching from land application of animal wastes was evident in all of the research studies reviewed. However, when manure applications were limited to the crop N requirements, there was little indication that nitrate leaching was a threat to groundwater from any manure source. Nitrate leaching can be a problem when manures (or any other N-containing materials) are applied at excessive rates. Land application of animal manures using a 'utilization' approach rather than as a disposal mechanism should minimize potential nitrate leaching problems.

### Phosphorus loss from soil

Unlike nitrate, phosphorus loss from soil is not a human health concern. Instead, the concern is that P increases eutrophication of fresh water streams and lakes. Eutrophication is the overenrichment of waters with mineral nutrients. Phosphorus is generally the limiting nutrient for biological productivity in fresh water streams and lakes (in contrast, N is usually most limiting in marine waters). Excess biological productivity increases growth of undesirable algae and aquatic weeds, which causes oxygen shortages when they senesce and decompose. This deteriorates the waters use for drinking, fisheries, recreation, and industry. Limiting P transport into surface waters is a critical component for reducing eutrophication of fresh water lakes and streams. Eutrophication has been identified as the critical problem in surface waters in the USA, with agriculture the major source of nutrients in 50% of the lakes and 60% of the rivers (Parry, 1998). The problems are most severe where water movement from soil to surface water is greatest and where soil P levels are highest. Since animal manures contain significant quantities of P, the potential for P loss following manure applications is apparent.

A recent symposium dealt with the issue of P loss and eutrophication (ASA-SSSA-CSSA 1996 Annual meetings in Indianapolis, IN). From this symposium, came several articles that dealt with the various factors of this issue (Cassell et al., 1998; Correll, 1998; Daniel et al, 1998; Ertl et al., 1998; Gburek and Sharpley, 1998; Lentz et al., 1998; Parry, 1998; and Sims et al., 1998). The impact of land application of animal manures on P loss and eutrophication is reviewed below with some of the information coming from the symposium.

Surface water runoff is the major cause of P loss from soil. Subsurface drainage can cause P loss in some soils (such as sandy soils overlaying a clay layer or high organic matter soils), but not generally a problem with soils in Kansas. Surface water runoff contains both particulate and dissolved P. Particulate P is the P associated with soil particles and P loss is part of soil erosion during runoff events. As erosion increases, the particulate P concentration of runoff increases. The relationship between erosion and particulate P was similar for both unfertilized grassland and fertilized conventionally tilled wheat fields, although soil and particulate P loss was approximately two orders of magnitude greater with cultivation (Sharpley et al., 1992). From cultivated fields, particulate P in sediments constitutes 60 to 90% of the P loss. In grasslands, with little soil erosion, dissolved P is the major form of P loss. Dissolved P can also be the major loss mechanism in no-till systems. As soil P increases, the potential for P loss (both particulate and dissolved) increases. Also, during detachment and movement of soil in runoff waters, finer-sized soil particles are preferentially eroded. This results in eroded material having higher P content than the source soil, a process referred to as enrichment. Under simulated rainfall, the enrichment of total P in runoff from several soils ranged from 1.2 to 2.5 and soil test P from 1.2 to 6.0 (Sharpley, 1985)

Although P losses in runoff are generally less than 5% of applied P, concentrations of dissolved and total P often exceed critical values associated with accelerated eutrophication (0.05 for dissolved P and 0.1 mg/L for total P) [Sharpley et al. 1994]. In some cases, the background concentration of P in runoff may exceed these threshold values even for unfertilized native grass watersheds. Also, P inputs in rainfall can contribute to freshwater eutrophication (Sharpley et al., 1994). Therefore, water quality criteria should include factors other than just P concentrations in runoff, such as proximity of P-sensitive waters, runoff potential, and land use (Daniels et al., 1998). For perspective, the average concentration of P in soil solution is about 0.05 mg/L; however, a solution P concentration of 0.2 to 0.3 mg/L is needed to obtain maximum yields of some crops (Tisdale et al., 1993).

Field research has shown a relationship between P loss in runoff and rate and method of P application. An increase in P loss in runoff has been reported with increasing application rate of fertilizer (Romkens and Nelson, 1974), dairy manure (Mueller et al., 1984), poultry litter (Edwards and Daniels, 1993; Westerman et al., 1983), and swine manure (Edwards and Daniels, 1994). Phosphorus loss in runoff is much greater with surface applications than when the P-containing material (fertilizer or manure) is injected or incorporated. The dissolved P concentration of runoff from areas receiving broadcast fertilizer P were 100 times greater than when the fertilizer had been injected below the soil surface (Baker and Laflen, 1982). Incorporation of dairy manure reduced total phosphorus loss in runoff five-fold compared to broadcast applications without incorporation (Mueller et al., 1984).

The timing of P applications also affects P loss in runoff. The major portion of P loss in runoff generally results from one or two intense storms. When P applications are made during the time of the year when intense storms are most likely, then the potential for greater P loss is increased (Edwards et al., 1992). Runoff P loss was reported to be the greatest during the spring planting season; a time with intense rains, high P application, and minimum crop cover (Burwell et al., 1975). Another factor that influences P loss, particularly from manure, is the length of time between manure application and the first storm. Westerman and Overcash (1980) found a

90% reduction in P loss from poultry and swine manure applications when simulated rainfall was delayed from 1 hour to 3 days after manure application. This reduction in P loss was attributed to increased time for P sorption. However, if manure is applied during the winter (no active plant growth) and not incorporated, sorption and plant uptake do not occur which increases the potential for P loss during spring rainstorms. Although, in some cases, manure winter-applied to plowed land may decrease soil erosion and runoff (Young and Mutchler, 1976).

Loss of dissolved P is dependent on the soil P content of the surface soil. Sharpley et al. (1996) showed a highly significant linear relationship between dissolved P concentration in runoff and soil P content of surface soil (0 to 5 cm or 0 to 2 inch depth). They showed that 1 mg/L dissolved P concentration in runoff would be associated with a soil test P (Mehlich 3) of about 200 mg/kg (ppm). A flow-weighted-annual dissolved P runoff concentration of 1 mg/L for agricultural runoff has been proposed in many areas of the country, which is similar to that required of sewage treatment plants. The 1 mg/L concentration of dissolved P associated with 200 mg/kg soil test P (Mehlich 3) represents an environmental soil test value four-fold greater than the agronomic critical value of about 50 mg/kg above which addition of fertilizer P will usually not produce an economic crop response.

Long-term application of P fertilizers and manures at rates that exceed the amount of P removed by crops results in elevated soil test P levels. Application of dairy manure has contributed to 200 mg/kg soil test P (Bray-1) levels in Wisconsin (Motschall and Daniel, 1982). Sharpley et al. (1991) found soil test P (Bray-1) levels of up to 279 mg/kg on soils in Oklahoma after long-term application of poultry manure and 121 to 147 mg/kg on soils receiving long-term application of swine manure. King et al. (1990) reported 450 mg/kg soil test P (Mehlich-1) in the surface soil after 11 years of applying high rates of swine lagoon effluent (total P application was 6100 kg/ha for the 11-year period). This would be about 10 times the level above which no response to P fertilization would be expected. Schlegel (1992) reported that soil test P (Bray-1) increased from an initial level of 13 mg/kg up to 67 mg/kg after 3 annual applications of 16 metric tons/ha (7.2 tons/acre) of composted beef manure. Mathers and Stewart (1974) reported soil test P (sodium bicarbonate) levels in the plow layer of more than 200 mg/kg after 3 years of applying 224 metric tons/ha (100 tons/acre) of beef manure, but no increases in lower depths. Application of effluent water (46 cm/year or 18 inch/yr) from a beef feedlot lagoon increased soil test P (Bray-1) in the surface soil (0 to 10 cm or 0 to 4 inch depth) to about 100 mg/kg after 2 years, but no movement was observed below 10 cm (Wallingford et al. 1974).

Excessive levels of soil test P following long-term manure applications are generally associated with either manure disposal (excessive rates to minimize land area for application) or when the application rate has been based on crop N requirements. The N:P ratio of fresh manure is about 3:1 for swine and beef and about 2:1 for poultry (USDA Agriculture Fact Sheet 345). However, the N:P requirement of grain crops is about 8:1 (White and Collins, 1982). This indicates that even if all of the nutrients in fresh manure were available for crop growth (and for N generally less than 50% is considered available the first year), manure applied at rates to meet crop N requirements would result in P rates several times greater than crop needs. A compounding problem is that manure N is much more subject to loss in storage and application than is manure P. The magnitude of N losses in storage have been reported to be 30-90% for aerated systems, 10-75% for anaerobic systems, and 25-99% from feedlot surfaces (Vanderholm, 1975). Also, surface applications of manure without incorporation may result in N losses up to 90% compared to less than 15% with disk incorporation. In Kansas, surface applied effluent from swine lagoons are assumed to have an available N:P ratio of about 1.2:1 when not incorporated (Kansas Dept. of Agriculture Nutrient Utilization Plan Form). One means of reducing nutrient loss is to add amendments to manure. Addition of slaked lime or alum to poultry manure has been shown to reduce ammonia loss and P solubility by several orders of magnitude (Moore and Miller, 1994).

Critical values (above which no yield response would be expected) for agronomic soil test P varies with the analytical test and geographic location (Soil and Plant Analysis Council 1992). Typical critical values for Bray-1 and Mehlich-3 P soil tests are 30 to 50 mg/kg. For the Olsen P soil test, often used on calcareous soils, critical values usually range from 10 to 15 mg/kg. Several states have set environmental critical values for soil test P. For example, the critical value for Arkansas is 150 mg/kg (Mehlich-3), for Oklahoma is 130 mg/kg (Mehlich-3), and Texas is 200 mg/kg (Bray-1) above which limits on P additions are restricted. Only recently, Kansas set critical values for soil test P of 100 to 200 mg/kg (Bray-1), varying within the state depending upon precipitation and slope.

Phosphorus loss from agricultural land can be minimized by controlling runoff and erosion and by managing phosphorus applications. Conservation tillage practices utilizing increased residue cover can reduce erosion and runoff. Sharpley et al. (1992) reported reduced losses of soluble P, particulate P, and bioavailable P in watersheds using practices that minimized erosion and runoff. However, soluble P losses can be greater from no-till than conventional tillage systems. In eastern Kansas, Janssen et al. (1999) found greater losses of soluble and bioavailable P from surface applications of P fertilizers in no-till than ridge-till or chisel-disk tillage systems. Additional measures to control runoff include buffer strips, riparian zones, terraces, contour tillage, and cover crops. These practices are generally more efficient in controlling particulate than dissolved P loss. Another means of reducing loss is to inject or incorporate P. However, incorporation may conflict with residue requirements of federal farm programs.

The most direct method for reducing P accumulation in soil is to apply lower rates of manure. Basing manure application rates on crop P rather than N requirements reduces application rates several-fold. This prevents excessive P accumulation in soil and reduces the risk of nitrate leaching. However, this approach requires more land area for manure application and increases handling and transportation costs. Also, this may prevent application on land with a history of long-term application, since many years are required to lower soil test P levels once they become very high.

Phosphorus is transported into surface water whenever water flows from agricultural fields. Loss of P is increased by increased water flow along the surface of soil having elevated P concentration. Since the majority of P loss from cultivated fields is in the form of particulate P associated with soil erosion, conservation practices that limit soil erosion generally reduces P losses. However, the most direct method for reducing P loss will be to limit P applications to crop requirements and place the P below the soil surface. Long-term application of excessive rates of manure (whether by using a disposal rather than utilization approach to manure application or basing application rates on crop N rather than P requirements) without incorporation causes the greatest loss of P to surface water. Land application of animal wastes using a "utilization" approach combined with appropriate conservation practices will limit P losses to surface waters and minimize the risk of eutrophication.

## Soil salinity

Animal wastes vary widely in chemical composition, but generally contain considerable amounts of total salts. When applied to soil, some of these salts can be used as plant nutrients to increase productivity but excess salts can create salinity and dispersion problems. Salt-affected soils are generally divided into 3 groups depending upon total soluble salts (measured by electrical conductivity), soil pH, and exchangeable sodium (Na) percentage (Lamond and Whitney, 1991). Saline soils have high amounts of soluble salts (electrical conductivity greater than 4 mmhos/cm) which reduce seed germination and cause irregular plant growth. Sodic soils are low in soluble salts but high in exchangeable sodium (greater than 15% exchangeable sodium). This combination tends to disperse soil particles, causing poor physical characteristics in sodic soils. Saline-sodic soils have large amounts of total salts and exchangeable sodium.

Excess applications of animal wastes can cause soil salinity problems and is a concern with land application of animal manures. Wallingford et al. (1974) reported that electrical conductivity of lagoon water from 12 beef feedlot lagoons in Kansas ranged from 1.0 to 12.8 mmho/cm. They reported decreased yield of corn forage because of increased soil salinity following two applications of lagoon water (3.1 mmho/cm) at rates of 26 and 46 cm/yr (10 and 18 inch/yr). Maximum yield and nutrient uptake were observed at an application rate of 15 cm/yr (6 inch/yr) with only a small increase in soil salinity. Travis et al. (1971) reported that salts increased 200% and infiltration declined to zero in soil columns from four Kansas soils after inundation with effluent water from a beef feedlot lagoon (electrical conductivity of 13.4 mmho/cm). In a study near Pratt, KS, the electrical conductivity of soil was linearly increased by application of beef-feedlot manure (Wallingford et al., 1975). Electrical conductivity greater than 10 mmho/cm was observed following accumulative application of manure at more than 1200 metric tons/ha (535 tons/acre). Plots receiving less than 800 metric tons/ha (350 tons/acre) showed a gradual but not excessive buildup of soluble salts. Schlegel (1992) reported increased exchangeable Na concentrations following three annual applications of beef manure compost at 16 metric tons/ha (7.2 tons/acre), but no adverse affect on grain sorghum production in western Kansas. In this study, the economic optimal compost rate was about 3 metric tons/ha (2.5 tons/acre) (Williams et al., 1994).

Mathers and Stewart (1974) reported increased soil salinity with increased rates of cattle feedlot manure. After 3 annual applications of 112 metric tons/ha (50 tons/acre) or more, soil salinity was increased to a high enough level to decrease germination of corn. However, rates of 45 metric tons/ha (20 tons/acre) or less did not increase soil salinity concentrations above that of the control. They concluded that the optimum manure rate was 22 metric tons/ha (10 tons/acre). Sutton et al. (1978) reported increased exchangeable Na in two Indiana soils after application of liquid swine at rates up to 134 metric tons/ha (60 tons/acre) for two years, but no increase in electrical conductivity in the soil or adverse impact on corn yield. Evans et al. (1977) reported increases in soil Na and electrical conductivity following two annual applications of solid beef (224 metric ton/ha or 100 tons/acre), liquid beef (636 metric ton/ha or 280 tons/acre), and liquid swine manure (636 metric ton/ha or 280 tons/acre). The electrical conductivity of solid beef manure was 1.9 mmho/cm compared to 3.7 mmho/cm for liquid beef and 5.0 mmho/cm for liquid swine manure. The sodium content of solid beef manure was also lower than for liquid beef or liquid swine manure (0.5% for solid beef manure compared to 2.0 and 2.6% for liquid beef and swine manure, respectively). They found electrical conductivity in soil extracts being greatest following application of liquid beef manure (more than 3 mmho/cm at some sampling times), somewhat less with solid beef, and lowest electrical conductivity with liquid swine manure. Although the salt levels were high enough to cause wilting of young plants, they were not high enough to depress corn grain yield. King et al. (1985) found little accumulation of Na in the surface of a sandy soil following six annual applications of high rates (up to 1340 kg N/ha or1200 lb/acre) of effluent from swine lagoons. However, they reported accumulation of Na deeper in the profile indicating that the Na was leached from the surface soil. The maximum concentration was in the 210 to 240 cm (84 to 96 inch) depth at about 40 mg/kg or about 6% Na saturation, which was not a high enough concentration to cause soil dispersion.

Soluble salts and Na from animal wastes can cause problems for crop growth and soil tilth when excessive levels accumulate in the soil. The salt content of the soil should be routinely monitored when applying animal wastes. However, salinity problems can generally be avoided by limiting application of animal manures to rates that meet, but don't exceed, crop nutrient requirements.

## Heavy metals

The potential toxicity of heavy metals in the environment depends on their concentration in the soil and soil solution (Del Castilho et al., 1993). Research involving heavy metals concentrations in soils has usually been associated with application of sewage-sludge. However, land application of animal manures may also impact the heavy metal status of soils. The solubility of heavy metals in manured soils is of particular concern in areas where animal manures are applied in excess. In the past, copper (Cu) and zinc (Zn) were added to swine feed as additives to improve animal performance. Since very little of the heavy metals in the feed are retained in the animal, this increased the potential for heavy metal accumulation in the soil. The normal range of Cu in many plants is 5 to 20 mg/kg, with concentrations greater than 20 mg/kg causing possible toxicity (Plank, 1979). For Zn, the normal range is 20 to 100 mg/kg with toxicity generally not occurring until concentrations exceed 200 mg/kg (Plank, 1979). Macnicol and Beckett (1985) report similar critical values for plant toxicity's of 21 to 40 mg/kg for Cu and 210 to 560 mg/kg for Zn.

Payne et al. (1988) evaluated the effects of 8 annual applications of Cu-enriched swine manure on Cu availability in 3 soils in Virginia. The swine feed averaged 251 mg Cu/kg, which was in the upper portion of the range considered to have growth stimulating effects. Zinc, which is commonly added to Cu-enriched rations to lessen the risk of Cu toxicity in swine, averaged 65 mg/kg in the feed. The manure averaged about 1300 mg Cu and 300 mg Zn/kg (dry weight basis), which was comparable to metal concentrations from other manure collected from pigs fed similar diets. They found that application of Cu either in manure or as fertilizer Cu at rates near the maximum safe loading rate of 280 kg Cu/ha (250 lb/acre) caused no decrease in corn yield or increase in Cu concentration in the grain. The Cu levels in the plant tissues increased less than 2.1 mg/kg with the highest rate of Cu additions and remained within acceptable levels. Soil Cu increased with increased Cu application but showed little downward movement and a substantial portion of the applied Cu reverted to forms not available to plants. The lack of adverse effects from applied Cu was attributed to the relatively high soil pH (greater than 6.1) and to the conversion of applied Cu to more stable forms that were not available to plants.

King et al. (1985) reported that application of swine effluent at high rates for six years affected soil copper (Cu) concentrations, although actual concentrations were low (less than 2 mg/kg). They found evidence of downward movement of Cu due high application rates, but the treatment effects dissipated after several years. In the same study, Cu concentration in bermudagrass forage was 8 mg/kg at the low rate of effluent and increased to 10 mg/kg when the effluent rate was increased four-fold (Burns et al., 1985), but still remained within acceptable limits. Del Castilho et al. (1993) reported greater concentration of Cu and Zn in the surface soil following application of cattle-manure slurry (25 metric tons/ha or 11 tons/acre) because of greater electrical conductivity.

Van der Watt et al. (1994) evaluated the impact of poultry litter on plant uptake of Cu and Zn using 3 soils in a greenhouse experiment. The poultry litter contained about 1200 mg Cu and 630 mg Zn/kg and was applied at rates equivalent to 0, 15, 30, and 60 metric tons/ha (7, 13, and 26 tons/acre). Metal concentration in sorghum plant tissue ranged from 5 to 15 mg Cu/kg and 19 to 55 mg Zn/kg, all within the normal range. The authors also determined Cu and Zn concentrations in soils collected from 5 fields with a history of poultry litter applications. In only one field, a field that had received 6 metric tons/ha (2.7 tons/acre) of poultry litter for 16 years, were Cu and Zn concentrations at possible phytotoxic levels. They concluded that continuous use of poultry litter involves some risk, but poultry litter can be applied if metal build-up is monitored.

The use of animal wastes generally poses less of a problem with heavy metal contamination than the use of municipal wastes. Limiting the use of heavy metals as feed additives and avoiding excessive rates of manure application can usually prevent accumulation of heavy metals in the soil. While concentrations of heavy metals should be monitored in the soil, limiting the rate of manure application to meet crop requirements will minimize toxicity problems with Cu and Zn.

## Groundwater Quality

Much public attention has been directed to the impact of agricultural on groundwater quality. Nitrogen has received particular attention because of the amount of N applied to cropland, the mobility of nitrate-N in the soil, and the health hazard associated with nitrates in drinking water. Although there has been much recent publicity on the impact of animal manures on groundwater quality, the issue of nitrates in groundwater has been studies for several decades. An extensive study of groundwater quality in the South Platte River valley in Colorado was conducted in the 1960's (Stewart et al. 1968). This river valley is an intensively farmed, irrigated area, underlain by a water table from 3 to 20 m (10 to 65 feet) beneath the soil surface. They collected 129 soil cores extending from the surface to the water table or bedrock under feedlots, irrigated fields, and non-irrigated pastures and fields. Most of the feedlots were in the valley and the non-irrigated areas in the surrounding hills. They found that the average total nitrate-N content to a depth of 6 m (20 ft) for the various land uses was: alfalfa, 88 kg/ha (79 lb/acre); native grassland, 100 kg/ha (90 lb/acre); cultivated dryland, 292 kg/ha (261 lb/acre); irrigated fields not in alfalfa, 567 kg/ha (506 lb/acre); and corrals, 1608 kg/ha (1436 lb/acre). However, there was considerable variability within classes of land use. The nitrate-N concentrations were not consistently higher under feedlots than irrigated fields. For example, the amount of nitrate-N under feedlots ranged from almost none to more than 5600 kg/ha (5000 lb/acre) in a 6 m (20-ft) profile. They estimated that the irrigated fields (excluding alfalfa) were losing about 28 to 34 kg N/ha (25 to 30 lb/acre) annually to the water table. The estimated nitrate loss from the feedlots was greater per unit area, but since they occupied far less land area, the total N was less for feedlots than for irrigated fields. Leaching losses from dryland fields have generally been considered negligible in the Great Plains because of low rainfall. However, they noted elevated nitrate-N levels (about 4 to 5 ppm) at the 2.4 to 3.0 m (8 to 10 ft) depth under dryland fields which is below the rooting depth of most crops. Since this accumulation of nitrate occurred in an area that averages only about 38 cm/yr (15 in/yr) of precipitation, they suggested that leaching losses might not be negligible from dryland fields in the Great Plains. Water samples from cores that reached the water table showed greater ammonium-N concentrations in water under feedlots (4.5 ppm) compared to adjacent irrigated fields (0.2 ppm). Similar differences were observed with organic C measurements (72 ppm under feedlots compared to 14 ppm under irrigated fields).

An assessment of agricultural practices on groundwater quality was also done in Missouri (Sievers and Fulhage, 1992). They sampled 226 wells in 8 sampling areas in the state. Nitrate-N was detected in 88% of the wells while 19% exceeded the EPA drinking water standard of 10 mg/L. The number of wells exceeding 10 mg/L was consistent with results from other states. Well water surveys in Iowa reported 18% of the wells exceeded the drinking water standard while 28% of the wells in Kansas exceeded the standard (Steichen et al., 1988). A number of factors were examined to determine the relationship of agricultural practices on well water quality. They concluded that nitrate-N concentrations were most strongly related to well depth with increasing nitrate-N with decreasing well depth. Other factors influencing nitrate-N concentrations were well construction and nature of the aquifer. They found little relationship between nitrate-N concentration and number of livestock in an area or distance from a livestock operation.

A study in Oklahoma looked at long-term changes in nitrate-N content of well water

(Phillips et al., 1997). They sampled 46 wells in north central Oklahoma from 1993 to 1995 that had been previous sampled from 1953 to 1972. This provided benchmark levels of nitrate-N to determine long-term changes in nitrate-N concentrations. Over 50% of the wells (24 out of 46) had nitrate-N concentrations exceeding 10 mg/L when sampled in the 1990's compared to 17% (8 wells) of the wells in the benchmark sample period. Using appropriate statistical comparisons (allowing for changes in analytical techniques), 39% of the wells showed increased nitrate-N concentrations while 15% showed decreases and the remainder being unchanged. Seven of the 18 wells that showed increases were identified as being likely contaminated by point source pollution, either because of poor well construction or sited near livestock corrals on sandy soils overlying a shallow water table. In the other wells with increased nitrate-N concentrations, they found little indication that surface application of N materials was the cause for the elevated levels and suggested that the elevated levels were from some other non-point source.

Spalding and Exner (1993) conducted a review of nitrate in groundwater. In the Great Plains, they noted that groundwater beneath irrigated, intensively cropped areas with well-drained soils were most impacted with nitrate. In general, nitrate content in groundwater tended to decrease with increased well depth. In many cases, substandard well construction and improper siting of wells were associated with high nitrate levels. In most states, the major areas of nitrate-contaminated groundwater have been delineated and they are small in proportion to the total area of the state. For example, there were 300,000 ha (740,000 acres) in Nebraska underlain by nonpoint nitrate-contaminated groundwater but this comprised only 1.5% of the state's area. They suggested that future research should focus on the dynamics of groundwater nitrate and assess the relative importance of vegetative uptake, denitrification, and geohydrology.

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# VI. Impact of Land Application of Animal Wastes on Soil Chemical, Biological, and Physical Properties

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## Summary

Soil chemical properties were measured in irrigated fields in western Kansas with a history of animal waste applications. The fields varied in the type of waste applied (solid cattle manure or effluent water from swine or cattle wastewater lagoons) and the duration of application (from 3 to 30 years). At most sites, soil phosphorus (P) levels were increased (up to 150 ppm) by waste applications, indicating that application rates exceeded crop P demands. The highest P concentration was 200 ppm Bray-1 P in the surface soil (0 to 6 inch depth), which is the maximum level established for continued application of swine waste. Soil nitrate levels were also increased (as much as 100 ppm) by waste applications. At some sites, considerable nitrate (30 to 50 ppm) had leached past the crop root zone to a depth of at least 10 feet. To determine the extent of nitrate movement, deeper soil cores (up to 50 ft) will be taken at selected sites. Soil chloride (Cl) was higher following manure application but, in most instances, Cl content was less than 35 ppm and would not be considered a problem (the drinking water standard is 250 ppm Cl). Extractable copper was about 2 ppm in fields receiving swine waste compared to about 1 ppm in non-manured fields. Extractable zinc was less than 2 ppm at sites receiving swine wastes compared to less than 1 ppm in the non-manured sites.

## Introduction

Application of animal wastes can enhance soil chemical and biological properties and serve as a valuable nutrient source for crop production. However, improper use of animal manure can adversely affect the environment. Two concerns associated with land application of animal waste are surface water runoff causing eutrophication of streams and lakes and nitrate leaching through the soil profile into the groundwater. The purpose of this study was to sample fields that have received land application of animal wastes and compare the soil chemical, biological, and physical properties to similar fields that have not received manure applications.

## Approach and Methods

Soil samples were collected from 8 irrigated fields in western Kansas (in cooperation with local landowners) that had a history of manure application. The rate and type of manure, number of years of application, and application method varied from site-to-site. The longest history of application was about 30 years. Some sites received solid manure and other received effluent water from wastewater lagoons. Two sites received swine wastes and the others received cattle manure. Each field was divided into 3 subfields. In each subfield, 3 soil cores to a depth of 10 ft were collected, divided into 12-inch increments (except for the surface foot), and composited. For the surface foot of soil, 6 additional cores were collected, divided into 0-2 inch, 2-4 inch, 4-6 inch, 6-8 inch, and 8-12 inch increments, and composited. Similar fields that had not received manure (identified by the landowner) were also sampled in the same manner. The samples intended for chemical analyses were dried and sent to the KSU Soil Testing lab for analyses for N, P, and other macro- and micro-nutrients (not all analyses complete at this time). Determinations of soil biological and physical properties are in progress with results not available at this time.

## Results and Discussion

Two sites were sampled that had received applications of solid cattle manure. Soil P levels were increased to about 200 ppm Bray-1 P (0-6 inch depth) in a field that had received manure for about 30 years (application rate unknown). In an adjacent field that had not received manure, the soil P level was about 45 ppm. Soil nitrate levels were also considerably greater in the manured field with some N accumulation below the crop root zone (generally about 5 ft). For instance, soil nitrate was 32 ppm in the 9-10 ft depth in the manured field compared to less than 1 ppm in the non-manured field. Chloride (Cl) levels were increased to about 20 ppm by manure applications compared to about 4 ppm in the control area, but remained well below potentially toxic levels of several hundred ppm. At the second site that received solid cattle manure, soil P levels were about 180 ppm following 3 annual application of cattle manure (20 ton/year); however, similar soil P levels were observed in an adjacent area that had not received manure in the past three years. Also, at this site, soil nitrate levels were similar for both the manured and the control field with considerable nitrate throughout the soil profile (40 to 50 ppm at the 9 to 10 ft depth). Chloride content was about 30 ppm in the manured field compared to about 5 ppm in the control field.

Three fields were sampled that had received effluent water from wastewater lagoons at cattle facilities. The impact of effluent water application varied considerably among the sites. Soil P levels were about 120 ppm at the site with the longest history of effluent water application (about 15 years). Soil nitrate levels were also elevated at this site with over 50 ppm nitrate in the 5 to 10 ft depths. At another site, soil P levels were relatively unchanged following 10 years of effluent water application (about 37 ppm Bray-1 P for manured and non-manured fields). However, the effluent water did increase soil nitrate levels with about 17 ppm nitrate in the 5 to 10 ft depth in the field receiving effluent water compared to about 1 ppm in the control field. At a third site that had received effluent water for only 3 years, soil P levels were increased to about 115 ppm compared to about 10 ppm in an adjacent area that had not received effluent water. Soil nitrate levels were increased by effluent water application, but mostly in the upper profile. For instance, in the top foot of soil, the nitrate level was more than 100 ppm in the field receiving effluent water compared to less than 5 ppm in the area not receiving effluent water. This nitrogen would be readily available for crop growth. However, there was some movement of nitrate below 5 ft, with 25 ppm nitrate in the treated area compared to 11 ppm in the untreated area. This site had the highest amount of Cl of any site sampled, with about 150 ppm in the surface foot of soil. The other two fields receiving effluent water from cattle lagoons contained less than 35 ppm Cl.

Two sites were sampled that had received applications of effluent water from swine lagoons. At the site with the longest history of application (since 1970), soil Bray-1 P levels were about 135 ppm (0 to 6 inch depth). There was considerable accumulation of nitrate in the soil profile with the highest concentration (170 ppm nitrate) at the 5 to 6 ft depth. Nitrate had leached past the crop root zone with about 59 ppm at the 9 to 10 ft depth. At another site that had received effluent water for about 8 years, soil P levels were about 70 ppm. Similar to the previous site, the highest level of soil nitrate (120 ppm) was at the 5 to 6 ft depth. Soil nitrate levels were also above 100 ppm in the 6 to 8 ft depths. Below 8 feet, soil nitrate levels decreased with 34 ppm in the lowest depth (9 to 10 ft). At both sites, soil Cl was less than 10 ppm in the surface foot of soil. A concern with application of swine waste is accumulation of heavy metals (copper and zinc) in the soil causing phytotoxic effects on crop growth. For these two sites, heavy metal accumulation was not a problem with less than 2 ppm DTPA-extractable Cu and 4 ppm DTPA-extractable Zn.

# VII. Use of Subsurface Drip Irrigation with Lagoon Wastewater

## Principal Investigators

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## Introduction and Project Objective

Use of subsurface drip irrigation (SDI) with water from animal waste lagoons has many potential advantages. They include, but are not limited to, less human contact with wastewater; no runoff of wastewater into surface waters; placement of phosphorus-rich water beneath the soil surface where it's less prone to runoff; greater application uniformity resulting in better control of the water, nutrients, and salts; less irrigation system corrosion; fewer climatic application constraints (especially high winds and low temperatures); and greater flexibility in matching field and irrigation system sizes.

The very small emitters in the SDI system may be prone to clogging by the various constituents of the wastewater. The challenge of using SDI with wastewater, then , is to prevent emitter clogging. Given that challenge, the objective of this projects was:

> Measure the performance of five different dripline types as affected by irrigation with filtered but untreated water from a beef feedlot runoff lagoon.

## Methods

This project was conducted at Midwest Feeders, Ingalls, KS.

The driplines were installed in April 1998. Dripline spacing was 60 inches, depth was approximately 17 inches. Each plot was 20 feet wide (containing 4 driplines) and 450 feet long. The system installation was completed and the first wastewater was used for irrigation on June 17. Each dripline type was replicated three times and there were two border plots for a total of 17 plots.

Five dripline types, each with a different emitter flow rate (and thus different emitter size), were tested. The emitter flow rates tested were 0.15, 0.24, 0.4, 0.6, and 0.92 gal/hr/emitter. Evaluation of this wide range of emitter flow rates can determine the optimum emitter size - one that would be less prone to clogging - for use with wastewater. The agricultural applications of SDI in the Great Plains with fresh, clean groundwater are normally associated with the smaller emitter flow rates.

The wastewater was filtered with a disk filter sized according to filter manufacturer recommendations. A controller was used to automatically backflush the filter after every hour of operation or when differential pressure across the filter reached 7 psi. Acid and chlorine were also injected into the system on July 9, July 27, August 4, August 31, September 4, October 6, and November 17 to help keep bacteria and algae from growing and accumulating in the driplines. Acid was added to reduce the pH to approximately 6.3. Driplines were flushed on August 4, September 2, October 6, and November 17.

To test the system, irrigations of 0.2 to 0.4 inches were applied daily until crop maturity. Each plot received the same amount of water daily and for the growing season. Nearly 21 inches of wastewater was applied from June through early September. This amount is in excess of the typical crop water requirement but allowed a more thorough test of the SDI system. Following harvest, the system was allowed to stand idle for two periods, followed by system flow testing each time. The first idle period was 32 days and the second was 41days.

After completion of the system, the lagoon wastewater was the only water applied with the SDI system. No clean waster was used for irrigation, flushing, or dripline chemical treatment.

Emitter flow rates for entire plots were measured weekly. Pressure gauges at the head and tail end of the plots were used to measure the pressure within the driplines. Totalizing flow meters measured the amount and rate of wastewater flow for each plot.

## Preliminary Results

Of the five dripline types tested, the three largest emitter size (0.4, 0.6, and 0.92 gal/hr/emitter) showed little sign of clogging. Their flow rates at the end of the season were within 2% of their flow rates at the beginning of the season, indicating that very little emitter clogging had occurred. The absence of emitter clogging and resultant flow rate decrease indicates that emitters of these sizes may be adequate for use with lagoon wastewater.

The two smallest emitter sizes (0.15 and 0.24 gal/hr/emitter0 showed some signs of emitter clogging. Within 30 days of system completion, the flow rates of plots with both emitter sizes began to decrease. The 0.15 gal/hr/emitter plots showed gradual decrease of flow rate throughout the remainder of the test. After the second idle period, the flow rate had decreased by 15% of the initial flow rate. The 0.24 gal/hr/emitter plots showed a decrease of flow rate of 11% of the initial flow rate by crop harvest. Following harvest and the first (32 day) idle period, the 0.24 gal/hr/emitter plot flow rates increased approximately 5% over the minimum measured flow rate. This increase indicates that some cleaning of the emitters had occurred in response to the flushing. The flow rate then stabilized for the rest of this test at about 9% less than the initial flow rate.

The disk filter and automated backflush controller operated well in 1998. Based on our observations, the hourly backflushes were adequate to prevent excessive differential pressure accumulation and the set point of 7 psi was never reached.

## Impact and Concluding Statements

These results show that SDI has potential for use within lagoon wastewater. It appears that the smaller emitter sizes normally used with groundwater in western Kansas may not be appropriate for use with lagoon wastewater. These smaller emitter sizes may be prone to clogging when used with wastewater. The results of this study, while very encouraging, should be considered preliminary.

Questions still remain about the long term, multi-season performance of SDI systems using livestock wastewater. Long-term performance will probably be necessary to justify the higher investment costs of SDI systems.

## Acknowledgments

We thank Midwest Feeders for providing the site, wastewater, and assistance with the project. We also thank the numerous companies that donated irrigation products and services in support of this project. Funding for the project was recommended by the Governor's office, approved by the Kansas legislature in 1998, and administered through the Kansas Center for Agricultural Resources and the Environment (KCARE) at Kansas State University.

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# VIII. Future Work

## Section I. Transport of Water and Solutes from Animal Waste Lagoons

## Section II. Odor and Air Quality Initiative

# VIII. Section I. Transport of Water and Solutes from Animal Waste Lagoons

**Principal Investigators:**
*Gerard Kluitenberg, Department of Agronomy*
*David Steward, Dept. of Civil Engineering*
*Kang Xia, Department of Agronomy*

## Introduction

Earthen lagoons are used to store and treat waste from concentrated animal operations. The effluent stored in these lagoons typically contains high concentrations of nitrogen, phosphorus, and other nutrients. By design, earthen lagoons serve only as temporary storage facilities for nutrient-rich effluent. Land application of lagoon effluent as liquid fertilizer accounts for a significant fraction of the nutrients temporarily stored in lagoons. In addition, nutrients are lost to the atmosphere from the surface of the lagoon. Nevertheless, some of the effluent stored in an animal waste lagoon seeps through the earthen liner and into the soil material beneath the lagoon. Compacted soil liners are used in the construction of most modern lagoons in order to minimize seepage losses, but these engineered liners can only minimize, not eliminate, seepage.

Seepage of effluent from earthen lagoons poses a potential risk to the quality of groundwater resources beneath these facilities. Many states have attempted to minimize this risk by enacting legislation to establish maximum allowable seepage rates from earthen lagoons. Unfortunately, little information on the fate and transport of effluent beneath lagoons is available to guide the regulatory process. As a result, there is wide variation in the maximum allowable seepage rates that have been established in various states. Maximum allowable seepage rate ranges from 0.018 inch per day in Minnesota and Missouri to 0.25 inch per day in Kansas and Nebraska.

The primary source of uncertainty in the regulatory process is lack of understanding regarding the fate and transport of effluent that has moved from an earthen lagoon into the soil material beneath it. Nutrients can be transported through soil material as a result of soil water movement, but also can interact with the soil material via ion exchange processes. In addition, some of the nutrients are altered as a result of chemical and biological transformations. This is particularly true in the case of nitrogen, a constituent of lagoon effluent that is of primary concern in assessing the potential impact of animal waste lagoons on groundwater quality. Although much is already known about the fate and transport of water and solutes in soil material, the conditions beneath animal waste lagoons pose several challenges that require new investigation. Thus, one purpose of this project is to identify the physical, chemical, and biological processes that control the movement of water and solutes from animal waste lagoons to groundwater.

In order to predict the impact of animal waste lagoons on groundwater quality, we must have a means of estimating the rates at which water and solutes move through the soil material beneath lagoons. Unfortunately, the methods available to measure these rates are extremely costly and difficult to implement. Alternatively, soil coring can be used to estimate the rate of solute movement, but the cost of this approach is also prohibitive. A more cost-effective approach for estimating rates of water and solute movement beneath lagoons is to develop a mathematical model that can be used to predict these rates. Once a mathematical model has been developed and calibrated, it can be used to examine rates of water and solute movement for a wide variety of lagoon placements, designs, and operating conditions. Another purpose of this project is to develop a model that can be used to predict the movement of water and solutes from animal waste lagoons to groundwater.

## Objectives

1) Identify the principle processes that control how water and chemicals move from animal waste lagoons to groundwater.

2) Develop a computer model of these processes for predicting the movement of water and chemicals from animal waste lagoons to groundwater.

3) Calibrate the model with data obtained by soil coring beneath animal waste lagoons in Kansas, and with data obtained by conducting leaching experiments with lagoon effluent in repacked soil cores.

4) Use the calibrated model to predict the impact of animal waste lagoons on the quality of Kansas groundwater resources.

## Plan of Work

An interdisciplinary approach will be used to accomplish the objectives of this project; however, the three principal investigators each will assume primary responsibility for specific tasks. The following sections describe the procedures that will be used to accomplish these specific tasks.

Successful completion of Objectives 3 and 4 will require availability of chemical, physical and biological characteristics for soil material beneath selected animal waste lagoons in Kansas. These results should be available as a result of the soil coring campaign being directed by Jay Ham.

## Water Seepage from Lagoons

The first issue is estimation of the flow of water through the liner of a lagoon and through the underlying soil to the top of the groundwater table. Accurate estimates are required since this flow drives the movement of nutrients from the lagoon to groundwater. This flow is controlled by parameters related to the hydrologic and geologic conditions found at a specific lagoon. Important hydrologic parameters include depth to groundwater, water level in the lagoon, and distribution of soil moisture under the lagoon. Important geologic parameters include hydraulic conductivity of the lagoon liner and the underlying soil (hydraulic conductivity is a measure of how quickly groundwater travels through a soil), thickness of the liner, and the three-dimensional geometry of the bottom of a lagoon.

A computer program will be developed for this project that incorporates all of the important hydrologic and geologic parameters. The parameters in this program will be calibrated to available data for a swine lagoon in Kansas. This program will also be run using a range of hydrologic and geologic parameters to obtain insight into the variability of groundwater flow rates from lagoons to groundwater. The flow rates obtained using this model will be used as input when modeling the movement of nutrients from the lagoon to groundwater

The computer program will be based on the mathematical framework of Richard's equation, the standard equation used to describe the flow of unsaturated water in soils. The boundary element method (BEM) will be used to implement this equation; this method is commonly used to model groundwater flow, the flow of air around airplanes, surface water waves, and stress/strain relations in rock mechanics. This approach has been implemented successfully in computer programs by the co-investigator to simulate three-dimensional groundwater flow. The BEM is counter to the standard numerical techniques used to model unsaturated flow, the finite element method (FEM) and finite difference method (FDM).

The boundary element method was chosen for two reasons. Both reasons are related to the fact that a three-dimensional model may be required to obtain accurate estimates of flow rates due to the three-dimensional geometry of the liner and the different hydraulic properties of the bottom and side liners. Firstly, the BEM is more numerically efficient since the boundary of a domain (a two-dimensional surface) is discretized whereas the FEM and FDM require discretization of the interior of the domain (a three-dimensional volume).This results in a practical limitation of FEM and FDM based unsaturated flow models being used only for one- and two-dimensional flow fields. Secondly, the BEM exactly satisfies the continuity of flow condition everywhere in the domain whereas the FEM and FDM do not. This results in incorrect prediction of lines along which water flows in the FEM and FDM, particularly near interfaces of regions with different hydraulic conductivity (such as that existing between the clay liner and the soil).

### Ammonium Adsorption, Desorption and Transformation

Ammonium (NH4+) is one of the dominant chemical constituents in lagoon effluent and is usually the primary source of nitrogen. Inasmuch as nitrogen is also one of the primary groundwater quality concerns, the fate and transport of ammonium will be a focal point of this project.

### Batch Studies

The fate of ammonium in effluent that has seeped from an animal waste lagoon is determined to a large extent by its interaction with the soil material beneath the lagoon. Adsorption and desorption processes are known to exert tremendous impact on the rate at which ammonium is transported through soil material. Knowledge of both adsorption capacity and the rates (kinetics) of adsorption and desorption are necessary to fully describe the interaction between ammonium and soil material. To date, most of the research on ammonium adsorption and desorption by soils has been conducted using simple ammonium salt solutions. Little research has been conducted to evaluate adsorption and desorption processes in the presence of lagoon effluent. We anticipate that the other chemical and biological constituents in the effluent will have a significant impact on ammonium adsorption and desorption processes in the soil material beneath animal waste lagoons. Thus, to accurately predict the fate and transport of nitrogen, there is a need to investigate ammonium adsorption and desorption processes in soil material exposed to lagoon effluent.

Batch adsorption/desorption studies will be conducted using a range of representative soil materials and samples of effluent from several different animal waste lagoons. Soil material will be mixed with lagoon effluent at different concentration ratios, and these mixtures will be allowed to equilibrate for a range of times. The quantity of ammonium adsorbed by the soil will be calculated from the reduction of ammonium in the liquid phase. When adsorption of ammonium by the soil material reaches a maximum, ammonium desorption kinetics will be evaluated by extracting the adsorbed ammonium with KCl for a range of times. Ammonium desorption from soil will be calculated from the increase of ammonium in the liquid phase. The effects of soil CEC, nitrifier activity, competing cations, pH, soil/effluent ratio, and temperature on ammonium adsorption and desorption kinetics will be evaluated. Nitrification of ammonium during the adsorption and desorption processes will be monitored by measuring the concentration of nitrate in the solution.

### Column Studies

To obtain information regarding the chemical and biological transformation of ammonium in lagoon effluent, nondestructive measurements with high spatial and temporal resolution using effluent-amended soil columns are needed.

Polysulfone hollow fiber solution samplers will be used to follow NH4+ transformation in soil columns amended with lagoon effluent. Soil is packed into the lysimeters to a bulk density similar to that beneath swine lagoon layer. Polysulfone hollow fiber solution samplers are evenly placed at different depths in the lysimeters during packing of the soil. Liquid animal waste will be applied on the surface of the soil column at a constant rate of 0.25"/day for one month to six months. Samples with the solution samplers are taken once every day starting on the day of liquid animal waste application. Concentrations of NH4+, NO3-, NO2-, major cations, dissolved organic C, nitrifier activities in the collected solution samples will be analyzed.

## Transport of Solutes from Lagoons

*[Text for this section to be provided by Gerard Kluitenberg]*

## Project Outcomes

We anticipate the following outcomes from the research proposed herein. First, we expect to identify the principle processes that control how water and chemicals move from animal waste lagoons to groundwater. This is a critical step in developing a model to predict the impact of lagoon effluent on groundwater quality. Reliable predictive modeling can only be achieved if the principle governing processes have been identified and incorporated into the model. In addition, process identification will greatly improve our ability to collect data that can be used for calibrating a predictive model.

A second outcome of this project will be a model that can be used for predicting the fate and transport of nutrients beneath animal waste lagoons. Development of the model will proceed in such a way that generality is preserved. Thus, the model also will be useful for application to a number of related problems. For example, we anticipate that the model will be useful for predicting the fate and transport of nutrients following closure of animal waste lagoons. It is also conceivable that the model could be used to evaluate strategies for remediating abandoned lagoons.

Third, the calibrated model will be used to assess the impact of seepage from animal waste lagoons on groundwater quality. Inasmuch as model calibration will be constrained to sites for which soil coring data is available, the predictive exercise also will be constrained to these sites. Despite this restriction, the predictive modeling exercise will yield important new insights into the potential for groundwater contamination.

Recommendations for improved lagoon placement, design, and operating conditions are anticipated as a fourth outcome of this project. These recommendations will result from using the model as a predictive tool to evaluate the effects of placement, design and operating conditions.

## VIII. Section II ODOR AND AIR QUALITY INITIATIVE

**Coordinated by:**
*Bill Hargrove, Director of KCARE*

We were recently asked by KDHE to submit some ideas for research and extension programs that would help provide a scientific basis for KDHE regulations regarding setback distances for confined livestock and for evaluation and promotion of best management practices that would help reduce the source of potential contaminants from livestock enterprises.

We would like to propose an initiative to do several things in support of KDHE's efforts to promote clean air and reduce public health concerns associated with airborne contaminants from livestock production. At a minimum, we propose to:

1) conduct a literature review on air quality issues associated with concentrated livestock and BMPs for minimizing odor, dust, trace gases and other airborne contaminants.

2) review the NPPC list of BMPs and test their effectiveness in Kansas

3) collect data on ammonia and methane evolution and dispersal from lagoons and other concentrated animal facilities in order to validate KDHE's separation distances.

Attached is a brief description of five project ideas that have been submitted to KDHE. We anticipate that one or more of these ideas will be developed into a proposal for further consideration by KDHE.

Several other activities related to odor and air quality are ongoing at K-State. Dr. Larry Erickson of Chemical Engineering, K-State, has been recently appointed to a national Odor and Air Quality Task Force by Secretary of Agriculture Dan Glickman. Also, Dr. Erickson leads a K-State campus wide initiative to establish an Air Quality Center to be funded by EPA. If we receive funding from EPA to establish the Center, we will be able to augment our efforts from other funding sources.

# BEST MANAGEMENT PRACTICES FOR ODOR CONTROL AND AIR QUALITY IN CONFINED LIVESTOCK PRODUCTION

**J. Pat Murphy, Professor, Team Leader**
**Biological and Agricultural Engineering Department**

Controlling dust, odor, and gases, like ammonia, methane, and others, is an essential component of environmental management plans for confined livestock production. We propose a three-part plan for a comprehensive educational program in odor control and air quality for producers of confined livestock in Kansas.

Literature Review
We plan to review the literature and survey current programs in other states to collect and summarize the most current information regarding odor control and air quality. Information collected and summarized by the National Pork Producers Council (NPPC) under its Odor Solutions Initiative will be a key starting point. We will also search the Worldwide Web for current information and recommended practices. We will summarize our findings in a written report.

Selection and Evaluation of Best Management Practices
We will use a panel of scientists, consultants, and producers to identify the most efficacious and cost-effective practices appropriate to Kansas conditions from the list of practices obtained from the NPPC and other sources. We will evaluate those practices at selected demonstration sites with the cooperation of willing producers.

Promotion of Best Management Practices
Using the results of the literature review and evaluation of BMPs, we will implement an educational program to promote BMPs for odor and air quality. The educational program will include printed materials, web postings, and producer meetings/field days. For the educational program, we will solicit the collaboration of the Kansas Department of Agriculture, KDHE, and key producer groups in Kansas including Kansas Pork Producers Council, Kansas Livestock Association, Kansas Dairy Association, Kansas Farm Bureau, and others.

Estimated Timeframe
24 months

Estimated Budget Needs
$80,000

Collaborators
Joe Harner, Biological and Agricultural Engineering
Jim Drouillard, Animal Science
Jim Nelssen, Animal Science
John Smith, Animal Science
Mike Tokach, Animal Science

# An Air Monitoring Network For Determining Optimal Setback Distances for Concentrated Animal Operations

Jay M. Ham, Department of Agronomy, Kansas State University, Manhattan, KS 66506

## Questions to be Answered

- What setback distances from concentrated animal operations (CAOs) are required to protect public health and comfort when living and working in areas adjacent to CAOs?

- What are the important gaseous compounds and particulate matter that are emitted from CAOs and how far do they travel from the operation? What are the emissions from agriculture fields where waste has been applied? How do concentrations of ammonia, methane, and hydrogen sulfide vary in space and time (seasonally) around a CAO?

- How does weather, terrain, and surrounding vegetation affect how far odorous compounds travel from a CAO (i.e., eastern vs western Kansas)?

- What are the differences in ammonia, methane, and hydrogen sulfide emissions from swine and cattle operations in Kansas? Should they have different setback distances ?

## Research Plan (Two Year Study)

An air sampling network will be established around a swine and a cattle-feedlot operation in both eastern and western Kansas (4 sites total). Ammonia will be monitored continuously at approximately 20 locations at various distances and directions from each CAO. A combination of diffusion tubes (passive) and acid-tube denuders will be used to sample air at each location. Each month, the network of air samplers will be retrieved and analyzed to quantify the average monthly ammonia concentrations at different distances from the CAO. Ammonia was selected for intensive study because: (1)it is emitted in high concentrations, (2) it is a known odorous compound, and (3) it has recently been shown to be a outdoor health hazard by acting as a nucleus for the formation of fine particulate (new EPA research thrust). In addition to the permanent ammonia monitoring network, additional grab samples of air will be collected from barns, lagoons, and open cattle pens. Also, grab samples will be collected by families living near the CAOs. The cooperating family will be trained to collect samples of air when they think the odor is most offensive. Grab samples will be analyzed for ammonia, methane, and hydrogen sulfide.

## Deliverables/Products

- Distance from the operation required to avoid 90% (or any other percentage) of the ammonia, methane and hydrogen sulfide emitted from a CAO

- Monthly contour maps of the ammonia concentration fields near swine and cattle production operations in both eastern and western Kansas.

- Data on emission rates from barns, anaerobic lagoons, and open pens (by season, by location)

- Identification of the scenarios most likely to cause an odor problem (landscape, time of year)

**Budget**

| | |
|---|---|
| Analytical Laboratory Equipment | $25,000 |
| Differential Global Positioning System | $6,000 |
| Air Sampling Equipment | $24,000 |
| Labor | $35,000* |
| Supplies | $9,000* |
| Travel | $9,000* |
| Total | $109,000 |

* requires funding in year 2 of study

**Budget Justification**

An autosampling steam distiller, colormetric system, or FTIR will be required to analyze air samples and ammonia denuders. A GPS system will be used to position the air sampling points around the CAOs. A network of passive (diffusion tubes) and active samplers (denuders, impingers) will be needed to establish the network. Some will require solar power and pumps. Manual gas sampling system will be also required to collect grab samples. Labor costs include a B.S. or M.S. level assistant scientist to service the air samplers and perform the chemical analyses. Supplies include general lab supplies, calibration gases, disposable field equipment, etc. Travel costs include, vehicle rental, travel to air sampling sites, and participate in meetings on air quality (state and national level).

# Impact of Animal Production Operations on Air Quality and Public Health

Animal production operations result in the generation of waste products which attract flies and support microbial growth and reproduction. Microorganisms can be carried by flies and dust through the air to significant distances. There is a need to conduct research to develop quantitative information on the effect of isolation distance on air quality, especially biological airborne particulate matter. This should include research to quantify the population differences in the feedlot, near the feedlot, and farther from the feedlot for flies and microorganisms carried by flies and dust. The public health impacts can be investigated by identifying the common species of organisms in the air samples and relating this information to the health impacts of each species. Particulate matter (PM 2.5 and PM 10) will be measured as well.

The proposed first year budget for this work is $75,000. This will provide support for graduate students, faculty summer salaries, and the purchase of sampling equipment and supplies.

The initial field work will be done using animal production facilites of Kansas State University. After methods are tested, studies will be conducted at other locations. Faculty participants may include Alberto Broce, Larry Erickson, Daniel Fung, Ronaldo Maghirang, Pat Murphy, and James Urban.

Rural Flies in the Urban Environment
Alberto B. Broce, Department of Entomology

The frequency of legal conflicts caused by rural flies in town is expected to increase as cities grow and expand into agricultural areas. Because of the potential for lawsuits, livestock operations are forced to increase efforts to control flies to levels which are much lower that those causing economic damage. Likewise, there is an increase in insecticide usage in the home environment in futile attempts to control these flies. Although stable flies and house flies can and do migrate from livestock operations to urban areas, urbanites believe that all urban flies are of an agricultural origin, when in fact a great portion of these flies have an origin in compost and grass clipping piles in homeowners backyards. These problems are expected to intensify as cities grow and encroach on agricultural areas, and the cost of sanitary landfill operation and the practice of backyard composting increase.

Although high numbers of house flies can be quite annoying to urbanites, stable flies are more noticeable and the complaint threshold for their presence is much lower; stable flies are more noticeable to urbanites because of behavioral differences between these flies. First, stable flies are quite annoying to people when outdoors, because of their blood sucking habits and painful bites. Second, their feeding upon pet dogs in backyards often results in noticeable bleeding ulcers on the tips of the dog's ears. Third, these flies are noticed by their dark feces soiling the surfaces of outside walls of residential (as well as farm) buildings.

Few studies have evaluated the dispersal of house flies and stable flies, but none in the conditions prevalent in the Midwest USA. These flies appear to disperse widely over short distances (under 10 km). The dispersal rate of house flies and stable flies appear to be inversely related to the frequency of breeding habitats and blood hosts, respectively.

This proposed study would determine population densities of both house flies and stable flies along transects from livestock operations to urban areas, using baited jug traps and Alsynite cylinder traps, respectively. In addition, determination of bloodmeal hosts for stable flies (by ELISA) trapped along these transects will indicate dispersal between these two conflicting habitats. In addition, marking of wild stable flies with fluorescent pigments at their breeding habitats (i.e., livestock operations) and their subsequent capture on radially distributed traps will provide quantitative information on rate of dispersal.

Required budget: To accomplish these goals, a two-year study would be required. Funding should include the following:

| | |
|---|---|
| One graduate research assistant . . . . . . . . . | $28,000 |
| One summer student (2 years) . . . . . . . . . . | 6,000 |
| Supplies (traps, ELISA, etc.) . . . . . . . . . . | 2,500 |
| Transportation. . . . . . . . . . . . . . . . . . | 1,500 |
| Miscellaneous . . . . . . . . . . . . . . . . . . | 1,000 |
| | -------- |
| Total. . . . . . | $ 39,000 |

# Treatment of Animal Wastes in Lagoons

Lagoons which are used for animal wastes are primarily anaerobic; however, there is some oxygen transfer at the surface of the lagoon. Odor is one of the concerns associated with the lagoons. Gases from anaerobic processes escape to the atmosphere. Ammonia and hydrogen sulfide are two of the gases. If the surface of the lagoon could be maintained as an aerobic bioreactor with adequate microbial numbers, this would reduce the release of odorous compounds.

In order to create an aerobic bioactive surface on the lagoon, one needs to create appropriate particulate solids which would float on the surface of the lagoon, provide surfaces for aerobic microbial growth, and be porous so that water and air could occupy some of the interior space. A low density porous polymer such that oxygen is soluble in the polymer as well as being present in the pores is needed. The pores should allow water to wet their surfaces. The design should be such that the floating particles remained wet enough to support microbial growth on their surfaces. The particles should be large enough to provide a sufficient aerobic zone to treat the gases coming from the anaerobic zone. The particles should adsorb and/or absorb ammonia, hydrogen sulfide and volatile aerobic compounds.

The recent doctoral dissertation of A.A. vande Graaf, Biological Anaerobic Ammonia Oxidation, University of Delft, Delft, The Netherlands, 1997, provides a good summary of what is known about converting ammonia and nitrate to nitrogen gas. Under aerobic conditions, one can convert ammonia to nitrate. Nitrate can be converted to nitrogen gas under anaerobic conditions by facultative organisms. Graaf found that under anaerobic conditions, ammonia can be converted directly to nitrogen gas if nitrate is present. Thus, the aerobic surface will allow some nitrate to be produced which will also allow for some conversion of nitrogen waste materials to nitrogen gas.

Experimental work needs to be done to investigate the potential of this inexpensive modification to reduce odor and improve the rate of conversion of nitrogen wastes to nitrogen gas.

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**New Kansas Swine Environment Laws: Implementing Them on Your Farm**

House Environment
2-11-99
Attachment 2

Linn, Kansas
American Legion
Wednesday, February 24, 1999

Garden City, Kansas
Finney County 4-H Building
Thursday, February 25, 1999

Newton, Kansas
Courthouse Community Room
Wednesday, March 3, 1999

Seneca, Kansas
Valentino's Restaurant
Thursday, March 4, 1999

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Kansas Dept. of Agriculture

Kansas Dept. of Health & Environment

Kansas Pork Producers Council

Local Extension Councils in
Washington, Finney, Harvey
and Nemaha Counties

2-2

Linn, Wednesday, February 24, 1999
Newton, Wednesday, March 3, 1999
Seneca, Thursday, March 4, 1999

6:00 to 6:45 — ***Meal***

6:45 to 6:50 — ***Welcome-Local County Ag Agent***
Duane Toews, K-State Research and Extension, Washington County
Ron Graber, K-State Research and Extension, Harvey County
David Key, K-State Research and Extension, Nemaha County

6:50 to 7:20 — ***Overview of Laws, Plan Requirements, and Timetable for Implementation.***
Jeff Clark, Kansas Department of Health and Environment

7:20 to 7:30 — ***Overview of NPPC on-Farm Environmental Assessment Program.***
Tim Stroda, Kansas Pork Producers Council

7:30 to 8:00 — ***Reducing Nutrient Excretion from Swine Facilities.***
Bob Goodband, K-State Research and Extension

8:00 to 9:30 — ***The Ins and Outs of Nutrient Management Plans.***
Pat Murphy, K-State Research and Extension
Garry Keeler, Kansas Department of Agriculture

Garden City, Thursday, February 25, 1999

1:00 to 1:10 — ***Welcome***
Dean Whitehill, K-State Research and Extension, Finney County

1:10 to 1:40 — ***Overview of Laws, Plan Requirements, and Timetable for Implementation.***
Jeff Clark, Kansas Department of Health and Environment

1:40 to 1:50 — ***Overview of NPPC on-Farm Environmental Assessment Program.***
Tim Stroda, Kansas Pork Producers Council

1:50 to 2:20 — ***Reducing Nutrient Excretion from Swine Facilities.***
Bob Goodband, K-State Research and Extension

2:20 to 4:00 — ***The Ins and Outs of Nutrient Management Plans.***
Pat Murphy, K-State Research and Extension
Garry Keeler, Kansas Department of Agriculture

Registration
New Kansas Swine Environmental Laws:
Implementing Them on Your Farm

Registration Fee is $10.00
Payable at the door

No Registration Fee will be charged for the meeting in Garden City because a meal will not be included

**Preregister by contacting the local extension agent by the following dates.**

Linn by February 19, 1999
Duane Toews (785)325-2121

Garden City by February 22, 1999
Dean Whitehill (316)272-3670

Newton by March 1, 1999
Ron Graber (316)284-6930

Seneca by March 1, 1999
David Key (785)336-2184