U.S. EPA Perspectives on CAFO Waste Issues

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The environmental problems associated with concentrated animal feeding operations (CAFOs) in the U.S. reflect the changes in agricultural production over the last several years. The total populations of livestock in the U.S. have increased greatly as diets have shifted toward more animal products. As a consequence, the quantities of animal manures have also increased. Animal manures contain several potential environmental pollutants including nutrients, metals, organic compounds that can become BOD (biological oxygen demand) and COD (chemical oxygen demand) in streams, microorganisms that can be human pathogens, and hormone compounds. Manure can also be a valuable resource, serving as a soil conditioner, nutrient source, and possibly as an energy source via methane generation. One of the largest areas of uncertainty in manure issues revolves around the presence of potentially pathogenic microorganisms in manure. Many well known pathogens are present in manure and their presence leads to a reasonable supposition that movement of large amounts of manure into streams could lead to significant outbreaks of illness. Compounding the risk from the presence of pathogens in manures is the presence of antibiotic resistance factors in the microbial population. A recent study in our lab demonstrated significant antibiotic resistance in both gram positive and gram negative organisms. Multiple antibiotic resistances are not uncommon in isolates of bacteria from the vicinity of CAFOs. Microbial source tracking methods may have a great impact on implementation of manure management practices. If the source of particular organisms can be identified, remedial actions can be more precisely applied. Land application of animal waste will serve as the management method of choice for the near and not so near future. Economically viable resource recovery from animal waste needs to exist before significant changes in waste management can be expected. Site suitability for disposal may become more restrictive as the environmental impacts of animal manure are more completely understood.

CAFO Rule and Future Research Needs

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In February 2003, under authority of the Clean Water Act, U.S. EPA published a new rule updating the regulations for Concentrated Animal Feeding Operations (CAFOs) originally promulgated in the 1970s. The new rule defined CAFOs, specified requirements for both the production area and land application areas, and included annual reporting requirements. The rule primarily focused on nutrient pollution from CAFOs to surface waters.

Litigants from both the agriculture and environmental communities sued EPA. In 2005, the U.S. Second Circuit Court of Appeals upheld most aspects of the rule, but vacated two major provisions which dealt with the duty of CAFOs to apply for a permit and the review and public availability of nutrient management plans (NMPs).

In 2006, EPA proposed another CAFO rule to respond to the court ruling. All other provisions of the 2003 CAFO rule remained unchanged, along with the 30-year old requirement that CAFOs that discharge must apply for a permit. The 2006 proposal responds to the court ruling by requiring that only CAFOs that discharge or propose to discharge must apply for a permit. In addition, the permitting authority would be required to review the NMP and incorporate the terms of the NMP into the permit, after public review.

Hormones were discussed in the supporting documents for the rules, not in the rules themselves. EPA believes that the setback requirements for land application of CAFO manure, litter, or process wastewaters will minimize the potential runoff of hormones and other pollutants. Additional research is needed to better understand the fate and transport of hormones from CAFOs to waters of the U.S. and the impact of on-farm technologies or management practices on hormones.

SESSION 1: Stakeholder Involvement in CAFO Environmental Issues

EPA Region 5 CAFO Waste Issues

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National Pollutant Discharge Elimination System (NPDES) Programs Branch

This presentation will provide an overview of animal feeding operations (AFO), as viewed from a regional wastewater regulatory perspective. Context for the remainder of the conference proceedings will be provided through a description of the sector, risks to water quality, the role of the National Pollutant Discharge Elimination System (NPDES) permitting program in minimizing these risks, and sources of manure, litter, and process wastewater from AFOs. Recommendations for further research to support existing predictive tools regarding precipitation- and winter-related runoff and discharge will also be provided.

Environmental Assessment for Veterinary Pharmaceuticals

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The U.S. Food and Drug Administration (FDA) Center for Veterinary Medicine (CVM) reviews and approves actions related to veterinary pharmaceuticals and feed additives. The primary law governing FDA's actions is the Federal Food, Drug, and Cosmetic Act but the National Environmental Policy Act (NEPA) also plays a pivotal role in the FDA CVM review and approval process. Following NEPA, CVM may require and review categorical exclusion and/or environmental assessments (EA) for actions. A categorical exclusion is a regulatory process for moving actions forward which will not likely impact the environment. An EA is a summary of a science-based risk process for determining whether an action may have an environmental impact. CVM has published guidance for developing data and preparing EAs. FDA has been aggressively involved in activities associated with pharmaceuticals in the environment and is moving forward with initiatives to help address environmental concerns associated with hormonally active products.

Overview of USDA research on hormones

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USDA has funded approximately 60 studies with some elements of hormones from livestock, poultry, and aquaculture. Hormone transport to the environment was the main focus of 14 projects and a minor part of 30 additional projects. Two multi-state research committees which include universities and the Agricultural Research Service as well as Tennessee Valley Authority are focused on hormones and other organic chemicals and pesticides.

USGS Research on Emerging Water-Quality Issues Related to CAFOs: Research Themes, Capabilities, and Opportunities for Collaboration.

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Among the missions of the USGS are mandates to provide the nation with unbiased information to (1) describe and understand the Earth, (2) manage water, biological, energy and mineral resources, and (3) enhance and protect our quality of life. Within that broad mandate, the USGS Toxic Substances Hydrology Program developed the Emerging Contaminants Project, with the goal of providing regulators, resource managers, industry, and the public the data and information on emerging chemical and microbiological contaminants needed to support sound decision-making. An interdisciplinary team of chemists, hydrologists, environmental scientists, microbiologists, and biologists have engaged in studies of the occurrence, sources, fate and transport and environmental or ecological effects of a variety of "emerging" chemical contaminants in the environment. New, sensitive analytical methods, developed by USGS chemists, for analysis of a wide range of chemicals including hormones, pharmaceuticals, and personal care products has allowed for studies of their occurrence and distribution in water, soils, sediments, waste, and tissue matrices. Interdisciplinary studies address hydrologic and environmental pathways for chemical dissemination, persistence, and effects on biota ranging from microbes and their genes (especially antibiotic-resistance) to earthworms to fish. This presentation will describe the types of research currently underway, with an emphasis on CAFO-related studies and on hormones, and discuss USGS Emerging Contaminants Project goals and collaborative opportunities.

SESSION 2: Current CAFO Contaminant Research at EPA

Assessing Ground and Surface Water Impacts from Hormones in CAFOs

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ORD's National Risk Management Research Laboratory (NRMRL) is conducting research to investigate sources of suspected EDCs that impact the environment. Risk management strategies are being developed by NRMRL to minimize exposure of humans and wildlife to suspected EDCs, and research efforts focus on areas such as CAFO sources, wastewater treatment, and drinking water treatment. This presentation focuses on the research being done on the CAFO source area by NRMRL's Ground Water and Ecosystem Restoration Division (GWERD), and proposed research on management practices as part of NRMRL's participation in the ORD CAFO EDC team.

GWERD's initial efforts focused on developing a method for analysis of low levels of natural (estradiol, estrone, estriol) estrogens in ground water and swine waste lagoon effluent. The method includes solid phase extraction of the estrogens, preparation of pentafluorobenzyl derivatives of phenolic groups and trimethylsilyl derivatives of hydroxy groups, and analysis using negative ion chemical ionization GC/MS/MS. This method is being used to evaluate the potential for ground water contamination by swine CAFOs through either land application of swine effluent wastewater or leakage from storage lagoons. At one field site, land application of swine waste for twelve years caused contamination of ground water by nitrate, but not estrogens. Another site had an unlined lagoon which directly contaminated ground water with estrogens as well as nutrients. Long-term monitoring continues at both of these sites.

GWERD has recently begun analysis of lagoons and ground waters for estrogen conjugates. Lagoons associated with swine, poultry, and cattle operations were sampled at three locations each for direct analysis for estrogens by GC/MS/MS, and for estrogen conjugates by LC/MS/MS. Estrogen conjugates were also analyzed indirectly by first subjecting the same samples to enzyme hydrolysis prior to GC/MS/MS analysis. Confirmed estrogen conjugates included estrone-3-sulfate, 17β-estradiol-3-sulfate, 17α-estradiol-3-sulfate, and 17β-estradiol-17-sulfate in some lagoons. Enzymatic hydrolysis indicated the presence of additional unidentified estrogen conjugates not detected by the LC/MS/MS method. In most cases estrogen conjugates accounted for at least a third of the total estrogen equivalents. Work is now in progress to develop a GC/MS/MS method for trenbolone analysis in ground water and CAFO lagoons.

Collectively, these methods will be used by GWERD in particular to evaluate the potential for ground water contamination by different CAFOs following land application of lagoon wastewater, and will contribute to NRMRL's overall risk management research on environmental impacts from hormones in CAFOs.

Overview of the ORD CAFO Research Project

Gerald Ankley
EPA, ORD National Health and Environmental Effects Research Laboratory

Preventing and controlling water pollution from concentrated animal feeding operations (CAFOs) is a major priority for EPA under the Clean Water Act. Nationally, there are an estimated 1.3 million farms holding livestock. About 238,000 of these farms are considered CAFOs where animals are held and raised in confinement. CAFOs annually produce more than 500 million tons of animal waste that can pose substantial risks to the environment and public health (EPA, 2003). Currently, very little is known about the fate, transport, exposures, and environmental effects resulting from exposures to the natural steroidal and synthetic hormones in generated waste and potential discharges from CAFOs.

At present, there is evidence that CAFO waste may have substantial potential to introduce hormonally-active materials, including high-potency natural and synthetic steroids, into surface and ground waters, as well as (through manure applications) to terrestrial systems. However, not enough currently is known to assess possible ecological (or human health) risks of potential exposures to EDCs from CAFO waste. This uncertainty is particularly important to EPA as regulatory efforts to control unacceptable impacts associated with CAFOs are implemented. The basic of goal of these studies, therefore, is to ascertain whether or not EDCs, primarily estrogens and androgens, contribute to unacceptable risks associated with CAFO waste.

To address this need, a team of scientists from across EPA/ORD has been assembled to conduct integrated research concerning hormones in CAFOs. The group includes researchers from the National Health and Environmental Effects Research Lab (NHEERL), the National Exposure Research Lab (NERL) and the National Risk Management Research Lab (NRMRL). The goals of this integrated project are multiple, including:

- Develop robust *in vitro* and analytical methods to identify and quantify compounds responsible for endocrine (e.g., androgenic, estrogenic) activity of complex CAFO discharges.
- Identify ecologically-relevant biomarkers, in aquatic species (primarily fish), of exposure to estrogenic/androgenic CAFO discharges through use of state-of-the-art genomic approaches.
- Evaluate the environmental fate, transport and metabolism of CAFO-derived EDCs relative to occurrence in surface and ground waters.
- Assess possible ecological impacts of EDCs from CAFOs using a combination of laboratory and field studies.
- Evaluate capability of existing risk management technologies for CAFOs to reduce exposure to EDCs.
- Characterize the magnitude and extent of the impact of hormones released by CAFOs and determine the impact of current CAFO waste management strategies on the fate and effects of hormones.

The presentations in this session will provide an overview of these activities in terms of progress to date and future research directions.

SESSION 3: New EPA STAR Awards on Fate and Effects of Hormones in CAFO Waste

Fate of hormones in tile-drained fields and impact to aquatic organisms under different animal waste land-application practices (EPA RD833417)

Linda S. Lee, Marisol S. Sepulveda, Chad T. Jafvert, Ronald F. Turco
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Objective: (1) Assess the relative amount of hormones discharged from tile-drained agricultural fields under different manure and lagoon effluent applications; (2) Assess hormone persistence in fields under these application practices; and (3) Evaluate the impacts of these hormone loads (relevant levels and mixtures) on aquatic organisms. We hypothesize that (1) tile drain discharge of manure-borne hormones to receiving waters will be primarily in the first rain events after land-application; (2) hormone degradation in manure- or effluent-amended soils will be rapid compared to persistence in typical anaerobic storage conditions (e.g., manure pit, lagoon), but may be measurably slower when subsurface injected compared to surface applied; and (3) under certain management and environmental conditions, mixtures of synthetic and natural hormones released from animal wastes can be sufficient and persistent enough in aquatic systems to induce irreversible gonadal changes in sensitive life-stages of fish that will persist in adult stages resulting in altered reproduction and population-level effects.

Approach: Field monitoring studies will be conducted to evaluate hormone discharges within in-line tile drain or stream collection and monitoring systems associated with agricultural fields receiving animal wastes. Natural and synthetic hormones and their primary metabolites will be measured in manure and effluent being land-applied and in field soils over time. Sexual differentiation and reproduction effects will be evaluated by exposing early life-stages of fish to hormones in controlled laboratory microcosms paired with field studies examining similar endpoints in native populations of fish in streams down gradient from CAFOs and in turtles inhabiting manure retention lagoons. Population-level effects due to hormone exposure will be estimated by fitting a population-matrix model to measured survival and fecundity parameters.

Expected results: Information obtained will help determine the relationship among different management practices (aerial spraying, subsurface injection, and solid broadcasting) on hormone discharges to aquatic bodies from primarily tile drains. The ecologically-relevant toxicity data generated will be valuable for future risk assessment of aquatic organisms exposed to mixtures of natural and synthetic hormones. The proposed studies will measure population significant endpoints and use relevant lengths, routes, and doses of exposure, which will increase the relevance of the data, and thus, its usefulness in the development of management practices and/or regulations.

Assessing occurrence, persistence and biological effects of hormones released from livestock waste (EPA RD833421)

Jocelyn Hemming, Martin Shafer, Terence Barry, James Schauer
University of Wisconsin, Madison.

Objectives:

The overall goal is to determine the presence, persistence and biological effects of natural and synthetic hormones that may be released into the environment from CAFOs, and evaluate the effects of different animal waste disposal practices on the fate and activity of these compounds. This research will help to evaluate whether CAFO waste is an important source of endocrine disrupting chemicals in the environment. The specific objectives are to:

1. Characterize the environmental transport and fate of natural and synthetic steroid hormones that accompany discharges and the disposal of animal wastes from CAFOs in Wisconsin.
2. Evaluate how various animal waste handling/management strategies (e.g., lagoon storage and spraying of liquid manure vs. deep-stacking and field application of solid manure) impact the transport, fate, potential exposure, and associated effects of steroid hormones discharged from CAFOs.
3. Investigate the ecological effects associated with steroid hormones in animal waste from CAFOs.

Approach:

The objectives of the study will be achieved by sampling representative cattle, dairy, swine and poultry operations. Waste loading will be estimated by measuring hormones in manure and urine. Transport/fate will be monitored in several environmental and engineered reservoirs such as tile drains, groundwater, soils, waste storage facilities and field-applied manure slurry. Steroids will be analyzed using LC-MS-MS. To evaluate potential biological activity of the CAFO waste, a suite of molecular and cellular-based bioassays (e.g. E- and A-screens and transfected yeast assays) will be used on extracts of collected samples. These bioassay results will be compared with compounds measured in the samples to determine if specific compounds present in CAFO waste samples can account for the endocrine activity measured by cellular/molecular bioassays. Additionally, full and partial life-cycle fathead minnow assays will be conducted using a suite of developmental and reproductive endpoints. The whole animal effects will be correlated with specific molecular and cellular-based bioassays to identify biomarkers of CAFO-associated endocrine disruption.

Expected Results:

The project will determine the potential for environmental release of hormones under various waste management practices, degradation of hormones and associated activities in these practices, the persistence of residuals in transport from CAFOs, and the relative importance of different natural and synthetic hormones to the biological activity of CAFO wastes and effluents. The results will assist CAFO operators to optimize management practices that mitigate environmental problems associated with hormones discharged from CAFOs, and help regulators with risk assessment as biologically relevant chemicals will be identified, quantified, and ranked. Ultimately, the proposed project will help protect sensitive aquatic environments, native species, and humans from wastes associated with CAFOs.

Transport/fate/ecological effects of steroids from poultry litter & evaluations of existing/novel management strategies (EPA RD833418)

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Objective: Given that fecal sex steroids persist at high concentrations in poultry litter, we hypothesize that runoff from fields treated with litter will exert a direct steroidal effect on aquatic organisms within receiving waters. Previous studies at our laboratory have demonstrated that: (1) fecal steroids in poultry litter reach receiving waters via rain-induced runoff; (2) this runoff is sufficiently estrogenic to feminize male fish; and (3) differences in agricultural management strategies can affect steroid concentrations in runoff and receiving waters. Proposed research will address remaining questions concerning environmental persistence and bioactivity of steroids upon reaching surface waters and further investigate affects of agronomic practices on mitigating resultant environmental steroid loads.

Approach: Objectives will be accomplished in laboratory, controlled research field, and in situ watershed investigations. Multiple litter sources (broilers, laying hens, etc) will be screened for steroidal constituents to determine inherent variability. Steroids in aqueous litter mixtures (lab-generated and field-collected) will be monitored over time to determine degradation rates and pathways. Particular attention will be given to ratios of free vs. conjugated steroidal constituents. Fish will be exposed to aqueous litter mixtures in laboratory assays to determine the affects of steroid degradation on bioactivity. Influences of agricultural management practices on steroid transport to surface waters (via rain-induced runoff and/or groundwater migration) will be investigated using adjacent 33 acre research fields cropped variously under existing no-till practices of direct surface litter application, or by a novel sub-surface litter application technique. Finally, Maryland Biological Stream Survey (MBSS) protocols will be applied to agriculturally impaired watersheds to assess possible community and population level disturbances resulting from fecal steroid exposure.

Expected Results: Laboratory assays will clarify exposure criteria required to induce previously observed steroid effects. Controlled field runoff studies will determine the abundance, chemical nature, and environmental fate of litter-associated steroids transported under various cropping strategies. Biological stream sampling (MBSS) will assess links between environmental degradation and regional agricultural practices. Proposed project elements, coupled with previous research, should provide regulators with sufficient information to assess the actual risks that poultry litter-associated steroids pose to aquatic ecosystems and thus improve environmental protection. The Delmarva Peninsula is the most densely concentrated poultry producing area in the U.S. generating over generating over 600 million birds and 730,000 metric tons of litter annually. Since the primary disposal method is land application, this represents an enormous source of nutrients and other contaminants, including steroids, to aquatic systems. If subsurface application of poultry litter proves effective at reducing contaminant runoff and becomes widely used as a management option in the region, it could dramatically reduce the impact of poultry litter-associated contaminants, including fecal steroids and nutrients, on the Chesapeake Bay watershed.

Fate of Hormones in Waste from Concentrated Broiler Feeding Operations (EPA RD833418)

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Objectives:
a) determine concentrations of 17β-estradiol, estrone, and testosterone in different classes of broiler litter; b) evaluate the effect of stacking broiler litter on the dynamics of hormone concentrations; c) evaluate the transport and decomposition of radiolabeled hormones mixed with broiler litter and applied on the soil surface; and d) evaluate the effect of runoff occurring at different times after broiler litter application, as well as the effect of mechanical aeration, on the concentration of hormones in surface runoff from grassed plots.

Experimental Approach:
A subset of broiler litter samples received by the Agricultural and Environmental Services Laboratory of the University of Georgia will be divided into different classes, and hormone concentrations in each class will be determined. Broiler litter in five stack houses will be sampled at the beginning and end of a storage period to determine the dynamics of hormone concentrations during storage. Radiolabeled hormones in their pure state or mixed with broiler litter will be applied to the surface of soil columns to evaluate transport and decomposition. Grassed, small plots (1.5 x 2 m) will receive simulated rainfall at different times after broiler litter application, in summer and winter, and runoff water and soil samples will be collected and analyzed for hormone concentrations. Grassed, large plots (0.8 ha) fertilized with broiler litter will be used to evaluate the effect of mechanical aeration on the concentration of hormones in soil and surface runoff under field conditions.

Expected Results:
Information on hormone concentration in different classes of broiler litter and at different broiler litter storage times will be useful to determine where research efforts should be concentrated to reduce hormone concentrations. Information on transport and decomposition of hormones in broiler litter placed on the soil surface would allow a better assessment of the risk of contaminating ground and surface waters with hormones in grasslands fertilized with broiler litter. Information on the effect of grassland aeration will be useful to determine if this practice should be used to reduce contamination of surface runoff with hormones derived from broiler litter.

Transport and Transformation of Natural and Synthetic Steroid Hormones at Beef Cattle and Dairy Concentrated Animal Feeding Operations (CAFOs) (EPA RD833422)

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Objective: This project will assess the occurrence, fate, and transport of synthetic steroid hormones used for beef cattle production and endogenous steroids produced by cattle and cows from concentrated animal feeding operations (CAFOs). We hypothesize that the most important pathways for steroid releases from CAFOs are the discharge of contaminated stormwater runoff and migration in groundwater recharged through animal waste lagoons and animal feeding areas.

Approach: The fate of synthetic hormones will be evaluated at research and commercial beef cattle feedlots located in California, Colorado and Iowa. Synthetic steroid hormones will be evaluated using a sensitive new analytical method that will be developed by modifying existing analytical methods. To quantify the relationship between growth hormone treatment and surface water releases, stormwater runoff samples will be collected at two research feedlots where hormone administration rates and waste handling procedures are rigorously controlled. Additional insight into steroid hormone fate and transport will be obtained by collecting samples at locations throughout two research feedlots and several full-scale commercial beef cattle CAFOs.

The fate of endogenous steroid hormones will be evaluated through the collection of samples at dairy CAFOs located in California. The potential for transport of steroid hormones via surface water pathways will be assessed through the collection of samples of stormwater runoff, animal waste lagoons and other sites that could release steroids during rainstorms. The potential for transport of steroid hormones in groundwater will be evaluated through the collection of groundwater downgradient of leaking animal waste lagoons and a series of tile drains that integrate groundwater recharged over large CAFOs. These results will be complemented by the development of a transport model and soil column studies with synthetic and endogenous steroids.

Expected Results:
Research conducted as part of this project will provide a better understanding of the relative importance of surface and groundwater pathways for steroid hormone releases from CAFOs. The results also will help in the development of policy guidelines and agricultural practices designed to minimize steroid hormone releases from CAFOs.

An Integrated Approach to Developing a Total Facility Estrogen Budget at a Swine Farrowing CAFO (EPA RD833732)

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Objectives: Little information is available regarding the concentration, release, fate and transport of estrogenic compounds in animal waste treatment and storage facilities. Naturally occurring estrogens in animal wastes present an emerging risk to terrestrial and aquatic environments through their potential release and action as endocrine disruptors. Given the trend in agriculture toward concentrated animal feeding operations and the extensive volume of waste generated, the potential for environmental impact "cannot be overstated. Large data gaps include: operation specific generation, concentrations and fate of these hormones, their conjugates and metabolites throughout CAFO facilities. Specifically, little data has been generated evaluating estrogen loads from differing swine operations such as farrowing and finishing facilities. We must develop quantitative information regarding: reproductive status and estrogen excretion by individual animals, the stability of estrogens in open pit holding lagoons and mobility of estrogens to surface waters following spray field application of swine waste as fertilizer. To address these data gaps we shall focus on a swine farrowing CAFO based on its operational units. By creating a hierarchical structure, assessments of estrogen fate will be "parameterized" and used for input into a Bayesian network model.

Experimental approach:
As such, we propose two specific aims: 1. Establish "total facility estrogen budget" based upon composite measurements of natural estrogenic compounds throughout a swine farrowing (CAFO). 2. Develop a Bayesian network model that will characterize causal relationships for a total facility estrogen budget in a probabilistic manner. Our experimental approach is designed as "proof of principle" to test the hypothesis that a mass balance for total estrogen equivalents from swine CAFOs can be predicted based on quantitative input and modeling of estrogen concentrations throughout each facility.

Anticipated results: The anticipated result of this project is prioritization of operational practices in regards to waste management strategies and contributions of total estrogens to the environment. With this knowledge we will be well poised to predict and determine the over all contribution of estrogenic compounds originating from differing swine operations. This will aid in developing a comprehensive understanding of the fate and movement of these compounds, their putative impact on surrounding environments and the ultimately the impact of these agricultural practices on local and regional watersheds.

Effects of Cattle Manure Handling and Management Strategies on Fate and Transport of Hormones in the Feedlot and the Field (EPA RD833423)

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Objectives: The proposed research focuses on the occurrence, fate and transport of exogenous and endogenous hormones during management of cattle manure produced at four concentrated animal feeding operations through its application to crop land and conservation buffers. The objectives of this research project are to (1) quantify hormones in various stages of the manure pathway in cattle feedlots, (2) determine the effects of different handling practices of cattle feedlot wastes on the stability and availability of hormones, (3) determine the effects of different land application strategies on the fate and transport of hormones used in beef cattle production, and (4) determine if grasses from conservation buffers assimilate hormones. The central hypothesis is that hormones in cattle manure will persist and accumulate in soil, but the fate and transport of hormones will be affected by the waste management and handling strategies utilized.

Approach: Five research tasks will address the objectives of this study. These tasks are: (1) to sample and survey four existing feedlots in Nebraska to determine the occurrence of hormones in the manure handling pathway over a climatic gradient; (2) to quantify fate of hormones as influenced by manure handling practices such as stockpiling, composting, and runoff retention basins; (3) to determine the effect of manure application strategies on hormone losses in runoff and erosion through the use of rainfall simulators; (4) to quantify hormones in select grass species in buffer strips fertilized by manure; and (5) to determine hormone fate and transport within irrigated soil systems.

Expected Results: It is expected that endogenous and exogenous hormones and their transformation products will occur in cattle manure, will remain for extended periods of time in soil receiving cattle manure, and will under certain conditions be found in runoff from feedlots and fertilized soil. Specific management strategies such as composting will likely increase the degradation rate of hormones compared to stockpiling and help to minimize impacts to the environment. Analysis of soil leachate collected in lysimeters beneath irrigated crops will demonstrate if some vertical movement can occur in soils. Measurement of hormones in grasses growing in buffer strips fertilized with manure will indicate whether plant uptake of hormones can occur. The results of the project will serve as a research base to enable the scientific and regulatory communities to better understand how waste management practices influence the fate of hormones introduced into the environment from animal manures. The data from this project will provide valuable information to both regulators and farm operators to promote and balance agricultural production and environmental protection.