POSTER SESSION

Evaluation of Swine Effluent as a Plant Nutrient Source for Sprinkler Irrigated Corn

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The expansion of large swine-production facilities in northeastern Colorado prompted a need to evaluate the use of swine effluent as a nutrient source for irrigated corn. The objectives of this study were to compare the impact of swine effluent to similar rates of commercial-N fertilizer on corn performance and N buildup in the soil profile. The 3-year study began in 1995 on a 36-acre sprinkler irrigated site, consisting of sandy to loamy sand soil and planted to field corn (*Zea Mays L.*). The total available nitrogen rate for swine effluent and commercial-N fertilizer treatments are 0, 130, 185, and 235 pounds (lb) N/acre. The fertilizer treatments were replicated three times in a completely randomized design. Ninety percent of the total nitrogen was present as ammonium-N in the effluent of a two-stage lagoon, where the total dry matter content was only 0.1-0.2% by volume. The feed ration and age of pigs grown significantly impacted the effluent content. Corn yield increased an average of 24% under swine effluent as compared to commercial-N fertilizer, resulting in significant soil-N buildup at the 4 to 8-foot depths under the commercial-N fertilizer. This buildup is most likely due to enhanced crop production in response to other nutrients found in the effluent. The total N and P plant uptake was 24% and 55%, respectively, greater under the swine-effluent treatments than under the commercial-N fertilizer treatments. As the swine-effluent-application rate increased, the plant N and P uptake and recovery rate increased.

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An Inquiry Into the Rationale for Prioritizing South Carolina's Animal Feeding Operations for Water Pollution Regulation

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Considering the extent of land-use restrictions and environmental-impact-monitoring requirements associated with operating animal feedlots in South Carolina, our state now arguably leads the nation in regulatory efforts to reduce polluted runoff from these sources. The research presented here is an inquiry into the rationale the South Carolina Department of Health and Environmental Control used in its recent promulgation of new animal agriculture regulations pursuant to the 1996 Hog Act.

Unlike other previous studies, this paper does not investigate or challenge the technical merits of the threshold values chosen for setback distances, lagoon dimensions, animal units, or pollutants monitored, for example. The work questions the rationale for prioritizing South Carolina's animal feeding operations for environmental cleanup in lieu of other sources of water pollution that are known causes of streams not meeting even minimum-acceptable Federal water-quality standards.

The research first summarizes and explains the data used to establish the State's implicit finding that polluted runoff from animal agriculture degrades or poses a potential to degrade water quality in South Carolina to a degree comparable to other sources. Relevant explanatory information made available to the public in promulgating the new regulations consisted primarily of inferences made from national ambient water quality monitoring-data and anecdotal information derived from incidents in other States. No data summaries, case studies, or incidents linking animal agriculture to water pollution in South Carolina could be identified, although a multitude of data are presented that suggest pervasive problems from other specified sources.

Since no studies linking animal feeding operations to nonpoint-source-water pollution in South Carolina could be identified, the research presented here attempts to initiate efforts to determine the absolute and relative contributions of animal feedlots and other sources to the water-pollution problem in South Carolina.

Fecal coliform bacteria and oxygen-depleting compounds are the two constituents in feedlot runoff that are suspected to be polluting South Carolina's waterways; two pollutants that also are common to industrial and municipal point-source discharges and urban-land runoff.

The study uses agricultural census data to map heads of cattle and hogs and chicken farms in South Carolina. Census data also are used to map human-population concentrations in the State. Watersheds containing streams prioritized for reductions in fecal-coliform pollution or oxygen-depleting pollutants are mapped and overlain with the animal/human data.

Eight maps relating water pollution, animal agriculture, and urban areas in South Carolina are presented. The maps are categorized into two broad groupings; animals and humans related to dissolved oxygen stream impairment and animals and humans related to fecal coliform bacteria stream impairment. In general, there seems to be a high presence of fecal coliform and oxygen-depleting pollutants in the State's streams that lie in urban watersheds and a very low occurrence in the regions of the State that harbor agricultural animals.

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Time-Series Sampling for Nutrients and Bacteria in Ground Water at Four North Florida Dairy Farms and Three Springs Along the Suwannee River, 1990-93

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Nitrate concentrations exceeded the primary drinking-water standard of 10 milligrams per liter as nitrogen in water samples from 24 of 51 monitoring wells sampled periodically from 1990-93 at 4 dairy farms in Lafayette and Suwannee Counties in northern Florida. The greatest concentrations of nitrate were detected in ground water from monitoring wells with 10-foot screens completed at the water table located downgradient from unlined wastewater lagoons and defoliated areas of intensive cattle use. Water from wells completed 10 feet deeper in the saturated zone, wells completed in areas with lower waste-loading rates (such as pastures), and wells located upgradient of wastewater lagoons and intensive-use areas had lesser concentrations of nitrate, but nitrate concentrations in water from those wells generally exceeded those from ambient-network wells sampled in the area by the Florida Department of Environmental Protection. Nitrate concentrations in water discharged to the Suwannee River from three springs in the vicinity of those and other dairy farms ranged from 2 to 7 milligrams per liter, which also was greater than nitrate concentrations in water sampled from ambient-network wells.

Most of the wells produced water containing dissolved oxygen, which favors the formation of nitrate (nitrification) from organic and ammonium compounds of nitrogen. Concentrations of organic and ammonium nitrogen generally were much less than nitrate concentrations. Phosphorus and orthophosphate-phosphorus concentrations were similar to concentrations measured in water samples from ambient-network wells. To investigate the potential for denitrification (reduction of nitrate to nitrous oxide or dinitrogen gases), counts of denitrifying bacteria were made in water from selected monitoring wells. Counts of those bacteria commonly exceeded 10,000 colonies/100 milliliters, but because most water samples contained dissolved oxygen, denitrification probably does not occur in shallow ground water in the area. Counts of fecal coliform and fecal streptococcal bacteria in water samples from selected wells commonly exceeded 1,000 colonies per 100 milliliters.

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Comparison of Water Quality in Four Small Watersheds Containing Animal Feeding Operations in Iowa, 1996-98.

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Agriculture constitutes 93 percent of all land use in Iowa, and Iowa leads the Nation in the production of hogs. Within many watersheds in Iowa, the number of animal feeding operations (AFOs), such as large-scale hog confinement facilities, has doubled in the past several years. A typical hog produces two to five times the waste as a human. Thus, the large number of facilities in some watersheds can produce as much untreated waste as a large city (100,000's to millions of people). There are concerns that large confinement facilities may have a negative impact on the water quality. AFOs may add to the overabundance of nutrients that are already introduced into the environment from chemical fertilizer, atmospheric deposition, soil mineralization, and municipal discharge. In addition, manure spills cause fish kills and introduce large loads of nitrogen and phosphorus directly into the waterways that drain to the Mississippi River. Excessive nutrients can cause water-quality problems such as excessive algal growth, taste and odor problems, health effects in humans, and have been linked to the phenomena called hypoxia (dissolved oxygen of less than 2 milligrams per liter) in the Gulf of Mexico.

The National Water Quality Assessment Program collected water-quality samples monthly from 1996 to 1998 at twelve locations in eastern Iowa. Four of the smaller watersheds were selected for comparison in areas where land-use practices are similar, but there are differences in the density of AFOs and the amount of estimated manure applied within the watershed. A Geographic Information System was used to delineate drainage basins, locations of large scale feeding operations, and manure inputs within each basin.

Concentration and yields of nutrients were compared between the sites using a Wilcoxon Rank sums test. There were statistical differences ($p < .05$) in concentrations and yields between some of the sites. Concentrations were greater in high-density AFO watersheds than low-density AFO watersheds for dissolved ammonia and organic nitrogen, total ammonia and organic nitrogen, and organic nitrogen. Nutrient yields for total nitrogen, organic nitrogen, and total phosphorus were statistically greater in watersheds with higher AFO densities. However, high-density AFO watersheds did not always have greater concentrations for total nitrogen, dissolved ammonia, nitrate, nitrite, dissolved phosphorus, total phosphorus, and dissolved orthophosphate than low-density AFO watersheds. Differences in physiography, agricultural practices (for example, amount and timing of manure and chemical fertilizer application), soil type, soil slope, and precipitation could be attributed to some of the differences. The data reflect a very complex system that requires long-term water-quality monitoring to determine if these differences in water quality are directly related to AFOs. Many of the AFOs have only been operating for a few years. More time may be required before their effects are reflected in the water quality of these basins.

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Agriculture and Bacterial Ground-Water Quality in Central Appalachian Karst

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The impact on water quality by agricultural activity in karst terrain is an important consideration for resource management within the Appalachian Region. Karst areas comprise about 18 percent of the Region's land area. An estimated one-third of the Region's farms, cattle, and agricultural market value are on karst terrain. An eight-year study (1991-98) was conducted in a karst region in southeastern West Virginia to determine the impact of agriculture on ground-water quality. The primary agriculture was grass-fed beef with some animal feeding operations, which were primarily dairy.

Fecal-coliform densities were measured weekly in the resurgences of three karst basins possessing different degrees of agricultural intensity (79, 51, and 16% land use in agriculture). Fecal coliforms also were measured in a creek at sites upstream and downstream from the known resurgences from the most agriculturally intensive (79%) basin.

The fecal-coliform densities in the resurgences followed a pattern of peak densities in the summer and a dramatic decline in the fall, with a recovery in late winter prior to the introduction of new cattle. The timing of the recovery indicated that significant storage of fecal material had taken place, which was transported to the ground water when soil-water conditions permitted. For most of each year, soil-water effects appeared to have a greater bearing on the fecal-coliform densities than did the presence or absence of cattle. The data did not generally support a strong relation with percent land use in agriculture, which was attributed to the high variability in the data and to low soil moisture during periods of recession that inhibited the transport of fecal material to the ground water. The karst resurgence springs of the most intensively agricultural basin were contaminated with fecal bacteria. Fecal-bacteria concentrations were observed to significantly increase, in the receiving surface stream, from a point upstream of the resurgence springs to a point downstream of the resurgence springs**.**

Fecal-bacteria densities also were measured in cave streams draining two primary agricultural land-management areas. The first area was pasture serving a beef cow-calf operation. The second area was a dairy. Neither area had best-management practices in place for controlling animal wastes. Median fecal-coliform and fecal-streptococcus densities were highest in cave streams draining the dairy. Median fecal coliform densities in the dairy-impacted stream were greater than 4,000 colony forming units per 100 milliliters (CFU/100 ml) and the median fecal-coliform densities in the pasture-impacted streams were less than 10 CFU/100 ml. Median fecal-streptococcus densities in the same streams were greater than 2,000 CFU/100 ml and 32 CFU/100 ml, respectively. A second dairy, with best-management practices for control of animal and milkhouse waste, did not appear to be contributing significant amounts of fecal bacteria to the karst aquifer. It was concluded that agriculture was affecting bacterial densities in the karst aquifer. New management practices specifically designed to protect karst ground-water resources may be one way to protect the resource.

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Preliminary Observations of Nitrogen Speciation and Transport in Two Watersheds of the Chesapeake Bay Estuary

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Sediment and water samples were collected from November 1997 through April 1999 from two watersheds, Popes Creek, Virginia, and the Pocomoke River, Maryland. The samples were collected to determine sites of nutrient storage and to evaluate nutrient concentrations that are associated with the sediments and dissolved materials being transported from watershed sources to the Chesapeake Bay. Popes Creek, which is located in Westmoreland County, Virginia, is a tributary to the Potomac River that flows into the Chesapeake Bay. The Pocomoke River, which is located on the eastern shore of Maryland, empties into the Chesapeake Bay through the Pocomoke Sound. The watershed of the Pocomoke River is 15 times larger than Popes Creek watershed and has tributaries that drain three counties in Maryland. Both watersheds lie in the Coastal Plain Physiographic Province. Since European settlement in the 1600's, agriculture has been the major land use in both watersheds. Popes Creek watershed, with very little agricultural activity at present, forms the basis for a reference in the comparison of the two watersheds. In the Pocomoke watershed, agricultural practices, such as ditching of fields and channelization of rivers and streams for improved drainage, are important factors in facilitating the transport of sediments and nutrients. Because of these practices, water that drains from agricultural fields effectively bypasses the riparian buffer zones where processing and uptake of nutrients takes place. In contrast to Popes Creek, poultry farming is extensive in the Pocomoke River watershed. In 1992, 182 million chickens were produced in three counties that are drained by the Pocomoke River. The intensive poultry farming, which produces nutrient-rich manure that is disposed of by spreading on fields in the watershed, has created a serious nutrient-enrichment problem in the river and in Pocomoke Sound. The spatial distribution of the concentrations of nitrogen species in sediment and in water in the two watersheds is displayed in a Geographic Information System (GIS) map format as an image coverage that overlies the ditches, river channels, and the geologic framework of the basins.

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High-Performance Liquid Chromatography/Electrospray Ionization–Mass Spectrometry Analysis of Agricultural and Human Health Pharmaceuticals in Surface and Ground Water

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A method is being developed to identify and quantify agricultural and human health pharmaceuticals isolated from surface and ground water. This is an emerging water-quality issue because of the potential for deleterious sublethal effects of pharmaceuticals in water on humans, other animals, and the ecosystems they live in.

Nineteen pharmaceuticals were selected on the basis of predicted environmental loadings calculated from prescriptions and dosages and on the metabolic pathway of the parent pharmaceuticals in mammalian systems. The classes included analgesics, anti-inflammatories, antihypertensives, antianginals, antidepressants, antihyperlipidemics, antibiotics, antiulcerants, and anticoagulants. The pharmaceuticals were isolated from 1-liter water samples using resin-based solid-phase extraction. Extracts were analyzed by high-performance liquid chromatography using a 2-millimeter (mm) x 150-mm column containing a 3 micrometer particle size C-18 reversed phase. All 19 compounds were separated in less than 40 minutes by using a formate-modified, water-acetonitrile gradient. Electrospray ionization–mass spectrometry was used for qualitative identification and quantitation. Fragmentation conditions in the electrospray source were controlled so that three characteristic positive ions were produced for each compound. Selected-ion monitoring was used to maximize sensitivity.

Initial tests indicate that the 19 pharmaceuticals can be detected at individual concentrations as low as 50 to 100 nanograms per liter. Water samples being characterized by this method were collected nationwide from sites where the impact of pharmaceuticals was likely to be high, including sites downstream from wastewater treatment-plant discharge and confined agricultural feeding operations.

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Odors, Nuisance, and the Right to Farm

Terence J. Centner[1]

Production agriculture has previously faced problems of odors. In the late 1960s, concern about new neighbors using nuisance law led agricultural-interest groups to advance anti-nuisance legislation. This legislation acquired the name of "right to farm" laws. While each state adopted individual legislation, the basic model sought to protect the existing investments of farmers in their agricultural operations. It sought this protection by incorporating a "coming to the nuisance" exception whereby persons moving to an offensive activity could not use nuisance law to seek judicial termination of the activity.

Right to farm laws gave a new life to many agricultural activities. While most of the laws were challenged, and provisions of the laws had to be interpreted by the judiciary, right to farm laws were fairly successful at discouraging nuisance lawsuits against farmers. At the same time, right to farm laws did not sanction offensive activities, negligent operations, or pollution. Because they only applied to nuisance actions, an incentive existed for farmers to be vigilant not to offend their neighbors or create problems. Zoning and local ordinances remained as vehicles for neighbors to seek redress against imprudent operations.

Recently, however, courts have been asked to view right to farm laws under constitutional takings jurisprudence. Current decisions and pending cases present some startling prospects--some state right to farm laws are unconstitutional. The Iowa Supreme Court found that a right to farm provision violated the Iowa Constitution and the Fifth Amendment of the U.S. Constitution. In the absence of compensation, the Iowa right to farm provision resulted in the taking of an easement of neighboring property without compensation.

A New York court is presented with a similar argument: does the N.Y. Agriculture and Markets law effect an unconstitutional taking of private property rights where it provides that agricultural practices will not constitute a private nuisance if the Commissioner of Agriculture has issued a Sound Agricultural Practice Opinion favorable to the farmer.

This paper will address these legal cases and the question of how AFOs might approach nuisance actions if courts adjudicate the demise of right to farm laws. Will AFO operators shop for the state where the right-to-farm protection has been upheld as not offending state and federal constitutions? Will nuisance law spur AFOs to adopt additional technology? Will AFOs be limited to locating in sparsely populated areas or selecting rural areas where their activities do not offend nuisance law? By examining right to farm laws, takings jurisprudence, and technology, the paper will seek answers to these questions.

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Ground-Water Quality at 94 Dairies in New Mexico

Clay Chesney[1]

In July 1998 two staff members from the Dallas Office of the U.S. Environmental Protection Agency (EPA) visited the Ground Water Quality Bureau of the New Mexico Environment Department and collected ground-water quality information at 94 dairies permitted by the State. This data-collection effort was part of a larger project to assess the ground-water-quality impacts of animal feeding operations in the five-State area comprising EPA Region 6.

New Mexico requires operators to monitor and report ground-water quality at dairy operations in the State, thus offering a unique opportunity to access a large data base suitable for statistical analysis.

Where available, information collected consisted of dairy location, depth to ground water, locations of monitor wells and the most recent four quarters of water-quality information on nitrate/nitrite and Kjeldahl nitrogen for ground water and waste lagoons. The number of monitoring wells at individual dairies range from 1 to 11. Site maps of all permitted dairies in the State were provided by the Bureau.

The dairies are concentrated in five areas; three of these are over river alluvium (middle Rio Grande, southern Rio Grande, Pecos River near Roswell), and two areas are on the eastern side of the State over the Ogallala aquifer. The alluvial environments are characterized by shallow ground water with strong temporal variations in flow direction and an abundance of highly permeable coarse-grained sediments. Ground water in the Ogallala aquifer typically occurs at greater depths and is generally considered less vulnerable.

The statistics of most interest for ground-water quality are median nitrate concentration and the percent of samples exceeding the maximum contaminant level (MCL) for nitrate as established by EPA under its public water-supply program. Analyses of 1,031 nitrate samples from the 94 New Mexico dairies showed the following:

- Median nitrate concentration for all samples was 4.4 milligrams per liter (mg/L).
- Thirty-six percent of dairies reported nitrate concentrations above the MCL of 10 mg/L.
- Monitoring wells located near the upgradient (with respect to ground water) boundary of the property exceeded the nitrate MCL at 20% of dairies having such wells (7 of 35). Cumulative effects caused by clustering of dairies in small areas are at least partly responsible for the high nitrate concentrations entering the individual sites.
- Samples from wells downgradient from waste lagoons suggest that these structures are typically involved in the most severe cases of contamination (59% of samples with nitrate-nitrogen above 100 mg/l are downgradient from lagoons).
- Samples from areas where liquid wastes are land applied had a high median nitrate concentration (8.3 mg/l) and a high percentage of values above the MCL (42% of the 36 dairies where ground water is monitored at land-application sites show nitrate above the MCL for those sites).
- Ground water from wells in barn areas and near runoff ponds had relatively low median nitrate concentrations, but wells downgradient from stock pens had very high nitrate levels (median of 18 mg/l with 7 of the 12 sites exceeding the MCL)

There appears to be a strong correlation between depth to ground water and nitrate concentration at the dairies, with few high nitrate concentrations where the water table is over 100-feet deep.

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Distribution and Fate of Nitrate in Shallow Ground Water of Citrus Farming Areas, Indian River, Martin, and St. Lucie Counties, Florida

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The surficial aquifer system beneath citrus farming areas in Indian River, Martin, and St. Lucie Counties, Florida was investigated to detect impacts of citrus agriculture on shallow ground-water quality. Six citrus grove sites and one reference site were selected based on representative agricultural practices, soils, and tree age and health. Water-quality samples were collected and analyzed and water-level data were measured from 1996 through 1998. Elevated chloride and dissolved solid concentrations (indicators of agricultural influence) were found in ground water from citrus sites. The median chloride and dissolved-solids concentration in samples from citrus sites was 130 milligrams per liter (mg/L) and 796 mg/L, respectively. Median chloride and dissolved-solids concentrations in samples from the reference site were 23 mg/L and 171 mg/L. Nitrate concentrations in ground water exceeded the maximum contaminant level (MCL) for nitrate as established by the U.S. Environmental Protection Agency in only five percent of samples. These exceedances came from wells with depths of 10 feet or less at citrus sites and mostly from samples collected during or immediately following heavy fertilizer application. Samples from deeper wells contained little or no nitrate.

Conditions in the aquifer indicate that denitrification was primarily responsible for the reduction of nitrate in ground water. Organic carbon and iron concentrations (medians of 35 mg/L and 2.1 mg/L, respectively) were high, and dissolved-oxygen concentrations were low (generally less than 0.9 mg/L). Ground water from wells 10 to 15 feet in depth was enriched in $\delta\,^{15}N$ (median 25.5 per mil) indicating that fractionation occurred as a result of denitrification. Fertilizer samples had a median $\delta\,^{15}N$ of 3.0 per mil. Excess nitrogen gas (produced during denitrification) was extracted from ground water in wells 10 to 25 feet in depth; concentrations ranged from 1.7 to 8.3 mg/L.

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Impacts of Animal Feeding Operations on Wildlife Health

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According to recent estimates, there are more than 450,000 Animal Feeding Operations (AFO's) located throughout the United States. More than 6,600 of these operations have greater than 1,000 animals and are classified as Concentrated Animal Feeding Operations (CAFO's). The number of new CAFO's has increased dramatically and many are located in the western United States. Because water resources are usually limited, the waste storage-lagoons used by many CAFO's attract a number of wildlife species, including migratory birds. Inadequate or poor waste management resulting in runoff, spills, or discharges and land application of waste from these facilities has the potential to impact wetlands and waterways that serve as important wildlife habitat. As a result, CAFO's may facilitate direct and indirect wildlife-health impacts by providing potential sources of disease agents or by providing suitable environments for the transmission and occurrence of disease in wildlife. Diseases and agents of concern for migratory birds and other wildlife species include Salmonellosis (*Salmonella* spp.), avian cholera (*Pasteurella multocida*), avian botulism (*Clostridium botulinum*), algal biotoxins, and other diseases. However, other than reported fish kills, the possibility that CAFO's cause wildlife mortality or negatively affect wildlife health is largely speculative. In addition, changes in waste-management operations that can reduce potential health risks to wildlife have not been adequately studied. The National Wildlife Health Center has the specific knowledge, capabilities, and expertise in toxicology, microbiology, virology, parasitology, and wildlife-health evaluation to play a lead role in determining health risks to wildlife species that use CAFO lagoons or adjacent lands and wetlands and in developing waste-management practices to reduce potential risks.

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Ground-Water Protection and Manure Management

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Confinement livestock-production practices in Iowa produce large volumes of manure. The manure is stored in large earthen lagoons or basins for treatment or containment prior to disposal. Animal confinement owner/operators are required to submit a Manure Management Plan to the Iowa Department of Natural Resources (DNR). These plans describe method(s) for manure disposal. The most common method of manure disposal proposed is to apply it on agricultural land as a nutrient resource. The concentration of livestock, related waste, and land application of manure has increased concern for ground-water protection from chemicals and pathogens found in animal manure. Specific concerns include seepage of manure-derived contaminants from lagoons and basins in vulnerable ground-water areas. To evaluate the potential for ground-water contamination, the Iowa Geological Survey Bureau conducts site assessments of proposed lagoon, basin, or manure-application areas.

A vital tool used by the Iowa Geological Survey Bureau in conducting an assessment is the application of Geographic Information System (GIS) technology. The GIS contains a wide range of geologic and cultural data (called themes), which can be layered together in map form to examine a particular area or site. These data themes can be easily retrieved from computerized databases and shown on the computer screen to allow for comparison and interpretation of the geographic features and hydrogeologic conditions of any location. Being able to bring together the most accurate, up-to-date information available from numerous sources of data is a state-of-the-art tool that is very efficient and useful in assisting the geologist to evaluate a site's potential for ground-water contamination.

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Microbiological Quality of Public-Water Supplies in the Ozark Plateaus Aquifer System, Missouri

Jerri V. Davis [1]

Missouri is widely dependent on ground water as a source of drinking water for public-water systems. Historically, water from the deep bedrock aquifers in the Ozark Plateaus generally has been free from total and fecal coliform bacterial contamination. Little is known, however, about viral contamination and its relation to the bacterial characteristics of the ground water in the Ozark Plateaus. The Ozark Plateaus aquifer system is characterized as a carbonate system with numerous karst features throughout. The most important source of water for public supplies is the Ozark aquifer, both where it is unconfined and where it is confined by the Ozark confining unit and Springfield Plateau aquifer in southwestern Missouri.

The U.S. Geological Survey, in cooperation with the Missouri Department of Natural Resources, sampled 109 public-water-supply wells in water year 1997 and again in water year 1998 to characterize the microbiological quality of ground water in the Ozark Plateaus aquifer system. Samples from each well were analyzed for the following microbiological organisms—total human enteric viruses, male-specific and somatic coliphage, and fecal indicator bacteria (fecal coliform, *Escherichia coli*, and fecal streptococcus).

The data indicate that microbiological contamination of public-water supplies in the Ozark Plateaus is not widespread. Of the 109 wells sampled in water year 1997, 86 (about 79 percent) showed no presence of microbiological contamination. Human enteric viruses were present in samples collected from 11 of the 109 wells at concentrations ranging from 1.0 to 9.3 most probable number per 100 liters [confirmation of these results currently is (August 1999) underway]. Coliphage were present in samples collected from 11 wells at concentrations ranging from 38 to 2,600 plaque-forming units per 100 liters, and fecal indicator bacteria were detected in three wells at a concentration of 1 colony per 100 milliliters. Coliphage and human enteric viruses were present in two wells. Of the 109 wells sampled in water year 1998, 98 (about 90 percent) showed no presence of microbiological contamination. Coliphage were present in three wells, including one that was fecal-indicator-bacteria positive in water year 1997, at concentrations ranging from 41 to 78 plaque forming units per 100 liters. Fecal indicator bacteria were present in eight wells at concentrations ranging from 15 to 50 colonies per 100 milliliters. Coliphage and fecal indicator bacteria were not detected in the same well.

Results varied considerably between the first and second times of sampling, and no apparent correlation exists between the presence of enteric viruses and coliphage or indicator bacteria. Most of the virus and coliphage detections were outside the area with the most mature karst features. The wells mostly were located where the Ozark aquifer is confined or where the Ozark aquifer is unconfined and karst features are not well developed. The locations generally correlated with the areas that have the most intense agricultural land use, have the largest population, or had a population increase of greater than 10 percent from 1990 to 1997.

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A Risk-Based Approach to Phosphorus Management on Manured and Non-Manured Soils

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Eutrophication of surface waters often is related to phosphorus (P) runoff from agricultural fields. We evaluated P runoff from 17 furrow-irrigated fields in three different watersheds in Colorado in order to to examine the relationship between soil test P and P forms in runoff, to evaluate the use of the P Index for furrow-irrigated fields, and to determine the impact of manure application on P runoff potential. Soil test P (STP) from shallow samples (0-1 inch) taken from the furrow only was significantly correlated to ortho-phosphate, total soluble P, and bioavailable P concentrations in runoff. The P Index was not significantly correlated to any form of P measured in the runoff. However, the length of irrigation run (not included in the P Index) and the Irrigation Erosion factor from the P Index can be used to predict bioavailable P (r^2=0.81). Manured fields tended to have higher concentrations of ortho-phosphate, total soluble P, and bioavailable P in runoff than non-manured fields; however, the soluble organic P concentration was significantly higher in runoff from non-manured fields than from manured fields. STP was highly significantly correlated (r=0.85) with the P Index factor, Manure Application Rate (MAR).

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Nitrogen, Sulfate, Chloride, and Manganese in Ground Water in the Alluvial Deposits of the South Platte River Valley near Greeley, Weld County, Colorado

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Ground water is used extensively for agriculture along the South Platte River in the study area, which is about 10 miles east of Greeley and about 50 miles northeast of Denver, Colorado. Significant changes in the reuse of water may result from use and reuse of water from the stream-aquifer system for irrigated crops, extensive use of crops and poultry farms. To help water users and managers better understand the effects of land use on ground-water resources, this report presents data on nitrite plus nitrate, sulfate, chloride, and manganese concentrations, which are good indicators of the water quality, and a brief description of the geology and hydrology of the study area.

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Abundance, Dissemination, and Diversity of Escherichia Coli in a Watershed in Northern Michigan

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Contamination of recreational waters with disease-causing microorganisms is a significant, but poorly understood, environmental problem. Effective management of water resources for recreational quality requires improved understanding of the delivery and dissemination of bacteria. An interdisciplinary study, being conducted by a collaboration between the U.S. Geological Survey and Michigan State University, addresses patterns of delivery and dissemination of *Escherichia coli*, a representative enteric bacterium and an indicator of fecal contamination, to surface and ground water in a watershed in northern Michigan. To date, 234 *E. coli* isolates have been collected on three sampling dates (September 1997, May 1998, and October 1998) from 25 surface-water sites within the watershed. Ground water (28 wells) contained no *E. coli*. Isolates have been characterized by DNA fingerprints (rep-PCR profiles), and are being further characterized by patterns of resistance to the antibiotics streptomycin, tetracycline and ampicillin. At each site and date, 15 common water-chemistry parameters (for example, nutrients, major ions, dissolved oxygen) were evaluated. At selected sites and dates, indicator contaminants, such as fecal sterols, caffeine, human drugs, hormones, antibiotics and selected pesticides, have been analyzed. All sites have been mapped and characterized with respect to land-use patterns and other environmental and socioeconomic features using a geographic information system. Preliminary results suggest that on the September and October sampling dates, *E. coli* abundance and rep-PCR patterns were related to the percentage of urban land use at a site as well as to concentrations of chloride, magnesium, and nitrate. These patterns did not occur in May. *E. coli* rep-PCR profiles were very diverse in this watershed, indicating multiple, diffuse sources over short-flow paths and variation in source from day to day. Our results have significant implications for the design of monitoring programs, for modeling of bacterial contamination of recreational waters, and for understanding how to manage watersheds for bacteriological water quality. Models of bacterial contamination of recreational waters that use point sources and in-stream die-off to account for bacterial numbers would not accurately describe our observations. Our data indicate that management of watersheds for bacteriological water quality may require more information than is typically obtained in monitoring programs that simply determine bacterial numbers. Finally, our isolate characterizations provide insight into the genotypic and phenotypic diversity of environmentally-derived *E. coli* and reveal challenges that will be encountered in programs designed to detect specific pathogenic bacteria in recreational waters.

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Use of a Hydrogeologic Framework to Examine the Effects of Agricultural Fertilizers and Manure Applications on Nutrients in Shallow Ground Water of the Mid-Atlantic Coastal Plain

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The spatial distribution of nutrients in shallow ground water of the Mid-Atlantic Coastal Plain and processes that control this distribution are being evaluated within the context of a surficial hydrogeologic framework and other landscape variables. The newly developed framework provides a more detailed understanding of the surficial hydrogeology in this area than was previously available. In the Mid-Atlantic Coastal Plain, agriculture accounts for 29 percent of the land use. Confined animal feedlot operations (CAFOs), including poultry and swine, are particularly prevalent in the Delmarva Peninsula and in North Carolina, respectively. Agricultural practices involving the application of inorganic fertilizers and animal wastes from CAFOs can have major effects on the water quality in the surficial aquifer system. For instance, application of manure and fertilizers, which adds nutrients to the soil, can lead to increases in the concentration of nutrients in shallow ground water. In previous ground-water studies of the Delmarva Peninsula and the Mid-Atlantic region, nutrient concentrations in ground water were found to be higher beneath agricultural areas than beneath other land uses.

The vulnerability of ground water to nutrient contamination is controlled by a number of factors such as geology, soil type, hydrology, and land use. We are conducting a regional synthesis of existing ground-water data from the Mid-Atlantic Coastal Plain as part of the National Water Quality Assessment (NAWQA) Program. The data will be analyzed in the context of a regional hydrogeologic framework that was developed to define areas of the Coastal Plain where the occurrence and movement of chemicals into the shallow ground water and streams are controlled by a relatively consistent set of natural factors. In our study, we will describe nutrient concentrations and their mobility in the shallow ground water, analyze spatial patterns in regional nutrient data, and compare these spatial patterns to fertilizer and manure application data for particular areas of the framework.

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Potential Exposure of the Nation's Waters to Animal Manure

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The National Water-Quality Assessment Program (NAWQA) has studied the effects of agricultural and urban land use on the quality of the Nation's streams and ground water since 1991. Analysis has emphasized the presence and distribution of nutrients and pesticides derived primarily from anthropogenic nonpoint sources. Regional investigations of major river and aquifer systems, called Study Units, give perspective to emerging water-quality issues, such as the potential movement of nutrients from animal-feeding operations (AFO's) to nearby streams and shallow ground water (less than 80 feet deep). Analysis of data from the first 20 Study Units distributed across the Nation has demonstrated that nitrogen and phosphorus yields to streams and nitrate concentrations in shallow ground water generally increase with increased concentration of land applications of fertilizer and animal manure. The concentrations of nutrients in water also are related to local conditions of soils, geology, and hydrology. Census of Agriculture data on animal populations from the 1980s and 1990s were plotted by county on national maps to compare regional distributions and patterns of change over time. Nitrogen content in manure from different animals also was estimated and compared to the distribution of well-drained soils as an initial estimate of potential AFO effects on shallow ground-water quality.

Although AFO's were not specifically studied as sources of nutrients in water, some inferences about AFO effects in various regions can be made from the available data. In five Study Units in the eastern and the central United States where animal manure was substantially applied to the land, rankings of nutrient concentrations in streams and shallow ground water were excessive compared to the other Study Units. The general trend was high concentrations of nitrate in ground water where manure was applied as fertilizer and where the soils and the aquifer material, such as those comprised of permeable sand and gravel, karst limestone, or fractured rock, were susceptible to relatively rapid recharge. Compared to background conditions, elevated concentrations of nitrogen and phosphorus were detected in some streams near farmland where animal manure was applied. Areas of sloping, low-permeable soils were associated with some of the highest concentrations of nutrients in streams.

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Regulating Intensive Livestock Operations in North Carolina

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On December 10, 1992, the North Carolina Environmental Management Commission adopted a rule modification (15A NCAC 2H .0217) to establish procedures for properly managing and reusing animal wastes from intensive livestock operations. The rule applies to new, expanding or existing feedlots with animal waste-management systems designed to serve more than or equal to the following animal populations: 100 head of cattle, 75 horses, 250 swine, 1,000 sheep, or 30,000 birds with a liquid-waste system. This rule requires all animal operations with these threshold numbers of animals to develop and implement a certified animal waste-management plan.

Since the adoption of this rule, North Carolina has become a leader in regulating intensive livestock operations. As the number of hogs in North Carolina rapidly increased to ten million, substantial legislation that continued to increase the regulatory requirements for intensive livestock operations was developed by the 1995, 1996, and 1997 North Carolina General Assemblies.

Existing intensive livestock operations currently are required to receive coverage under a general permit or receive an individual permit from the Department of Environment and Natural Resources (DENR). New and expanding operations must receive a permit prior to beginning any construction. The permits incorporate site-specific conditions that were developed and implemented as part of the facility's certified animal waste-management plan.

In addition to requiring a permit, all intensive livestock operations undergo yearly operation reviews by staff from the DENR (the Division of Soil and Water), as well as, yearly compliance inspections by DENR (the Division of Water Quality) staff. Facility owners and operators are required to keep extensive records of animal waste-management practices and operations and to make these records available to staff during annual reviews and inspections. DENR has been tracking the results of these two annual visits since they began in January 1997.

All intensive livestock operations are required to have a certified animal waste-management operator. These operators must attend a ten-hour training course, pass an exam, and pay an annual fee. In order to be able to renew their certification, an operator must attend six hours of approved continuing education courses over a three-year period.

The 1997 North Carolina General Assembly enacted House Bill 515 (an Act to Enact the Clean Water Responsibility and Environmentally Sound Policy Act), which established a moratorium on the construction or expansion of swine farms. The purpose of the moratorium was to allow counties time to develop local zoning ordinances, as well as to allow studies to be done as to the impact of swine operations on the environment and public health in North Carolina. In addition, the North Carolina Environmental Management Commission recently adopted air-quality regulations for intensive livestock operations.

Regulating intensive livestock operations has developed very rapidly in North Carolina. We are confident that time will show that the efforts made by the State in regulating animal waste-management operations have made a positive impact on our environment, public health, as well as the industry itself.

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Ecological Effects of Antibiotics in Runoff from an Eastern Shore Tributary of the Chesapeake Bay

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Manure containing dietary antibiotics from approximately 82 million chickens is used to fertilize the fields in the Pocomoke River Basin. The Pocomoke River is a tributary of the Chesapeake Bay, in the Delmarva Peninsula of Maryland. Runoff from agricultural fields on which the manure is applied affects the ecology of the Pocomoke River. The altered ecology has been suggested as a contributor to outbreaks of toxic microorganisms including *Pfiesteria picicida* resulting in large fish kills and human health problems. In this paper, we describe results of screening studies of microbial populations in Pocomoke River bed sediments and from the bed sediments of a reference basin, Popes Creek, Virginia. Popes Creek is a tributary of the Potomac River that empties into the Chesapeake Bay. In addition, we propose a comprehensive study to evaluate antibiotic resistance of microbial populations from the two watersheds.

Preliminary studies have demonstrated differences in microbial populations in the two watersheds. Screening studies suggest that antibiotic resistant microorganisms are present in Pocomoke River sediments. By comparison, microorganisms from Popes Creek sediments were sensitive to the antibiotics that were tested.
We propose a collaborative study between the U.S. Geological Survey and George Mason University in which the distribution of antibiotics originating in poultry feed is determined and the effect of this distribution on the microbial communities in the two watersheds is evaluated. Water and sediment samples will be extracted and analyzed using high performance liquid chromatography with ultraviolet diode array and integrated pulsed amperometric detectors for a broad spectrum of hydrophilic and hydrophobic antibiotics often included in poultry feed. Aerobic and anaerobic microbial communities from the two watersheds will be compared with respect to sensitivity and resistance to the antibiotics found in water and sediment samples.

Data collected from this study will assist researchers in targeting and monitoring key antibiotics in tributary watersheds of the Chesapeake Bay. The data also will help to determine the environmental fate of animal antibiotics with respect to their partitioning between aqueous and solid phases. A goal of this project is to assess the effects of antibiotics on microbial activity in an environmentally sensitive watershed.

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National Association of State Departments of Agriculture (NASDA) CAFO Survey Results

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One of the major environmental challenges facing our country today is nonpoint source (NPS) pollution/runoff from agricultural lands, urban streets, construction activities, individual septic systems, parking lots, and other areas. Agriculture, in particular, has received considerable attention in recent years as State and Federal agencies have sought to increase water-quality-protection efforts. States are aggressively pursuing and expanding resource-conservation activities to minimize agricultural nonpoint source pollution. Significant environmental improvements have been achieved while enhancing agricultural competitiveness and farm profitability. Successful efforts have been obtained where the activities are voluntary, partnerships use a team approach, and specific needs of each area are met. All of this has occurred without legislation or regulation from the Federal level.

The Clean Water Act (CWA) and the National Pollution Discharge Elimination System of permits (NPDES) do not stand alone in protecting America's waters from NPS runoff from animal feeding operations. In particular, the State-led programs, when coupled with various Farm Bill, Clean Water Act, and Safe Drinking Water Act incentives and support, can provide significant and continuing opportunity for major environmental-quality protection. Federal water policies must recognize that the value of the State programs, if enhanced through Federal efforts, could provide a firm foundation for a sound national NPS policy, including addressing the runoff associated with animal agriculture.

States often have tackled environmental-quality issues before they reach national attention and federal efforts. Recently, the Environmental Protection Agency (EPA) and the U.S. Department of Agriculture (USDA) issued a final strategy to curb water pollution from animal feeding operations (AFOs). Further, almost all States are utilizing existing laws, regulations, strategies, and programs to address water quality concerns associated with animal-waste management. In many cases, States have effective programs for protecting water quality without the use of a permit program.

NASDA recently completed a survey of state programs and requirements for Concentrated Animal Feeding Operations (CAFOs). Our survey found that about one-half of the states presently require the development and implementation of a nutrient management plan for the application of manure to the land based on the application of nitrogen, phosphorus, or both, depending on the most limiting nutrient. In addition, over one-third of the States have statutes or requirements that are more stringent than current Federal regulations. This presentation will provide additional information on the results of the CAFO survey.

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Development of Comprehensive Nutrient Management Plans for Animal Feeding Operations

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Over 1.4 million agricultural enterprises in the United States have livestock or poultry operations of more than 0.1 animal units associated with their farms or ranches. While the number of animals raised has increased, the number of livestock operations has declined by 25 percent since 1992 and is expected to continue to decline over the next 10 years as "economies of scale" encourage larger size animal feeding operations (AFOs). This continued expansion and concentration of confinement-type facilities often is generating more animal waste and organic by-products than can be applied to a producer's land in an environmentally sound manner. In addition, the implementation of phosphorus-based nutrient-management standards will require more land for manure application, accentuating the challenges for AFO operators with scarce land.

The goal of the President's Clean Water Action Plan and its associated joint U.S. Environmental Protection Agency/U.S. Department of Agriculture (EPA/USDA) Unified National Strategy for Animal Feeding Operations identifies a national expectation that all AFOs will develop and be implementing comprehensive nutrient management plans (CNMPs) by 2009. The USDA-Natural Resources Conservation Service (NRCS) has estimated that 298,500 AFOs will need a CNMP to be developed and implemented in order to protect America's waters.

A CNMP is an interdependent group of conservation practices and management activities that allow a producer to achieve reasonable production goals while ensuring his/her AFO has minimal potential to adversely impact water and air quality, public health, and related natural resources around the facility and off-site. The components of a CNMP may include the following: 1) inputs to animals/internal functions (for example, animal feed, enzymes, diet supplements); 2) outputs of animals, to include animal waste and waste-water collection, handling, storage and treatment, and dead animal disposal; 3) site and/or operation inventory and evaluation along with recommended site treatment; 4) land application; 5) record keeping or maintenance of records that document nutrient and other organic by-products utilized and/or transported off-site; and 6) utilizing manure and organic by-products to provide for environmentally safe uses such as power generation, pelletization, composting, or converting to high-value products. Land application will consider nutrient budgets or balances for all potential sources of nutrients, runoff control, erosion control, leaching and deep percolation, atmospheric emissions (for example, spray aerosols, odors, dust), salts, pathogens, and other environmental concerns as identified.

Conservation practices used in a CNMP are to meet NRCS technical conservation practice standards. If NRCS does not maintain a technical standard for a CNMP component, the component is to meet the standard of another entity recognized by NRCS, such as Cooperative Extension, Land Grant Universities, State agencies, or industry. A CNMP is comprehensive to the extent that it considers nutrients from all sources. The final selection of a site-specific CNMP component is the producer's decision based on technically sound and economically feasible alternatives offered. Through voluntary participation, the extent to which the landowner/operator chooses to address the various natural-resource concerns is their decision.

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Hepatitis E Virus Antibody Prevalence Among Selected Populations in Iowa

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Hepatitus E Virus (HEV) causes an enteric infectious disease endemic in developing areas with hot climate. A case of endogenous HEV infection has been reported in the United States. Recently, HEV-like virus was isolated from swine in Iowa. Swine production is a major industry in Iowa with the potential for human exposure to swine in and around industrial and family farm operations. In order to determine whether individuals in Iowa are exposed to HEV, anti-HEV antibody prevalence in four selected Iowa populations was determined. Sera were collected from 204 patients with non-A, non-B, non-C hepatitis (non-A-C); 87 staff members of the Department of Natural Resources (DNR); 332 volunteer blood donors in 1989; and 111 volunteer blood donors in 1998. All sera were tested for anti-human HEV IgM and IgG by ELISA with confirmation of positivity by a peptide neutralization test. Both patients with non-A-C hepatitis (4.9%) and the healthy field workers from the Iowa DNR (5.7%) showed significantly higher prevalence of anti-HEV IgG antibodies compared to normal blood donor sera collected in 1998 ($p < 0.05$). None of the sera had circulating HEV detectable by reverse transcription polymerase chain reaction amplification. In conclusion, human HEV, or a HEV-like agent, is present in the Iowa geographical area. At-risk human populations with occupational exposure to wild animals and environmental sources of domestic animal wastes or with unexplained hepatitis have increased seroprevalence of HEV antibodies.

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A Multi-Tracer Approach for Determining Sources of Nitrate Contamination of Ground Water and Springs, Lafayette County, Florida

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Wastes from animal farming operations (milk and beef cows, poultry, and swine) can potentially contribute large quantities of nitrogen (N) to ground water in Lafayette County, a rural area in northern Florida and one of the leading producers of milk and broiler chickens in Florida. During 1955-95, N inputs estimated from animal wastes (not corrected for losses due to volatilization and waste-handling practices) accounted for 28 to 53 percent of the estimated total N inputs (1.4 to 4.6 million kilograms per year) from all sources of N (fertilizers; atmospheric deposition; wastes from cows, poultry, and swine; and septic tanks). A multi-tracer approach, which consisted of the analysis of spring-water and shallow ground-water samples for naturally occurring chemical and isotopic tracers ($\delta^{15}N$, $\delta^{18}O$, δD, $\delta^{13}C$, CFCs, tritium) was used to determine sources and chronology of nitrate contamination of ground water in Lafayette County and other parts of the Suwannee River Basin. Water samples from six springs in Lafayette County [flows greater than 280 liters per second (L/s)] had $\delta^{15}N\text{-}NO_3$ values ranging from 5.4 to 9.1 per mil, likely indicating a mixture of inorganic and organic sources of nitrogen. Nitrate-N concentrations in spring waters ranged from 1.7 to 5.5 milligrams per liter (mg/L). Springs integrate ground water from large parts of the aquifer and mixing of waters from various convergent flow paths is reflected by the separation in apparent ages determined from measured concentrations of CFC-11 and CFC-113. Estimated residence times for ground water discharging to springs range from 15 to 77 years, based on CFC concentrations and the use of different flow-system models. Increases in nitrate concentration in water samples from Troy Spring (flow greater than 2,800 L/s) during 1960-98 track the increase in estimated fertilizer N inputs through the early 1980's followed by the increase in estimated N inputs from animal wastes during the mid-1980's to 1998.

In contrast, water from wells in the Upper Floridan aquifer (sampled zones were 7-13 meters (m) and 26-32 m depth below land surface) had $\delta^{15}N\text{-}NO_3$ values of 10.2 to 12.8 per mil, indicating an organic source of N. Ground-water ages ranged from 8-16 years based on measured CFC-113 concentrations and a piston-flow model. Nitrate-N concentrations in ground water were 18-20 mg/L during low-flow conditions (July 1997) in the Suwannee River, but decreased to 10-13 mg/L after a period of prolonged rainfall (March 1998). Slightly elevated concentrations of N_2 gas indicate that denitrification reactions may account for some of the decrease in NO_3 concentrations during high-flow conditions. Future studies in this area would benefit from the analysis of animal pharmaceuticals and their metabolites in ground water in an attempt to discriminate among various animal-waste sources of nitrogen, which cannot be done using nitrogen-isotope data alone.

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Integrated Approach for a Comprehensive Nutrient Management Plan at Pahrump Dairy, Nevada

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Pahrump Dairy is located in Pahrump, Nevada, approximately 45 miles northwest of Las Vegas. Pahrump Dairy opened in 1988 and operates continuously with 2,300 milking cows and 600 dry cows/calves on-site. Pahrump Dairy operates under a State of Nevada approved Ground Water Discharge Permit which requires a Comprehensive Nutrient Management Plan (CNMP). The CNMP includes: land application of blended wastewater for on-site crop production, calculation of nitrogen loading rates, ground-water-quality monitoring, soil chemistry and crop yield monitoring, and prevention of ponding and runoff. Pahrump Dairy generates 99,040 gallons of wastewater per day, which is blended with ground water for irrigation of 196 acres of seasonally rotated cropland. Averaged over the year, the nitrogen uptake rate of the crops (sordan and wheat) exceeds the nitrogen application rate [59,285 pounds per year (lbs/yr)]. Depth to water in four monitoring wells completed into the alluvial aquifer ranges from 35 to 50 feet, and ground-water quality (nitrate, chloride, total dissolved solids) has been monitored since 1995. Nitrate concentrations exceeding 7 milligrams per liter (mg/L) have been reported, and Pahrump Dairy installed a solids separator in March 1999 to prevent recurrence. Removal of wet manure by the separator should result in decreasing nitrate concentrations in ground water and should eliminate the potential for excess nitrogen loading. This integrated approach to nutrient management and monitoring can be adapted to regions with shallow alluvial aquifers and highly transmissive unconfined aquifers such as portions of the Ogallala aquifer of the Great Plains.

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Methods of Assessing Microbial Contamination of Surface and Ground Waters by Animal Feeding Operations

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Animal feeding operations have been recognized as potential major sources of nutrient, antibiotic, and microbial contamination to surface water and ground water. Management of animal wastes, however, has not included monitoring and assessment of microbial pollutants. The American Society for Microbiology has called for a national monitoring program to assess the status of the Nation's waters in relation to animal (and human) waste contamination. State and Federal monitoring programs have largely underassessed the status of microbial contamination of water because of the emphasis in recent years on chemical contamination. The lack of information from past monitoring programs on the microbial contamination of water can be remedied by future monitoring efforts. Available techniques and methods for sampling and analyzing bacterial, viral, and protozoan pathogens and their indicators need to be disseminated to water-quality professionals. This information can be used to help assess the status of the Nation's waters in relation to microbial contamination.

Recently developed methods for sampling and analysis of microbial contaminants are applicable to monitoring and assessing the effects of animal waste on streams, lakes, and ground water. Sampling and analysis of waterborne pathogens require special protocols for collection and analysis. These protocols include large volume samples and specialized sampling equipment. Waterborne pathogens often require sophisticated methods for separation from the water media, and detailed preservation, culture, and identification techniques. Conversely, improved and recently modified methods for sampling and analysis of microbial indicators are cost-effective and do not require specialized equipment or highly trained personnel.

Specialized sampling and analysis methods for ground water and surface water for microbial pathogens include 1-MDS filters for collection of enteric viruses and reverse transcriptase-polymerase chain reaction for analysis of enteric viruses. For *Cryptosporidium parvum,* examples of sample-collection methods and EPA method 1622 for analysis will be shown. New indicator methods will be reviewed including simultaneous determination of total coliform bacteria and *Escherichia coli* on MI media, methods for analysis of spore-forming and chlorine resistant indicators such as *Clostridium perfringens*, and methods of analysis of viral indicators --somatic coliphage and F-specific coliphage. These methods are readily applicable to the study of microbial contamination of natural waters by animal feeding operations.

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Dairy Impacts to Water Quality and Orange County Water District's Comprehensive Dairy Waste Management Strategy

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The Santa Ana River watershed has the highest density of dairy cows in the Nation, averaging 25-30 cows per acre. Currently, 270 dairies operate on 25,000 acres within the Chino Basin portion of the watershed, with over 336,000 animals. Although the number of dairies continues to decrease, the number of animals is increasing, and the resulting impact on water quality is enormous. In the Chino Basin, the nitrate-nitrogen levels and total dissolved solids in the ground water exceed State and Federal water-quality objectives. The accumulation of salts and nitrates released from manure stockpiles and runoff of dairy washwater degrades the quality of the Santa Ana River, which recharges the Orange County ground-water basin.

The Orange County Water District (OCWD) manages both the flows of the Santa Ana River and the ground-water basin it recharges, which supplies over 2 million residents with about 75% of their water. The impact of large-scale dairies on recharge water quality is a critical issue for OCWD in protecting Orange County's primary drinking water supply. Manure-laden discharges to surface water during storm events contain protozoan parasites such as C*ryptosporidium* and *Giardia*, and pose a potential threat to public health. Organic loading into surface waters significantly decreases dissolved oxygen levels and has resulted in massive fish kills in recharge basins, which erodes public confidence in the safety of water supplies. In addition, increased salts and nitrates in the water supply shifts costs to the public sector as the economic costs of salts and salt reduction measures are transferred to the water purveyors and consumers.

OCWD is proceeding with a comprehensive approach to reduce the impact of dairy wastes on the Orange County ground-water basin, which includes: 1) incentive program for manure management, 2) enforcement of existing laws and regulations, and 3) participation in research and source-water-protection programs:

1) OCWD developed the "Tipping Fee Reduction Demonstration Program" to remove salt from the watershed by encouraging co-composting and export of manure. OCWD provided $175,000 in incentives to lower the tipping fee at a local co-composting facility to increase the deliveries of manure to 150,000 tons, a reduction of 11,550 tons of salt. The benefits of salt reduction by direct manure removal ($15 per ton of salt) far exceed ground-water-desalting costs ($318 per ton of salt).

2) OCWD works with regulators for monitoring and enforcement of dairy-waste-management regulations to ensure compliance with State and Federal law. OCWD is assisting the U.S. Attorney's Office and U.S. Environmental Protection Agency on a multi-agency Dairy Task Force to prosecute illegal discharge and disposal practices to prevent further deterioration of water quality.

3) OCWD is actively engaged in educational outreach with the dairy industry on source-water-protection efforts. OCWD also is pursuing collaborative research projects into the impact of dairy waste on water quality and public health. Research issues include: management of salts, nutrients, and pathogens released from manure; impacts of discharges containing hormones and antibiotics; and the fate and transport of pollutants to ground-water basins.

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Quantity and Quality of Seepage from Two Earthen Basins Used to Store Livestock Waste in Southern Minnesota, 1997-98--Preliminary Results of Long-Term Study

James F. Ruhl[1]

Numerous earthen basins have been constructed in Minnesota for storage of livestock waste. Typically, these basins are excavated pits with above-grade, earth-walled embankments and compacted clay liners. Some have drain tile installed around them to prevent shallow ground and soil water to discharge into the basins. Environmental concerns associated with the waste include contamination of ground water by nitrogen compounds and pathogens.

The U.S. Geological Survey, in cooperation with the Minnesota Pollution Control Agency (MPCA), studied the quantity and quality of seepage from two earthen basins used to store livestock waste in southern Minnesota during their first year of operation. One basin (site A), located at a small dairy farm, holds a manure-silage mixture, milkhouse wastewater, and local runoff; the other basin (site B), located at a large hog farm, holds a manure-water mixture from a nearby gestation barn. Monitoring systems were installed below compacted clay liners in portions of the sidewalls and bottoms of the basins to determine the quantity and quality of the seepage.

Total seepage flow from the site A basin ranged from about 900 to 2,400 gallons per day (gal/d) except during April 1998 when the flow increased to about 4,200 gal/d. Seepage flow in areal units, which closely correlated with flow in gallons per day, ranged from about 0.07 to 0.28 inches per day (in/d), which exceeded the recommended maximum design rate of 0.018 in./d established by the MPCA. Seepage flow commonly was greater through the sidewalls than through the bottom.

Seepage from the site A basin (based on 11 samples each from the bottom and sidewall) had chloride concentrations of 220-350 milligrams per liter (mg/L); ammonium-N (nitrogen) concentrations of 2.40 mg/L or less (except for one concentration of 18.4 mg/L); nitrate-N concentrations of 5.24 mg/L or less; and organic-N concentrations of 6.97 mg/L or less. Ground water would be enriched in chloride and diluted in nitrogen compounds from mixing with basin seepage. Fecal coliform bacteria, although abundant in the basin wastewater, were present in very small amounts in the seepage.

Total seepage flow from the site B basin generally ranged from 400 to 2,200 gal/d except during 1-month and 3-month periods when the flow ranged from about 3,800 to 6,200 gal/d. Seepage flow in areal units ranged from about 0.025 to 0.43 in/d, and, as at the site A basin, exceeded the MPCA recommended maximum design rate of 0.018 in/d. Seepage flow in areal units generally correlated with the flow in gallons per day except through the sidewalls when the basin was unfilled. Except during the first three months of the study, seepage flow was greater through the sidewalls than through the bottom.

Seepage from the site B basin (based on 11 samples each from the bottom and sidewall) had chloride concentrations of 11 to 100 mg/L; ammonium-N concentrations of 2.58 mg/L or less; nitrate-N concentrations of 25.7 mg/L or less (except for one concentration of 146 mg/L); and organic-N concentrations of 0.920 mg/L or less. Although background ground-water quality indicated nitrate contamination, seepage from the basin was potentially an additional source of nitrate contamination of the ground water. Nitrate-N concentrations in the seepage exceeded the U.S. Environmental Protection Agency drinking water standard of 10 mg/L in 17 of 22 samples. Fecal coliform bacteria, as at the site A basin, were abundant in the basin wastewater but not in the seepage.

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The Shaping of Law through Ten Years of Hog Production in Oklahoma

Karl M. Rysted[1]

Oklahoma is viewed as a microcosm of all States that have, or will have huge, industrial-style hog production facilities. The central problem examined is the state's experience of rapid social, economic and legal changes during the last ten years as a result of a huge increase in Confined Animal Feeding Operations (CAFOs).

Statistics of hog production in the State are examined. Oklahoma statutory agricultural law is examined as being inseparably intertwined with this huge increase in hog production. The discrepancy between appearance and reality in recent legislation is examined as it relates to actual production, particularly the role of State boards comprised of political appointees in enforcing the legislation. It is postulated that the legislation may be a "toothless tiger," which does more for the image of a governor seeking reelection, for example, than for solving the problems with CAFOs. To bring about significant change, the continued involvement of concerned citizens in many venues is proposed.

The role of litigation is examined, as the conflict between public and special interests escalates through time. As a last resort, appeals are seen as necessary to continue shaping the common law in this area, possibly forcing State boards to protect the public interest as mandated by statutory law.

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Minnesota's Generic Environmental Impact Statement on Animal Agriculture

Susan K. Schmidt[1]

Laws of Minnesota 1998 directed the Minnesota Environmental Quality Board (EQB) to conduct a Generic Environmental Impact Statement (GEIS) on animal agriculture. The purpose of the GEIS is to provide State and local policy makers with: objective, balanced information regarding the economic, environmental, health and social concerns related to animal agriculture; and develop recommendations regarding future options for animal agriculture in the State. The GEIS will involve three broad phases over approximately 2 ½ - 3 years: scoping, study and analysis, and finalizing the GEIS. A 25 member Citizen Advisory Committee (CAC) representing all interests has been established by the EQB to provide advice on the scope and content of the GEIS.

The GEIS Scoping Document -- a study outline that is based on extensive public input – was adopted by the EQB in December 1998. The Scoping Document includes an explanation of the 12 economic, environmental, social, and health topics to be addressed in the GEIS.

The EQB recently initiated the second phase of the GEIS aimed at study and analysis of the 12 identified topics. The first step of this phase is an in-depth summary of existing research on these 12 study topics. The "literature summary" will be conducted under the direction of the EQB through a contract(s) with outside experts during April through August 1999. The EQB, working with the CAC, will use the results of the literature summary to address the questions outlined in the GEIS Scoping Document and to determine the need for additional, new research that might be needed on the identified topics. Additional research is expected to be conducted during 2000.

The EQB also will gather information on location, size, species, and number of feedlots in the state. This GEIS "inventory" work will be conducted under EQB direction with outside experts during 1999. Existing data sources will provide the basis for this inventory. The statewide information on feedlot location, size, species, and number will enable the EQB to look at feedlot location and concentration relative to other variables of interest to the GEIS, such as population, population density, land use, water resources, ground-water sensitivity, and land base.

The GEIS process and status will be shared with interested conference participants as an example of one State's effort to address the feedlot controversy.

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Contaminants and Related Effects in Fish from the Mississippi, Columbia, and Rio Grande Basins

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The overall objectives of this project are to describe the occurrence and distribution of contaminants and their effects on fish at selected sites in the Mississippi River, Columbia River, and Rio Grande basins; to quantitatively evaluate the performance of aquatic methods used by the U.S. Geological Survey (USGS) Biomonitoring of Environmental Status and Trends (BEST) program; and to evaluate potential collaborations with the USGS National Stream Quality Accounting Network (NASQAN-II) and National Water Quality Assessment (NAWQA) programs. Fish were collected in 1995 at 46 sites in the Mississippi River basin (*n*=1,338); in 1997 at 16 sites in the Columbia River basin (*n*=560) and 10 sites in the Rio Grande basin (*n*=368); and in 1996 from a reference site in West Virginia (*n*=39). Sites were located at historic National Contaminant Biomonitoring Program stations in all three basins; at NASQAN-II sites in the Columbia and Rio Grande basins; and at NAWQA sites in the Mississippi Embayment and Eastern Iowa Basins study units within the Mississippi River basin. The primary species targeted at each site were common carp (*Cyprinus carpio*) and largemouth bass (*Micropterus salmoides*). Other species, mostly other black basses (*Micropterus* spp.), percids (*Stizostedion* spp.), salmonids, suckers (Catostomidae), and catfish (Ictaluridae) were collected as alternates, depending on habitat and location. Individual fish (about 40 per site) were analyzed for reproductive biomarkers (plasma vitellogenin and sex steroid hormones), histopathological alterations, macrophage aggregates, hepatic EROD activity, plasma lysozyme activity, and general fish health measures (organosomatic and ponderal indices, observations of grossly visible lesions, deformities, and parasites).

Organochlorine (pesticides and total PCB's) and elemental (heavy metals and metalloids) contaminant analyses and the H4IIE bioassay for dioxin-like activity were performed on fish samples composited by species and sex. DDT residues (mostly as *p,p'*-DDE) in fish remained sufficiently high to represent a hazard to sensitive species of fish-eating birds at sites in all three basins. Toxaphene residues also remained evident at sites in the lower Mississippi and Rio Grande basins. The combined results of organochlorine chemical, H4IIE bioassay, and biomarker analyses indicated the presence of other organic contaminants in the lower Mississippi valley. Cyclodiene pesticides (dieldrin, endrin, and chlordane) were present in many agricultural areas, especially in the Corn Belt. Concentrations of these pesticides also were elevated near Memphis, Tenn., where there is a point source. Selenium concentrations were sufficiently high to constitute a hazard to piscivorous fishes and wildlife at one site in the upper Arkansas River, where levels have been increasing for approximately 10 years, and at several sites in the central Rio Grande basin. Mercury concentrations were higher in the predator species than in bottom fish and were elevated at one site in the Rio Grande and two in the Columbia basins. In the Mississippi basin, the occurrence of vitellogenin in plasma and of ovarian cells in the testes of male fish from several sites, along with abnormal ratios of sex steroid hormones, suggest that fish from some sites are exposed to endocrine-modulating substances. Biomarker results for the Columbia and Rio Grande basins are still pending.

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Phosphate Sorption by Base Metal Hydroxides Generated in the Neutralization of Acid Mine Drainage

P. L. Sibrell[1] and P. R. Adler[2]

Excess phosphorus (P) in runoff from animal production facilities can result in nutrification of watersheds with serious consequences for aquatic life and water quality. In this research, the metal hydroxide waste product generated in the neutralization of acid mine drainage (AMD) was tested for adsorption capacity of P as phosphate. Acid mine drainage is caused by the oxidation of sulfide minerals such as pyrite to form sulfuric acid. The acid dissolves metals present in the sulfide minerals and associated rock, such as iron, aluminum, and manganese. Acid mine drainage is widespread in the Appalachian region due to decades of coal-mining activities predating regulation of acid discharge. When AMD is treated by neutralization with alkaline substances such as limestone or lime, a precipitate or floc is formed, consisting mainly of base metal hydroxides and unreacted alkaline material. Disposal costs of the floc can be as much as one half of the total operating cost for a treatment facility. Therefore, the floc would be an economical and widely available source of material for P sequestration should adsorption densities prove adequate. The effects of AMD composition and choice of alkaline neutralizing substances on floc formation and P adsorption were investigated. The test results were consistent with adsorption of P rather than chemical precipitation. Freundlich adsorption isotherms showed loadings of 30 to 50 milligrams (mg) P per gram dry weight of the sludge in equilibrium with solutions containing 0.1 to 1 mg P per liter. These loadings are much greater than for most natural soils. Phosphate adsorption also occurred under anaerobic conditions, such as would be found for wastes submerged in ponds or lagoons. Longer-term soil bag tests are planned to confirm these promising initial results.

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Delaware's Animal Agriculture: Its Role in Nonpoint Source Pollution and Options for the Future

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Delaware agriculture has been dominated by a large and geographically intense poultry industry for more than 20 years. Today, about 260,000,000 broiler chickens are produced annually in a state with about 225,000 hectares of cropland. More than one-half of this cropland is used for the production of soybeans, where land application of animal manures is not recommended. Research dating back to the 1970's has investigated the relationship between poultry manure management and water quality, particularly nitrate-N contamination of ground waters and eutrophication of fresh and estuarine waters by nitrogen (N) and phosphorus (P). The fundamental cause of the nutrient-management problems facing Delaware's animal agriculture today is that geographic intensification has resulted in large surpluses of N and P, with no options to land application to agricultural crop land. A second, non-trivial cause is the numerous difficulties in efficiently managing animal wastes as nutrient sources (for example, storage, handling, analysis of nutrient content, and timely applications). Together, these factors have resulted in nutrient accumulations in soils to excessive levels and nutrient losses to ground and surface waters and to the atmosphere.

Today, Delaware's poultry industry faces many challenges. The U.S. Department of Agriculture/U.S. Environmental Protection Agency (USDA-USEPA) Unified Strategy for Animal Feeding Operations contains recommendations and requirements that will affect the economics of poultry production by intensifying the requirements to protect the environment. Further, in 1997 Delaware entered into a total maximum daily load (TMDL) agreement with USEPA as a result of a lawsuit filed against USEPA by a consortium of environmental groups. In the TMDL agreement, the State of Delaware agreed to reduce N and P loads to surface waters by as much as 60-85%. State legislation has been passed in Maryland, Virginia, and Pennsylvania and is now under consideration in Delaware that directly affects nutrient use by poultry producers and also impacts the poultry integrating companies. Clearly, a proactive approach is needed to address the nutrient-management challenges faced by Delaware's poultry industry.

This paper first presents an historical review of the research conducted in Delaware since the 1970's on the relationship between poultry waste management and water quality. Understanding the nature of the N and P management problems faced by the poultry industry is critical to the development of solutions. Next, a summary of the options available to reduce nonpoint-source pollution by nutrients origination in animal agriculture is provided, along with an analysis of the pros and cons of each option. Finally, a systematic approach forward is proposed, one that will both sustain the profitability of animal agriculture and protect and improve water quality in Delaware.

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Identification of Sources of Nitrate in Ground Water-- A Feasibility Evaluation

Timothy B. Spruill[1]

Information is needed by State, county, and municipal water managers, as well as various industries, to determine (1) parties responsible for ground-water contamination and (2) where reduction and management efforts need to be focused to accomplish non-point-source management goals. Geochemical-isotopic indicators can be used to identify contamination sources. For example, N^{15} has been used to identify animal or fertilizer nitrogen contamination. However, N^{15} cannot always distinguish unique sources because of variability caused by fractionation of the isotope in the environment, particularly in areas where denitrification is taking place. In addition, the analysis is relatively expensive, so its use on a routine basis may not always be practical. A study is being conducted to determine if combinations of major ions (ionic concentrations or ratios of various ionic species), organic compounds, isotopes, and other chemical data exist as unique or multivariate indicators for sources of ground-water contamination. Can the source of the contaminated sample be determined from the chemical data alone?

Discriminant analysis and cluster analysis were applied to limited data collected from 20 sites in four source categories (commercial fertilizer, septic, chicken/fertilizer, and hog wastes) in summer and fall 1996. Preliminary results of the discriminant analysis indicate the following:

(1) Potassium may be useful in identifying hog-waste sources because potassium is elevated in hog wastes.

(2) The discriminant model correctly identified hog-waste-contaminated ground water, hog-lagoon water, and fertilizer-contaminated ground water. These samples were ionically unique.

While initial results were promising for some categories, the procedure produced inconclusive results in other waste categories. The chicken/fertilizer-contaminated ground-water samples were correctly placed in only 25% of the cases. Two of the four chicken/fertilizer category samples were placed in the septic-system category and one in the unknown category. One of the two septic-system cases was incorrectly placed in the chicken/fertilizer category. Initial results indicate a need to better distinguish between the chicken/fertilizer and septic-system categories. Other variables or ratios and greater sample sizes within each category could improve the discrimination power.

Five sources of nitrate-contaminated ground water currently are being evaluated--commercial fertilizer applied to crops, hog waste, chicken waste, human wastes, and commercial fertilizer applied to golf courses. Water samples will be collected and analyzed from 10 temporary wells per category. Potential indicators that are being investigated include N^{15} of nitrate, major ion concentrations, organic carbon, zinc, copper, and methylene blue active substances.

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Molecular Tracers of Organic-Matter Sources to Drinking-Water Supplies

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We investigated the utility of various compounds for use as molecular tracers of contaminant sources in drinking-water supplies. Contaminant sources included wastewater treatment plants (WWTP), agricultural/feedlot runoff, urban/suburban runoff, and nature. After analysis of source materials, we selected the following tracers: fecal steroids, laundry detergent fragrances, caffeine, nonylphenols, polycyclic aromatic hydrocarbons, *n*-alkanes, and the unresolved complex mixture (UCM). Results were then correlated with measures of land-use obtained through surveys of drinking-water utilities.

Water samples (4 liters) were extracted using C-18 disks. Tracers were quantified using GC/MS, with selected ion monitoring to improve sensitivity.

Tracers associated with WWTP effluent, including coprostanol, fragrances, and caffeine, correlated well with each other, as did groups of molecular tracers targeted for other sources. Tracers also correlated with land-use values associated with their target source. For example, WWTP molecular tracers correlated with variables such as wastewater discharge and combined-sewer overflows. Urban tracers, such as UCM, correlated with transportation and other urban measures. Agricultural tracers correlated with factors such as feedlot runoff and animal densities of cattle.

When the watersheds were ranked according to increasing urban and agricultural influence using their molecular tracers, the influence of natural sources decreased, as would be expected where anthropogenic activity is greater.

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Cycling of Sulfur in the Anoka Sand Plain Aquifer and Its Relation to Denitrification

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The fate and transport of agricultural nitrate is of major concern in the Midwest cornbelt, especially where farms are underlain by surficial glacial deposits. To better understand this problem, a multiscale study focused on an agricultural-management system and its impact on ground water. As part of this study, we investigated sources of dissolved sulfate, sulfate reduction, and pyrite oxidation coupled to nitrate reduction along a ground-water-flow path in the Anoka Sand Plain aquifer, Battle Brook drainage basin near Princeton, Minnesota. A sampling transect was designed to parallel the ground-water-flow path and a nitrate plume in the upper surficial aquifer. Ground-water samples were collected from single- and multi-level wells beneath the Management Systems Evaluation Area (MSEA) and from sites further downgradient in an adjoining wetland. Sediment samples were collected from two cores, one beneath the MSEA field and one beneath the wetland. In addition, water samples were collected from domestic wells and streams throughout the drainage basin to provide a regional geochemical datum.

This study identified high amounts of nitrate [up to 80 parts per million (ppm) NO_3] in domestic wells throughout the Battle Brook drainage basin. Most surface waters, however, are relatively uncontaminated. In oxygenated waters beneath the MSEA field, sulfate concentrations and $\delta^{34}S_{SO4}$ values versus depth are related linearly. Because the ground water is stratified, this relation likely reflects the evolution of meteoric recharge water (3 ppm SO_4 and $\delta^{34}S$ value of 8 per mil (‰) sourced from precipitation, fertilizer, and irrigation water) along the flow path. The deepest ground water has 15 ppm SO_4 and a $\delta^{34}S_{SO4}$ value of –3‰. A decrease in nitrate concentrations with depth (60 to 14 ppm NO_3), together with the increase in sulfate concentrations and decrease in $\delta^{34}S_{SO4}$ values, indicate that denitrification occurs along the flow path.

In waters beneath the oxygenated interval, in wetland samples below the nitrate plume, and in wetland samples from the well closest to Battle Brook, redox conditions are sufficiently anoxic (O_2 <1 ppm) to support sulfate reduction. With increasing depth, sulfate is progressively reduced with an isotope enrichment factor of –4.5‰ (estimate of $\Delta_{SO4\text{-}H2S}$). The calculated $\delta^{34}S$ value for the initial sulfate is –2.6‰, similar to that in deeper ground water.

In wetland sediment at the distal end of the nitrate plume, an active denitrification zone has been identified. Within this zone, NO_3 concentrations range from 14 to 55 ppm and are inversely related to dissolved SO_4 concentrations that are greater than 15 ppm (up to 80 ppm). The isotopic composition of the dissolved sulfate ranges from –8‰ to -14‰. Sediment in the denitrification zone contains between 0.17 and 0.60 wt% pyrite that similarly is depleted in ^{34}S ($\delta^{34}S$ -4‰ to –10‰). The pyrite occurs as <2 micro-meter (µm) euhedral crystals, 1-2 µm grains aggregated into framboids that are 10-20 µm across, and detrital grains up to 400 µm across. These data and their relations show that sedimentary pyrite, most likely that in the 1-2 µm grains, is an important electron donor in the denitrification process.

Our results and those from collaborative studies on the MSEA nitrate plume show that denitrification coupled to pyrite oxidation occurs along the ground-water flow path and in wetland sediments prior to ground water discharging to the surface. Pyrite oxidation releases sulfate to the ground water. In anoxic ground water, bacterially mediated sulfate reduction further modifies sulfate concentration and isotopic composition. Our understanding of sulfur cycling in the Anoka Sand Plain aquifer and how it relates to the fate and transport of agricultural nitrate in the Battle Brook drainage basin provide a foundation for studying denitrification in other glacial deposits having similar geochemical and hydrologic characteristics.

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Roxarsone in Natural Water Systems

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Organic arsenic compounds are extensively added to the feed of broiler chickens. The most commonly used arsenic compound is roxarsone (3-nitro-4-hydroxyphenylarsonic acid), which is fed to poultry to control coccidial intestinal parasites, thereby improving feed efficiency. Very little of the roxarsone is retained in the chicken meat (FDA limit is 0.5 parts per million in chicken muscle tissue). Most of the roxarsone is excreted unchanged; however, the degradation product, 3-amino-4-hydroxyphenylarsonic acid, has been detected in the urine of hens fed roxarsone. We estimate that approximately 10^6 kilograms (Kg) per year of roxarsone and its degradation products are introduced annually into the environment from the disposal of poultry litter spread onto agricultural fields near the chicken houses. This practice could result in localized arsenic pollution.

No studies have been conducted on the fate of roxarsone or the degradation pathways of the compound in soils and natural waters. However, it is possible to predict the types of degradation reactions that roxarsone could undergo by consideration of the environmental behavior of compounds that contain one or more of the same structural units as roxarsone. Three of the most likely reactions are listed in Table 1.

Table 1. Possible environmental reaction mechanisms of roxarsone

Reaction	Examples
Reduction of nitro group	Reduction of trinitrotoluene in soil to monoamines and diamines.
Oxidative aromatic ring fission	Enzymatic oxidative fission of lignin units to form aliphatic acids.
Rupture of C-As bond	Conversion of organoarsenicals to arsenate by ultraviolet irradiation.

Microbial biodegradation of aromatic compounds takes place in the following sequence: N- and O- demethylation, hydroxylation, and deamination followed by ring fission, chain shortening, and oxidative removal of substituents. Oxidative ring fission leads to the formation of carboxylic acid groups on the cleaved ends of the rings. If roxarsone were to undergo such a reaction sequence, arsonoalkyl acids would be produced. The arsonoalkyl acids could then undergo conversion to alkylarsines, which are stable under anaerobic conditions. Under aerobic conditions, methylarsines undergo rapid oxidation to AsO_4^{3-}. The degradation reactions outlined above indicate that 3-amino-4-hydroxyphenylarsonic acid, methylarsines, and AsO_4^{3-} are possible environmental-degradation products of roxarsone. In order to assess the environmental impact of introduction of large amounts of roxarsone into a watershed, the concentrations of each of these compounds must be measured in the soils, sediments, and natural waters of the watershed at different times during the hydrologic cycle.

The U.S. Geological Survey will develop separate analytical methods to measure roxarsone and its organic and inorganic degradation products in surface water, ground water, and soils. Inorganic arsenic species currently are determined by using ion chromatography to separate the species followed by hydride generation and inductively coupled plasma–mass spectrometric detection. Detection limits are 0.2 microgram per liter (µg/L) for arsenate and arsenite using a 100–microliter (µL) injection. Organoarsenic compounds, including roxarsone and 3-amino-4-hydroxyphenylarsonic acid, will be separated using reverse phase liquid chromatography and determined by electrospray mass spectrometry. We anticipate a detection limit for roxarsone of 50 nanograms per liter (ng/L) using a 50-µL injection. Surface- and ground-water samples will be processed in the field to separate the inorganic and organic species using a polymeric solid phase extraction cartridge. Organoarsenic compounds will be extracted from the cartridge with 0.2% trifluoracetic acid in acetone. Roxarsone and its metabolites will be extracted from soils using methylene chloride prior to analysis by electrospray mass spectrometry.

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Nitrous Oxide Emission from a Spray Field Fertilized with Liquid Lagoonal Swine Effluent in the Southeastern United States

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Contemporary agriculture is characterized by the intensive production of livestock in confined facilities and land application of stored waste as an organic fertilizer. Emission of nitrous oxide (N_2O) from receiving soils is an important, but poorly constrained term, in the atmospheric N_2O budget. In particular, there are few data for N_2O emissions from spray fields associated with industrial scale, swine-production facilities that have rapidly expanded in the southeastern United States. In an intensive, 24-day investigation over three spray cycles, we followed the time course for changes in N_2O emission and soil physicochemical variables in an agricultural field irrigated with liquid lagoonal swine effluent. The total-N [535 milligrams per liter (mg/L^{-1})] of the liquid waste was almost entirely NH_4^+-N (>90%) and thus had a low mineralization potential. Soil profiles for nitrification and denitrification indicated that >90% of potential activity was localized in the surface 20 centimeters (cm). Application of this liquid fertilizer to warm (19 to 28°C) soils in a form that is both readily volatilized and immediately utilizeable by the endogenous N-cycling microbial community resulted in a sharp decline in soil NH_4^+-N and supported a rapid and short-lived (days) burst of nitrification, dentrification, and N_2O emission. Fluxes of nitrous oxide as nitrogen (N_2O-N) as high as 9,200 micrograms per gram dry weight of soil per hour ($\mu g\ g_{dw}^{-1}\ h^{-1}$) were observed shortly after fertilization, but emissions decreased to prefertilization levels within a few days. Poor correlations between N_2O efflux and soil physicochemical variables (temperature, moisture, NO_3^--N, NH_4^+-N) and fertilizer-loading rate point to the complexity of interacting factors affecting N_2O production and emission. Total fertilizer N applied and N_2O-N emitted were 29.7 grams per square meter (g/m^{-2}), and 395 milligrams per square meter (mg/m^{-2}), respectively. The fractional loss of applied N to N_2O (corrected for background emission) was 1.4%, in agreement with the mean of 1.25% reported for synthetic fertilizers. The direct effects of fertilizer application appear to be more immediate and short-lived for liquid swine waste than for manures and slurries that have a slower release of nitrogenous nutrients.

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Evaluating the Cumulative Impacts from Animal Feeding Operations within Impaired Watersheds in Texas: A Regulatory Approach

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The State of Texas benefits from a thriving livestock and poultry production industry. The diverse geography and climate of Texas allows each industry to concentrate in regions suited to its production demands. Beef cattle feedlots and swine operations are located in the West Texas High Plains; the dairy industry has developed in Central Texas; while broiler and layer hen operations are concentrated in East Texas. However, the cumulative impacts of these facilities have resulted in water-quality impairments in certain watersheds in the State.

In 1998, Texas submitted a list of impaired water bodies to the U.S. Environmental Protection Agency (EPA) to meet the requirements of Section 303 (d) of the Clean Water Act. Through the National Pollutant Discharge Elimination System (NPDES), the EPA has subsequently proposed additional regulations to address concentrated animal feeding operations (CAFOs) located in these watersheds. Preliminary studies conducted by EPA have indicated that discharges from CAFOs occur frequently and have the potential to contribute to water-quality impairments.

Concurrently, the State of Texas has initiated its own studies to independently evaluate the potential water-quality impacts associated with CAFOs. Three studies are presented outlining the latest research initiated by the Texas Natural Resource Conservation Commission (TNRCC). The research presented includes (1) a study on the impacts of nonpoint-source pollution associated with dairies located in Central Texas; (2) a poultry operations study on the existing or potential adverse impacts on water quality in three East Texas watersheds; and (3) a study on the impacts from point-source discharges from feedlots and swine operations located along the Canadian River in the Texas High Plains.

Armed with the results of these on-going studies, the TNRCC has proposed new regulations to address the potential impacts to water quality in Texas. The new regulations include additional requirements for nutrient utilization planning to limit pollutant runoff from land-application practices, as well as additional training and education requirements for facilities located in impaired watersheds. Furthermore, the TNRCC is coordinating with stakeholders and local and state agencies in the development of a total maximum daily load evaluation to further identify cumulative impacts from CAFOs as well as other sources of pollutants. And with the recent delegation of the NPDES program to the State of Texas, the TNRCC has increased coordination with EPA to provide a comprehensive and multi-media regulatory approach to solving the environmental problems associated with animal feeding operations.

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