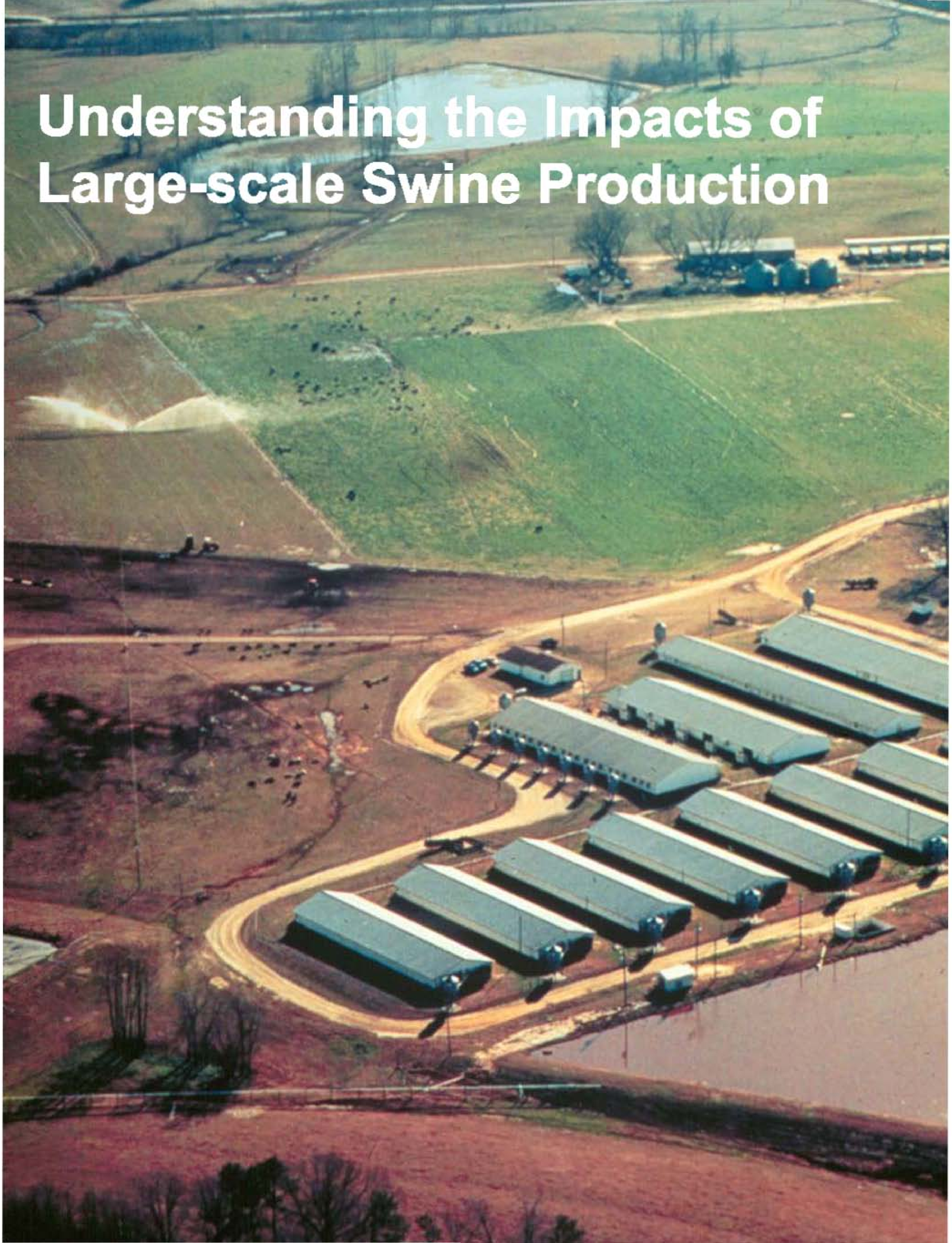
Understanding the Impacts of Large-scale Swine Production



UNDERSTANDING THE IMPACTS OF LARGE-SCALE SWINE PRODUCTION

Proceedings from an Interdisciplinary Scientific Workshop

June 29-30, 1995 • Des Moines, Iowa

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TWO-YEAR PROCESS OF THE SCIENTIFIC WORKSHOP:

Understanding the Impacts of Large-Scale Swine Production

Purpose: To Provide the Best Available Scientific Answers to Citizen and Producer Questions/Concerns about Large-Scale Swine Production

Systematic Collection of Concerns/Questions from Citizens and Producers

- Regional/National Conference
  "Livestock Production for Sustainable Rural Communities"
  October 28-30, 1994 – Kansas City, Missouri
- Producer Surveys

↓

Scientific Workshop Planned to Respond to Concerns/Questions
Planning and Steering Committee Representatives from:

- The University of Iowa
- Iowa State University
- University of Northern Iowa
- Drake University

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UNDERSTANDING THE IMPACTS OF LARGE-SCALE SWINE PRODUCTION
An Interdisciplinary Scientific Workshop
June 29-30, 1995 – Des Moines, Iowa

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PROCEEDINGS RELEASED
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INTRODUCTION

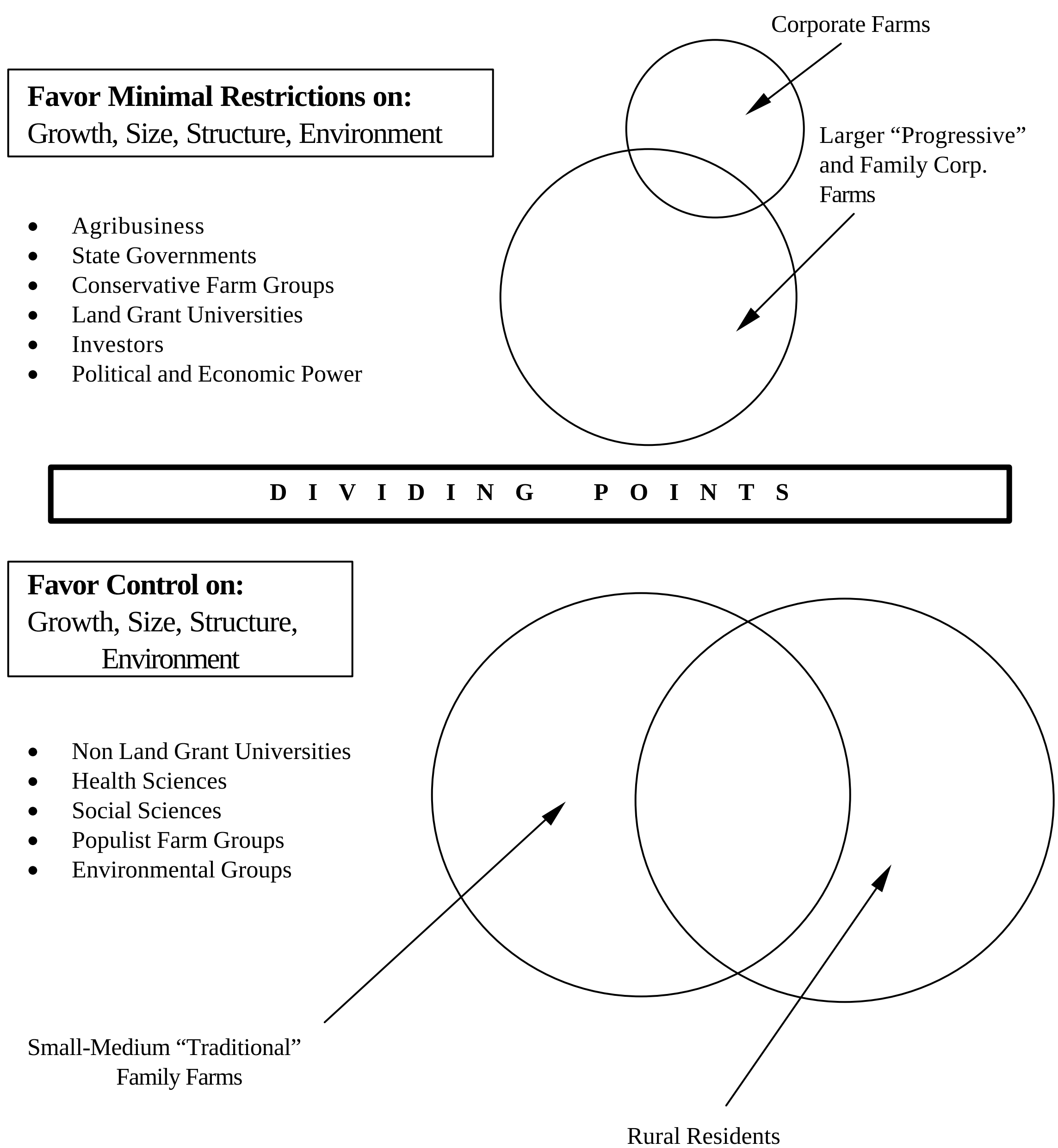
Kelley Donham and Kendall Thu

The rapid growth and proliferation of relatively large-scale swine production operations has raised a number of questions and concerns throughout the country. For the past several years, the agricultural community, rural residents, state and local officials, policy makers, researchers, and many others have struggled to respond to issues accompanying changes in the nation's swine industry. Discussion is frequently characterized by speculation, special interest, and strong emotions. Within this environment, there is a distinct need to provide consolidated scientific information addressing the range of interrelated swine industry issues. This scientific information should be available to any and all interested parties in a format that is understandable, comprehensive, and independent from special interests. That is the intent of this document. The following provides an overview of the process leading up to the production of these proceedings.

Large-scale swine production issues have resulted in factions which pit farmer against farmer, rural residents against farmers, citizens against the government and academic institutions, the agricultural community against different segments of the academic community, different farm groups against one another, and smaller independent family-oriented pork producers against large-scale corporate-style producers. The academic community has been sought after to justify the beliefs and agendas of various segments of the agricultural community (see Figure 1, page 2). We are variously asked to put a "positive spin" on results when research runs counter to dominant industry interests or provide research bullets as ammunition for rural groups fighting the encroachment or expansion of swine production facilities. This pressure has split the academic community. With funding sources changing from peer-reviewed government funding to funding from private sources and special governmental appropriations, even more pressure is applied to the academic community

Figure 1.

Perceptions or Realities?
Dividing Points in the Swine Issue



to serve special interests. These events challenge scientists to examine our role and fundamental purpose.

The success and viability of the American scientific community is rooted in academic freedom. Academic freedom is a public trust, allowing scholars to teach, research, and publish ideas and issues that may not be politically popular. There must be a system that can openly and scientifically identify, discuss, and review issues that may run counter to views from a prevailing power structure or the status quo. Quite simply, research entails a process to seek the truth based on fundamentals of the scientific method and honest reporting of peer-reviewed observations without fear of political interference.

Academic freedom is being challenged from various forces connected to swine industry change. Many of us in the academic community have felt pressure from the outside, or internally, with respect to our research or presentation of ideas and opinions. It was just two years ago that a nutrition professor at a major Midwestern university was pressured to change statements about research conducted on the health effects of dietary intake of beef. Additionally, The University of Iowa was pressured by swine industry interests because of the reporting of citizens' problems and concerns with the concentration of the swine industry in North Carolina. These are not isolated incidents. In private discussions with many of our colleagues, most have felt a variable amount of pressure from certain elements in society. These political-academic dimensions of swine industry change warrant considerable research attention and should be reported to the general public.

As the trend toward the concentration and consolidation of swine production has accelerated in the last few years, producers, rural residents, county officials, policy makers, and many others are asking many questions, and questioning the answers they are given and who is giving them. For example, many swine producers in Iowa, Kansas, and Missouri, are uncertain who to turn to for help, seeing their state and national pork producer organizations as part of the problem, as an enemy conspiring with big business, land grant institutions and government to work against their interests. In addition, farmers and rural residents are organizing thousands of people into protest groups against large-scale swine facilities across the country. They share a similar sentiment: they see a lack of credibility among agricultural experts. And many aggressive independent swine producers and their representatives see themselves being wrongly implicated by luddite producers and environmental and political extremists whom they label as emotional reactionaries.

How do we deal with this maze of conflicting views and the credibility crisis that underlies it? As Professor Cornelia Flora has said, "what we say cannot change the views of those who have drawn a line in the sand, nor is that our goal." We should not placate any particular group on any particular side of issues, nor should we discuss them in terms of "sides." As scientists, we are responsible for providing leadership by addressing the tough issues in a directly responsive manner. Consequently, we developed a process to understand the questions of farmers and rural residents and respond to them directly as scientists, without any special interest, political, or media influence. The scientific workshop upon which these proceedings are based, provided an interdisciplinary scientific forum to directly and independently respond to questions from farmers and rural residents experiencing problems with swine industry changes.

The nature, range, and sources of concerns and questions are often not clearly defined, giving rise to presumptions about the types of problems and challenges being faced by different groups. A clear understanding of concerns and questions is critical in order for scientists to respond with the appropriate scientific information. This document results from a systematic two-stage process: 1) documention of swine industry questions and concerns; and 2) assembling current scientific information in response to those concerns.

Stage One: Documentation of Swine Industry Questions and Concerns

On October 28-30, 1994, the Center for Rural Affairs and the North Central Regional Center for Rural Development co-sponsored a conference in Kansas City, Missouri, entitled "Livestock Production for Sustainable Rural Communities." The purpose of the conference was to bring rural people together with scientists from land grant and other institutions to identify and discuss issues related to changes in the livestock industry. Invitees included farmers and rural residents from throughout the United States concerned with the impact of large-scale swine production facilities in their area. A team of scientists from Iowa's Center for Agricultural Safety and Health (I-CASH) at The University of Iowa and the North Central Regional Center for Rural Development (NCRCRD) at Iowa State University cooperated to systematically record the concerns and questions of farmers and rural residents in each session of the three-day conference. Following the conference, these concerns and questions were summarized and found to fall into five topical areas: air quality, water quality, economics, social issues, and worker health. A second scientific conference was then organized to provide scientific responses to the specific questions posed by farmers and rural residents in the first conference.

Stage Two: Assembling Current Scientific Information in Response to Swine Industry Concerns

A second conference, entitled "Understanding the Impacts of Large-scale Swine Production: An Interdisciplinary Scientific Workshop" was organized for June 29-30, 1995, in Des Moines, Iowa. The purpose of this workshop was to provide a document summarizing and synthesizing current scientific research in direct response to concerns posed in the first conference. It was decided that the document would be scientifically grounded, generally understandable to a lay audience, and targeted to farmers, rural residents, policy makers, farm groups, environmental groups, government officials, and the wider academic community. A planning committee consisting of eleven scientists (see list on page *vi*.) from The University of Iowa, Iowa State University, the University of Northern Iowa, and Drake University was formed to formulate the workshop structure and to identify and invite appropriate scientists.

The issue of credibility quickly became the focus of workshop planning. In the midst of often tumultuous swine industry debate, the issue of maintaining independence was critical. It was decided that a completely independent forum should be created to allow the free and open exchange of scientific perspectives without outside pressure. Following considerable discussion, it was decided that only scientists with relevant research experience would be invited to participate. Consequently, the media, swine industry representatives, farm groups, policy makers, rural resistance groups, and others who might influence the process and product were not invited. The danger of this approach is that the process and results might be perceived or represented by certain sectors as a veiled attempt to push a particular political agenda. It was decided that this was a risk worth taking since our responsibilities lie in the realm of providing independent scientific information, which can be assessed based on the merits of the proceedings.

The Planning Committee appointed appropriate scholars to take the lead in developing the scientific responses to questions in each of the five topical areas. These session leaders are:

- Water Quality: Dr. Laura Jackson, University of Northern Iowa
- Air Quality: Dr. Stewart Melvin, Iowa State University
- Social Issues: Dr. Kendall Thu, The University of Iowa
- Economic Development: Dr. Paul Lasley, Iowa State University
- Occupational Health: Dr. Kelley Donham, The University of Iowa

The initial task of session leaders was to identify leading scientists qualified to respond to questions in each topical area (see list of participants on page *vii.*). Scientists were selected on the basis of their scholarship relative to questions posed, understanding of relevant scientific literature, and ability to integrate results. In addition, Professor Neil Hamilton, Ellis and Nelle Levitt University Distinguished Professor of Law and Director of the Agricultural Law Center at Drake, was invited to serve as the general rapporteur, observing scientific discussions in each of the five areas, and reviewing all five documents to provide an overview conclusion to the proceedings.

The questions posed by farmers and rural residents at the first conference were sent to scientists selected to participate in the scientific workshop. Scholars were asked to prepare a written scientifically-based document in direct response to these questions well in advance of the workshop. These responses were then circulated to other participants for review prior to the June 1995 workshop. They were informed that the purpose of the workshop was different from traditional academic conferences in that they were being asked to review the various contributions within their area and integrate them into responses for each of the five areas. Where scientific information was lacking in response to particular questions, participants were instructed to indicate there was insufficient information and to suggest needed research. Consequently, the majority of the workshop was spent in working sessions where scientists reviewed contributions and integrated them into responses. An extended edit and review process followed the conference with participants providing follow-up input and comment to refine the document resulting from their session. All five section documents plus the introduction were then provided to Professor Hamilton to formulate the conclusion.

To address issues related to large-scale swine production facilities, it was necessary to have a working understanding of what constitutes "large-scale swine production." In the introduction to the workshop, Dr. Kendall Thu suggested that "large-scale" is a relative concept with no single defining feature or quantitative measure. However, he pointed out that it can be characterized by a range of interrelated features:

- management, labor, and ownership are separate;
- family labor plays a limited role if any in the operation;
- owners, management, and labor in many cases do not live on or near the operation;
- a non-family corporate or company organizational structure; and
- capital intensive production technology.

Taken together these characteristics provided a guide for what is referred to as "large-scale swine production" in the scientific workshop. Large-scale swine production is not a monolithic category, and the characteristics presented are not intended to capture the full range of variation. However, they did provide a working definition for the workshop. It should be pointed out that this definition is not necessarily that of all workshop participants, but rather was provided as a guide for workshop discussion.

PRELUDE TO THE PROCEEDINGS

The domestication of plants and animals and the appearance of intensive agriculture is a relatively recent development, occupying a mere fraction of our human existence on this planet. Within the total chronology of human adaptation, industrial agriculture has emerged in the blink of an eye making its overarching implications difficult to see. Perhaps this is because we as scientists do not or cannot see them as we attend to our day-to-day tasks, or perhaps because its emergence is clouded by the haze of bureaucracies within which we are all forced to acquire certain types of knowledge in order to survive. The words of one farmer are worth noting: “Why do we keep getting more of you experts when there are less and less of us?” He raises a very important point. From his perspective, we, the agricultural experts, ought to be the subject of examination, not the other way around.

The nature of a food production and distribution system in any society, regardless of its complexity, is the single most important factor shaping the social, economic, political, and cultural fiber of that society. The implications of this are enormous as we examine issues and concerns related to fundamental changes in this country's food system. It is incumbent on scientists to realize how their research specialties interrelate with a range of issues. We must do a better job of understanding that the realities of rural life and food production systems are not encompassed in any single academic specialty at our scientific institutions. If we expect rural residents and swine producers to work together, then we must take responsibility to do the same between academic departments and between institutions.

We hope these proceedings and the responsive, interdisciplinary, and interinstitutional process upon which it is predicated will set a precedent for the future. It is no longer adequate to depend on any single institution or scientific discipline to provide answers, or even pose the correct questions. Perhaps the process we developed and the results presented here will serve as a model for the role of science and the academic community in newly emerging efforts to create a sustainable agriculture.

WATER QUALITY

Rapporteur: Laura L. Jackson, Ph.D., University of Northern Iowa

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INTRODUCTION

Water quality is a topic that is much more complex than it first appears. The Clean Water Act and subsequent legislation to bring states into compliance with its intent have focused on a relatively narrow set of water quality parameters which have in turn shaped the perceptions of the public and scientists. In trying to responsibly answer the questions presented to our group, we first had to deal with the narrowness of that customary framework.

First, distinctions made in law between surface water, groundwater, and precipitation are artificial. Surface water and groundwater intermingle, and deposition of contaminants from precipitation and dryfall – part of the water cycle – is generally treated as a separate air quality issue. Second, "point" and "non-point" source pollution are dealt with separately. Much progress has been made on the control and reduction of point source pollution (pollution coming from an identifiable place), but non-point source pollution – the pollution caused primarily by the way land is used over a large area – has not been successfully addressed. Often, whether pollution is from a point or non-point source in fact depends on the scale at which it is observed. Third, water quality regulation in agriculture has traditionally addressed only one scale rather than multiple scales including regional and transregional scales on which the water and nutrient cycles actually operate. Finally, water quality has been assessed primarily on the basis of chemical and physical tolerance limits, effectively ignoring the biological integrity of water systems until quite recently.

Similarly, customary approaches to livestock concentration have looked only at one part of the food chain – from animals to manure. Another part of the food chain – feed production – has been ignored. The way animal feed is produced e.g., annual row crops vs. perennial forages, has an equal or greater impact on water quality than manure handling. The issue of large-scale swine confinement involves not only swine concentration and waste management, but also how and where swine feed is produced. Until the mode of feed production is addressed, analysis of livestock concentration and water quality will be incomplete.

A good scientific assessment of the effects of livestock industry change on water quality should start with an adequate framework rather than simply what is customary. Without such a framework, the future will continue to present us with annoying "side effects" that are in fact not side effects at all, but predictable parts of a larger system we chose not to consider at the outset.

Another serious concern of the group was our ability to assess future, as yet unknown problems with hog confinements. For instance, we know little about the ability of human pathogens (causes of disease) to survive in hog waste and eventually be transmitted to drinking water supplies. Current microbiological techniques are insufficient to answer this question – we may find out the hard way. As another example, at any given hog confinement site, the interactions of hydrogeology, rainfall and soils may result in serious contamination problems that could have been forecast, given enough time and money – but were not. These are examples where scientific knowledge may be insufficient, or have inadequate foresight, to assist in making policy recommendations. While our group was generally able to respond to questions put to us, we worried about the questions no one thought to ask.

There are a large number of examples of unknown, unforeseen errors in the field of conservation which do not become evident for many years, usually caused by large-scale change in ecosystem processes, such as nutrient cycling or land use. Changes in the structure of livestock production and the flow of nutrients on a large scale could create unforeseen problems down the road. Ludwig et al. (1993) have emphasized the uncertainty in making environmental predictions due to the inherent complexity of large ecosystems, and the often long time lags between system perturbation and response.

WATER USE, TREATMENT AND POTENTIAL CONTAMINATION

Question # 1. What are the effects of large-scale confinement production facilities on water usage and availability?

The impacts of livestock water use on human water supplies have not been considered a major issue for confinement operations in the Midwest, but nevertheless could be an important consideration in particular places. We are aware of no systematic study of actual water use by facilities, so these comments can only give the theoretical range of possibilities. Variation from year to year, operation to operation, and manager to manager within an operation can be expected. Effect on the local water supply will depend on the swine facility's demand for water, plus the characteristics of the local ground or surface water. The likely effects of any operation must be considered in the context of current and future competing users, such as other livestock confinements or growth of municipalities; aquifer storage and transmission; and aquifer recharge rate.

Water use in a hog confinement system is related to the actual water consumption of the hogs, plus the amount of fresh water used to clean the facility and flush the gutters, plus any fresh water used to help refill the lagoons after occasional sludge removal. Finishing hogs drink three to five gallons of water a day while sows and their litters may drink as much as eight gallons per day (Midwest Plan Service 1985). Facilities that use fresh water to flush the gutters in hog facilities may use an additional 15 gallons per finishing hog or 35 gallons per sow and litter per day (Midwest Plan Service 1987). Some facilities flush the pits with water recycled from waste lagoons, others use fresh water only, and some mix the two sources.

The choice to use recycled lagoon water versus fresh water is driven partly by the ratio of rainfall to evaporation, and availability of water. Lagoons must be kept filled to a certain level to maintain their treatment efficiency. In humid climates where rainfall exceeds evaporation e.g., North Carolina, lagoons levels are maintained by rainfall, water used to flush the gutters, and liquid wastes. In dry climates where evaporation exceeds rainfall, fresh water must be added to lagoons to counteract evaporation. Therefore, water use per animal is likely to be lower in humid environments, because there is no need to add fresh water to lagoons. In areas of low precipitation and water availability, there will be less flush water recycling and more demand per animal for fresh water. Evaporation water loss from lagoons will be a function of climate and the surface area:volume ratio of the lagoon.

The degree of wash water recycling is also determined by worker health considerations. Flushing the gutters with fresh water is thought to be healthier for confinement workers. Thus even where recycling is possible, it may not be practical or desirable.

Question # 2. A large swine production facility may produce as much waste as a city. How does the need to treat human waste differ from that of swine?

Most human waste treatment systems are designed to allow the treated waste water to be discharged directly into a river, stream or other surface water. Swine and other animal waste treatment systems are designed to allow the waste to be applied to land as a fertilizer. Because they go to different ends, the two kinds of waste are treated differently.

The primary goal in treating human waste is to eliminate human pathogens. The second goal is to reduce the biochemical oxygen demand (BOD – the carbon and nutrient substrate for microbial decomposition) so that the receiving waters do not become anaerobic. Finally, some heavy metals must be removed before discharge. Aerobic decomposition of human sewage kills human pathogens and reduces the BOD. The settling process removes heavy metals to sludge. Anaerobic decomposition in animal waste lagoons is less effective at eliminating pathogens, BOD or heavy metals. However, exposure of land-applied wastes to sunlight and microbial activity in the soil will generally finish the job of pathogen control, and, given the constraints discussed below, nutrients will be used by crop plants. In effect, application to farm land is a final step in the "treatment" of swine wastes if the amount of land to which it is applied is sufficient to perform this function.

Question # 3. What methods of detection are available to determine swine-specific sources of water contamination?

Currently there are no known methods for detecting microbial contamination due to swine wastes. The ratio of fecal strep to fecal coliforms is no longer considered a valid indicator of animal contamination because some human enteric pathogens (bacteria and viruses) are harbored in domestic animals (Fedorka-Cray 1995).

Until a few years ago, our ability to determine the survival of these microorganisms in the environment was limited by our ability to culture them in the laboratory. We now have new tools that enable us to find and identify forms of potential pathogens that are not culturable under certain conditions or not culturable at all. The most common are molecular genetic assays (Abbaszadegan et al. 1991; Bej et al. 1990; Tsai et al. 1993) the use of genetic probes, typing of genetic patterns among various microbial species and strains, and immunochemical assays (Desmonts et al. 1990; Morgan and Winstanley 1991; Rose et al. 1989). However, the application of these methods to environmental and public health has been slow and most of the work is being done in countries other than the U.S.

Because human and animal wastes and environmental samples such as soils, sewage, sludges and sediments contain materials that interfere with the use of PCR (polymerase chain reaction, a molecular method) and immunoassays, samples generally require rigorous cleanup and/or extraction. In spite of these difficulties, current research in identifying specific microbial strains and types of rDNA (genetic codes) may eventually allow investigators to trace specific sources of environmental contamination.

A final possibility would be to look at the amount of ^{15}N (a stable but uncommon isotope of nitrogen) in hog manure relative to its natural concentration in the air (0.36 percent), expressed as a percent difference ("♎^{15}N"). This amount may differ from the ♎^{15}N originating from human sewage, anhydrous ammonia, or biological nitrogen fixation. However, the accuracy of this method depends on being able to detect very small amounts of isotope enrichment or depletion in one form of nitrogen compared to another. Also, there is great variability among samples. For these and a number of other reasons, researchers have agreed that this method should be regarded as at best a qualitative estimate of the relative contributions of nitrate sources (National Research Council 1978).

Question # 4. What currently unknown aspects of swine waste storage and application could pose problems in the future?

Several questions remain about the safety of animal waste application. There is some potential for microbial contamination of ground or surface water from waste (Bitton and Harvey 1992). Gastrointestinal illness resulting from consumption of contaminated water continues to be a threat to human health, especially in rural areas where water supplies may not be regularly tested. The pathogens responsible are often not identified. During the most recent outbreaks of acute gastrointestinal illness due to drinking water (1991-1992), the cause of 23 of 34 outbreaks (68 percent) could not be identified. Of all outbreaks, 76 percent occurred in non-community or private water systems although these sources serve only 9 percent of the population (Moore et al 1993).

There are a number of conditions that must occur for contamination to take place. First, human pathogenic organisms must be present in the animal waste. It has been well documented that zoonotic infectious diseases can be transmitted by the shedding of human pathogens in livestock fecal waste (Yu 1993). Second, the microorganisms must be transported from the area of disposal to a water supply i.e., runoff from a field on which animal wastes have been spread. Finally, the organisms must be able to survive in the stream or aquifer.

Large numbers of microorganisms are excreted in animal waste and some of them are human pathogens. Helicobacter pylori, a human pathogen associated with gastric ulcers and possibly stomach cancer, has been found in swine feces and a swine lagoon (Lee et al. 1993). Bacterial species include Campylobacter, Salmonella, and Listeria (Fedorka-Cray 1995); other pathogens include viruses, protozoa and helminths (worms). Approximately 85 percent to 90 percent of viruses and 45 percent to 50 percent of bacteria are destroyed in the lagoon (Hurst 1995). Survival in the soil after wastes are spread on land depends on the temperature, moisture, pH, sunlight, competition with other microorganisms, and predation (Bitton and Harvey 1992). The smallest microorganisms, viruses, are able to move more freely through soil pores and are thus more likely than bacteria to be transported by groundwater flow (Mathess and Pekdeger 1985).

Other bacteria may carry genes for antibiotic resistance. Hogs in confinement are routinely fed antibiotics, though not those normally given to humans, and persistent use of antibiotics leads to evolution of resistance in bacterial populations. Genes for resistance to a particular antibiotic can be easily transferred to other bacteria in the microbial population, even bacteria of other genera (Bates et al. 1994; Davies 1994 and 1995; Endtz et al. 1991; Velasquez et al. 1995). Thus, resistance to antibiotics may be broad-spectrum and include resistance to antibiotics that humans depend on.

RELIABILITY OF WASTE HANDLING FACILITIES

Question # 5. What is the functional life of lagoons and lagoon liners? Where do the data come from? What is the impact on ground and surface water at different ages of lagoons?

To our knowledge, no field surveys of lagoons, designed to determine their functional life or compare the performance of old and new lagoons, have been attempted. What we know about lagoon functional life and impact on ground and surface water is their *expected* performance based on certain assumptions.

Assuming proper design, management and maintenance of lagoons, the functional life of lagoons should be indefinite. Lagoon designs are based upon sludge storage volume, permanent treatment volume, temporary storage volume (typically six months normal operation), normal precipitation minus evaporation, and storm water volume for a 25-year, 24-hour rainfall (Midwest Plan Service 1987). There are several dynamic processes that affect a lagoon's functional life, as outlined below.

Soil Sealing

At the time of start up, soil pores in walls and floor are gradually sealed with solids from the animal waste. In new, unlined lagoons, seepage rates have been observed to decline, indicating sealing, in relatively short time periods: from 122 to 0.5 cm/day in 4 months (Chang et al. 1974); essentially zero after 29 days (Davis et al. 1973); and from 11.2 cm/day to 0.3 cm/day in six months (Robinson 1973). Subsequent pumping of the lagoon every six months or so for waste disposal can cause temporary drying and cracking of exposed portions of the walls and bottom of the lagoon, allowing a pulse of seepage before the cracks "seal up" again (Chang et al. 1974).

In one of the few extensive surveys of agricultural lagoon performance, Huffman and Westerman (1995) studied the seepage rate and total nitrogen export of 14 unlined lagoons in North

Carolina in operation for at least seven years. They found that seepage rates underneath the lagoons were related to soil texture. Sandy soils did not seal adequately and resulted in significant nitrogen losses to the surrounding soil and groundwater. Lagoons built on “clay” soils had much lower rates of seepage.

Lagoon Liners

Lagoon liners are thought to reduce the risks of excess seepage, particularly where the underlying native soil is too coarse to seal. Soil-lined lagoons are lined with a soil chosen to have low permeability, such as a fine silt or clay. Soil lined lagoons should perform better than unlined lagoons built on a sandy substrate; however, we found no studies that documented seepage underneath soil-lined lagoons. Drying of the liner could cause shrinkage cracks that would permit seepage for a period during re-wetting. Freeze-thaw action could have a similar effect. Regardless of the integrity of the liner, drawing down of the lagoon below the level of the water table (in areas of high water table) would cause failure of liners because of hydraulic pressure behind the liner.

Long-term experience with clay liners (a type of soil liner) for landfills has been mixed. Contrary to designer expectations, clay lined landfills have leaked. In some cases this has been due to solvents that increased the permeability of the clay; this would not occur in a normal animal waste lagoon because such solvents are not part of the waste stream.

Fabric liners are sufficiently new that their functional life has not been established; manufacturers’ claims of design life are difficult to verify. Rock or wood fragments in the soil, animal activity, or incorrect sealing of joints in assembly of the liner could create seepage problems. Gas buildup under the liner can cause it to float to the top of the lagoon; incorrect sludge removal can also damage the liner.

Hidden Tiles

Recent spills in Iowa and North Carolina have been attributed to forgotten tile lines under or near the walls of confinement lagoons. Some of these tiles were installed years ago, by a different owner, and their existence was not known until lagoon waste started flowing through them.

Sludge Buildup

Without sludge removal, a lagoon will eventually fill up and cease to function properly. Sludge removal typically must occur every 5-15 years. When sludge is removed by draining the lagoon and excavating, there is an opportunity for extensive physical disturbance of the liner, as well as thorough drying of the sides and base of the lagoon. Drying can result in the formation of shrinkage cracks in lagoon liners and dikes, followed by the passive process of sealing discussed above. Other methods of sludge removal (agitation and pumping of the lagoon contents) result in less potential disturbance, but are limited by the size of the lagoon.

The rate at which a lagoon refills after draining also affects the amount of seepage. Slow return of the liquid will allow capillary movement of water in the banks and re-swelling of the soils, preventing some seepage.

Biological Activity and Soil Formation

Accumulation of holes in lagoon dikes and liners caused by tree roots and large animal holes can undermine the lagoon structure and result in the escape of animal waste outside of the lagoon. While trees and large animals can be easily controlled, pores caused by earthworm burrows, small plant roots, and physical cracking related to freeze-thaw and wet-dry cycles, are under far less control. McCurdy and McSweeney (1993) examined soil profiles at the surface, middle and base of a leaking, 10-year-old Wisconsin dairy sewage lagoon. They found earthworm burrows (1-3 mm diameter) traversing the lagoon liner at all three depths, and root channels (2-5 mm and >5 mm at the surface and 1 mm to <1 mm diameter at the base). Furthermore, the originally massive soil structure of the liner acquired some blocky and lens-like structure and pores from freezing and thawing. Drying of the soil caused by ice lens growth at the liner-manure interface also created pores.

Animal waste lagoons have only been used for about 25 years, and little testing of old lagoons has been conducted. If soil forming processes such as those described by McCurdy and McSweeney (1993) are widespread, then lagoon liners may indeed have a finite performance life.

Rainfall

Unusually large rainfall events as well as average rainfall have been incorporated into the design of lagoons built in the past ten years (Midwest Planning Service 1987). These lagoons have been engineered to withstand the 25-year, 24-hour record precipitation record for a region. Rainfall events in excess of this could cause the lagoon level to rise above its engineered limits, eventually spilling over and possibly creating a breach in the dikes. Also, several days or weeks of persistent rainfall coupled with failure to distribute excess lagoon volume (for instance, if it is impossible to get into the field with spray equipment) could also cause the dikes to overflow or fail. Emergency spillways have been used in some regions to protect the dike in extreme events. In other regions, such outlet works have not been allowed. Local officials felt that operators would consider them an invitation to discharge.

The spill of 25 million gallons of hog waste into the New River in North Carolina[1] in the summer of 1995 was attributed to improper dike and lagoon maintenance and persistent above-average rainfall. The dike was apparently weakened by an extended period of heavy rains and a newly installed irrigation pipe. The lagoon was only 18 months old and had been inspected and certified by the Natural Resource Conservation Service.

[1] Recently revised to 22 million gallons.

Evaporation

Lagoon levels must be maintained to prevent drying and cracking of the sides and bottom. Animal wastes and fresh water used to flush the pits are generally enough to compensate for evaporation when the facility is operating normally. However, in regions where evaporation exceeds rainfall, a temporary interruption in operations would require that the lagoon be slowly refilled to prevent a pulse of seepage.

Because of the dynamic processes affecting lagoon performance, maintenance and management of lagoons is as important as engineering in determining their actual performance. Human behavior, including responsibility and error, will continue to play a central role in the safety of lagoons.

Question # 6. What is the functional life of pits? Do they contribute to contamination of ground water, and under what circumstances? Are they tested, regulated or monitored?

While lagoons have received the most attention, pits underneath hog facilities are another potential source of groundwater contamination. Pits are made of concrete and over time the concrete can crack, allowing animal waste and wash water to leak directly into the soil underneath the pits. Presumably, the soil around these points would begin to seal up as it does underneath unlined lagoons, and would be subject to the same limitations as that of unlined lagoons e.g., soil texture. However, hydraulic pressure would be much less in a pit than the bottom of a lagoon, so we might expect less potential leakage than a lagoon.

Our group was not aware of any studies to monitor the functional life of concrete pits, and to our knowledge there are no regulations or permit processes governing the design and maintenance of pits.

Question # 7. How have lagoon closures typically been handled?

Our group was aware of no published systematic study of lagoon closures, although there are a number of scattered anecdotes of abandoned lagoons. We agreed that abandonment of lagoons without appropriate clean-up was a distinct possibility with potentially negative effects on water quality.

APPLICATION OF WASTES TO FIELDS AND THE FATE OF NUTRIENTS AND FEED ADDITIVES

Question # 8. What is the extent of water contamination from field application of swine manure? How does field application of swine manure differ from application of commercial fertilizer?

There is ample documentation of surface water contamination related to run-off of animal wastes from fields, lagoons and feed lots. Each state publishes a comprehensive biannual report on water quality, called a “305b report,” which lists all fish kills and their apparent cause based on field site observations and water samples. About half of all fish kills are of undetermined cause. In Nebraska, seven fish kills in 1992 and 1993 were attributed to livestock production operations (Nebraska Department of Environmental Quality 1994). In Iowa, from October 1991 through September 1993, four of six fish kills (>47,000 fish killed overall) whose cause could be determined were attributed to feedlots (Iowa Department of Natural Resources 1994). Nationwide, the percentage of fish kills attributed to livestock production was over 50 percent.

It is more difficult to assess the impacts of field application of manure on groundwater. The movement of nutrients in shallow and deep surface waters is spatially and temporally complex, and does not lend itself to tracing particular sources. As summarized by Hallberg and Keeney (1993:316):

> The nitrate concentration noted at any well will reflect a complex interaction of the land uses and N [nitrogen] sources in areas of different recharge characteristics, the nature and thickness of material over the aquifer, the hydraulic properties of the surface materials and aquifer, the three-dimensional groundwater-flow system, and possible related stratification of

solutes . . all in relationship to the very small portion of the aquifer tapped by that well. With stratification of solutes and/or the nonuniform, preferential flow of water and contaminants, even subtle differences in the depth of the open portion of a well can make a major difference in nitrate concentrations.

Once nitrogen is in a water soluble form (nitrate, or NO_3), its source – sewage, chemical fertilizer, hog waste, or local geological deposits – cannot be easily distinguished (see discussion above). However, numerous studies on various scales have shown that nitrate concentrations in groundwater can be related directly to agricultural land use (summarized in Hallberg and Keeney 1993), which combines changes in cropping patterns, fertilizer nitrogen application, and manure nitrogen.

In southern Delaware, Ritter and Chirnside (1984) repeatedly sampled nearly 500 wells and found the greatest nitrate concentrations in areas with intensive broiler production i.e., related to poultry manure, or intensive crop production. In the Big Springs, Iowa study (Hallberg et al. 1984), groundwater nitrate concentrations in the self-contained basin rose from about 3 mg/L in the late 1950s to 10 mg/L in 1983. This three-fold increase paralleled increased use of fertilizer nitrogen (300 percent increase) and to a lesser extent manure nitrogen (30 percent increase).

It is worth noting that prior to 1950, when manure and biological nitrogen fixation were perhaps the most important source of nitrogen for crop production, and manure spreading was a ubiquitous practice, average annual groundwater nitrate levels were below 3 mg/L. Thus, manure spreading *per se* need not cause groundwater contamination. It could be argued that since crop production and animal production are inextricably linked both economically and ecologically, it is of little consequence whether groundwater contamination in a region comes directly from crop production (fertilizer nitrogen) or from animal wastes (manure nitrogen). It would be more accurate to say that the *entire production* system – now relying primarily on industrially synthesized nitrogen rather than nutrient cycling of biologically fixed nitrogen – results in groundwater contamination because of the excess application of all sources of nitrogen. This would be true whether the production system involved crops and livestock on the same farm, e.g., a traditional crop-livestock operation, or different farms widely separated in space, e.g., modern cash grain farms serving hog confinement facilities.

While it may be difficult to put the blame for ground and surface water contamination definitively on field application of animal wastes, the practices which lead to runoff and nitrate leaching from those fields are well understood. Applied to frozen or snow-covered ground, liquid wastes will not infiltrate the soil and will instead run off (Schulte et al. 1979). The applicator must consider the infiltration capacity of the soil, which is affected by soil texture and structure, surface slope and cover conditions. Typical infiltration capacities for sprinkler application range from 32 mm/hour for flat, deep sands with good cover, to 2 mm/hour for bare clays on 10 percent slopes (Schwab et al. 1993).

A second factor is amount of nitrogen applied to the soil. Nitrate losses to shallow groundwater are proportional to nitrogen loading of the soil in typical row-crop production (Baker and Johnson 1981; Hallberg 1987 and 1989; Kanwar et al. 1983; Olsen et al. 1970). At high fertility, the building of soil reserves is limited and the efficiency of nutrient uptake by the crop diminishes. Nitrogen recovery by corn silage from liquid hog manure can decrease from 40 percent to 18 percent as the rate of application increases (Antoun et al. 1985).

Nitrogen applied above the amounts used by a crop is subject to leaching, once it is converted to a mobile, water soluble form by mineralization and nitrification.[2] Greater soil concentrations of nitrates results in greater opportunities for leaching. In small and large operations alike, over-application of swine manure to limited land area is likely to cause nitrate leaching. In regions of

[2] Mineralization and nitrification are chemical reactions, mediated by bacteria and the local concentration of oxygen, that change the form of nitrogen-based molecules.

concentrated livestock production, where there is more animal waste generated than land to safely apply it on, water contamination from over-application is almost guaranteed.

Nutrient management issues are aggravated by differences between fertilizer nitrogen and manure nitrogen, and the difficulty of precise, safe application of manure. Hog manure is unlikely to result in greater nitrate nitrogen leaching than is chemical fertilizer *if it is applied at the same nutrient rate and at the same time as a chemical fertilizer*. However, several differences between manure and inorganic fertilizer make this difficult:

1. The actual nutrient content of animal waste is often unknown. Purchased inorganic fertilizers are pre-tested for actual nutrient content, but animal wastes are heterogeneous and it is up to the applicator to test them.
2. Inorganic fertilizer can be applied evenly over a field, but even distribution of animal manure is difficult.
3. The dilute concentration of nutrients in liquid wastes compared to purchased fertilizers makes their transport more expensive, especially at some distance from the lagoon site. There is a strong economic incentive to apply liquid wastes as closely as possible to the waste source. Tractors pulling large capacity spreaders filled with liquid animal waste can also cause soil compaction that reduces water infiltration capacity and limits crop growth.
4. While fertilizer can be purchased at any time and applied at an appropriate time in the crop cycle, animal wastes must be removed from lagoons on schedule, when the lagoon is full or before. This schedule may not coincide with appropriate field conditions for application, e.g., frozen or saturated soil, or for the crop's needs. Animal waste from confinements is often applied to hay fields which take up large amounts of nitrogen and can convert it into plant biomass throughout

the growing season. The availability and distribution of hay fields may constrain the rational application of animal wastes as nutrients. Since conventional hay production uses little purchased fertilizer, applying animal wastes to hay fields does not substitute free manure nitrogen for expensive fertilizer nitrogen. No greater nutrient cycling is achieved and the practice in general only adds to the total excess nitrogen in the region.

5. The nitrogen-phosphorus-potassium (N-P-K) ratio of animal waste does not necessarily match the needs of the crop. Hog waste, especially sludge from the bottom of pits and lagoons, is typically phosphorus enriched relative to crop needs. The ratio of available nitrogen to phosphorus from hog manure can be up to 1.5:1, whereas the corresponding requirement for corn grain is about 6:1 (Pennsylvania State University 1994). When waste is tested and applied to meet the nitrogen needs of the subsequent crop, phosphorus is over-applied. This has resulted in about one million hectares of phosphorus-saturated soils in the Netherlands (Reijerink and Breeuwsma 1992; Vos and Zonneveld 1993). Potassium build-up in soils spread with lagoon sludge over a 15-year period can result in loss of water infiltration capacity (Russell 1973). The accumulation of nutrients and metals over time is discussed in greater detail below.

Even if manure application could reach the precision of inorganic fertilizer application, there would still be a groundwater problem in some areas. Corn produced with the economic optimum amount of chemical fertilizer can result in nutrient losses by leaching that exceed the Environmental Protection Agency's drinking water standard of 10 mg/l (Jemison and Fox 1994; Roth and Fox 1990). Animal wastes applied at the same rate would also result in leaching of nitrate.

Question #9. To what extent do farmers appropriately apply manure?

First it is important to define "appropriate." What may be appropriate at one scale of operation may either be inadequate or overkill at another scale. Three factors that determine appropriate manure management strategies on a particular farm are the animal density – the ratio of livestock to the area on which manure can be applied; the feed source – on- or off-farm; and nitrogen fertilizer use per acre (Table 1). Where animal density is low, fertilizer use is also low, and where feed sources come primarily from the farm, the potential for non-point source pollution is also low. On this type of farm there is adequate land for spreading manure, and therefore appropriate application of manure may be easily achieved (Table 1). Testing manure before application may be unnecessary, and adherence to general guidelines and principles of manure handling and distribution may be entirely adequate. The low (less than 1 mg/L) nitrate concentrations found in groundwater in the Big Springs basin (Clayton County, Iowa) prior to 1930, when virtually all farms met the above criteria, support this prediction. On this sort of farm it is in the farmer's best economic interest to manage manure more efficiently, because it contains nutrients that are in relatively short supply.

On the other hand, where the animal/acre ratio is high, more than half of the feed is produced off-farm, and purchased fertilizer per acre is also high, the overall farm nutrient balance is more likely to be in excess, and thus the potential for non-point source pollution is greater (Table 1). At this scale, "appropriate" application of manure may require detailed record keeping, regular manure and soil testing, advanced mapping of disposal sites and crop needs, equipment to transport waste long distances and to precisely spread manure, monitoring of wells and streams, monitoring of soils for heavy metals, phosphorus and potassium, and other precautions (Boyd 1994). Clearly, efficient use of swine waste for nutrients may not be economically advantageous at this scale (Lanyon and Beegle 1993; Lemberg et al. 1992) given current market incentives, and thus may require regulation and enforcement from outside the industry.

Note that the classifications of farms in Table 1 are not based on farm size. Farms with small, as well as large numbers of swine, could fit into category 3 and pose a high risk for nonpoint source pollution. However, there are probably few cases in which an extremely large swine operation would also fit into category 1.

Table 1.
Characteristics of Farms Based on the Potential for Available Soil Nitrogen Balance

	Farm category		
Assessment	1	2	3
Feed source (% off-farm)*	On-farm (<50%)	Combination (50 to 80%)	Off-farm (>80%)
Animal density (Animal units/acre routinely manured)	Low (<1.25/A)	Medium to high (1.25 to 2.25/A)	Very high (>2.25/A)
Nitrogen fertilizer use (lb/A on corn)	Low to moderate (<50 to 150)	Low to high (<50 to >150)	Low to high (<50 to >150)
Land for manure spreading	Adequate	Limited	Inadequate
Manure nutrient balance	Deficit	Balanced	Excess
Nonpoint source pollution potential	Low	Low to high	Very high

(taken from Lanyon and Beegle 1993)

The proportion of farmers who currently test their animal wastes for nutrient value before application is not known. In Iowa, only 50 percent of farmers take any nitrogen credit for the manure they apply to row crops (Duffy and Thompson 1991; Kross et al. 1990; Padgitt 1989). A much smaller proportion of farmers test for nitrogen levels in late spring to determine soil nitrogen available throughout the season. Then they can apply the fertilizer needed to make up the difference between crop needs and amount available in the soil (Blackmer, et al. 1995). This practice also credits manure nitrogen.

A 1994 survey of producers in North Carolina found that 76 percent of swine producers reduced their chemical fertilizer costs by applying animal waste. Three-quarters of those with greater than 1000 animals, about half of those with 250 to 1000 animals, and 1 in 10 of those with less than 250 animals had written waste management plans (North Carolina regulations do not require written plans for less than 250 animals; existing operations above 250 animals have until the end of 1997 to comply). Larger swine operations were more likely to frequently calibrate their waste spreading equipment, use buffer strips or terraces on cropland, and test their soils and waste (Hoban and Clifford 1995).

Question #10. Is there a build up of trace heavy metals, antibacterials, phosphorus, and potassium due to long-term spreading of lagoon sludge?

Phosphorus, sodium, potassium, copper, and zinc can build up in soils where swine manure is applied. Unlike nitrogen and sodium, which are water soluble and highly mobile, other elements tend to be adsorbed and lost through soil erosion. Phosphorus and potassium are plant nutrients that are removed from the soil by crop harvest, but if applied in excess of what crops use they will nevertheless accumulate in the soil. This is often the case, since swine waste is typically applied at rates calculated to dispose of the maximum amount of nitrogen that the crop can use (see discussion above). Sodium will build up in dry climates where evaporation exceeds rainfall.

Phosphorus is a particular problem in the Netherlands, which has a long history of animal agriculture. Increasingly in the last 40 years, a large number of small livestock farms have imported most of their feed. About one million acres of phosphorus saturated soils in the Netherlands caused by over-application of manure has resulted in eutrophication (excess nutrients causing algal blooms) of surface water and phosphorus movement into groundwater (Reijerink and Breeuwsma 1992; Verhoeven et al. 1993). In the U.S., Ohio has recently changed its recommendations, so that wastes are spread according to the phosphorus, rather than the nitrogen needs of the crop. Thus, more land is required for disposal.

The impact of metals accumulation on soil health and productivity is not being monitored and is not yet known. Copper and zinc, added to pig feed to promote growth, are used in very small quantities by crops, so they accumulate in the soil nearly as fast as they are spread with manure and sludge. No statistics appear to be available on the total area or condition of soils to which zinc and copper-enriched animal wastes have been applied over time. Soil type, organic matter content, etc., will affect how long this can continue without obvious damage to soil productivity.

ECOSYSTEM EUTROPHICATION-LINKAGES BETWEEN THE ATMOSPHERE, THE SOIL, AND GROUND AND SURFACE WATERS

Question #11. What is the extent of increased atmospheric nitrogen deposition in precipitation and dryfall?

Data for increased atmospheric nitrogen deposition related to livestock production are available from the Netherlands. Currently the Netherlands receives on average 45 kg nitrogen per hectare per year from atmospheric deposition, which is 10 times background levels. The greatest deposition rates (50 to 65 kg nitrogen/hectare/year) occur in the southeastern part of the country where the livestock industry is the most intensive (Erisman 1991; Van Aalst and Erisman 1990). On a local scale, soil nitrate levels increased and pH decreased in the immediate vicinity of a poultry farm (Berendse et al. 1993), demonstrating that much of the ammonia "lost" to the atmosphere during manure storage did not go very far.

The extent of atmospheric deposition has been studied over broad regions of the U.S. with respect to acid precipitation, but not on a local scale with respect to manure management. The extent of nitrogen loss from different manure management systems is some indication of potential local effects. Typical anaerobic lagoons employed for manure storage and treatment in swine facilities lose

70-80 percent of the original nitrogen to the atmosphere (Sutton 1994). This contrasts with losses of 15-40 percent for daily scrape and haul or manure pack systems. Most of the nitrogen is lost as ammonia, but a small portion is lost as nitrous oxide (N_20), a greenhouse and ozone-depleting gas. Very little enters the atmosphere as dinitrogen gas (N_2).

Ammonia is also lost to the atmosphere when animal wastes are applied to fields, particularly if they are applied by irrigation (30-40 percent) or to the soil surface without incorporation (10-25 percent) (Sutton 1994). In contrast, injection (knifing) of liquid waste results in a 0-2 percent loss. Thus, under the worst conditions, total nitrogen leakage to the atmosphere is 70-88 percent of the original nitrogen content of manure and urine.

Question #12. What are the effects of atmospheric nitrogen deposition on surface and groundwater quality?

Atmospheric deposition of nitrogen may appear to be "free fertilizer," a fringe benefit to farmers living near a hog confinement facility. Nitrogen in the rain that falls on a crop can immediately be taken up by the crop. However, the nitrogen also falls onto roads, parking lots, fallow fields, fence row weeds, lakes, streams, ponds, forests, wetlands and prairies. Depending on where it falls, this nitrogen can run off impervious surfaces, polluting streams and ponds. It can also fertilize unwanted weeds. During the fall, winter and spring when crops are not taking up nutrients, nitrate nitrogen can leach or run off the soil surface, just as fall-applied anhydrous ammonia can convert to nitrate and leach over winter.

Atmospheric deposition of nitrogen can also damage natural habitats, which are a part of the water cycle that helps to keep surface and ground waters pure by absorbing excess nutrients from surrounding nutrient-leaky systems. Plants in natural environments are often adapted to conditions of fierce competition for available nitrogen. When artificially fertilized, weeds and other non-native species take over. This process has been best documented in the Netherlands, where forests, dunes, and heathland ecosystems have been both artificially fertilized and acidified by atmospheric deposition caused primarily by confinement livestock production. In Dutch heathlands, the dominant dwarf shrub *Erica tetralix* has been almost totally replaced by the grass *Molinia caerulea* (Berendse et al. 1993). Rare species have disappeared as well. In dune slacks and ponds, fifty species adapted to low-medium nutrient conditions have declined while high nitrogen use species now dominate (Verhoeven et al. 1993). The same is true of forest herbs in the Netherlands, central Europe, and southern Sweden (references in Berendse et al. 1993). To preserve the species composition and functioning of natural communities in the Netherlands, managers now harvest the vegetation and underlying sod to remove nitrogen.

Atmospheric nitrogen deposition is estimated to contribute a significant proportion of new nitrogen inputs to eastern coastal waters, ranging from 20-30 percent in estuaries to as much as 50-60 percent in fully saline waters. In these typically nitrogen-limited systems, additional nitrogen inputs can trigger algal blooms and shifts in populations of species (Paerl 1993 and 1995).

In the upper Midwest, the last remaining tallgrass prairies persist in less than one-tenth of one percent of their former area. Nitrogen is the nutrient most likely to limit productivity of tallgrass prairie (Risser and Parton 1982). Prairies in the upper Midwest may be receiving substantially more nitrogen in the form of wet and dry atmospheric deposition than they were 100 years ago, potentially changing the competitive balance between many different species (Vitousek 1994). Electrical storms and biological nitrogen fixation (nitrogen fixed by legumes) are responsible for the normal nitrogen deposition rate of about 13 kilograms/hectare/year (Tjepkema and Burris 1976). Anhydrous ammonia fertilizer, coal-fired power plants, auto emissions and high-density livestock operations can all increase that rate of nitrogen deposition.

Invasion of prairies by exotic species such as bromegrass (*Bromus inermis*) is one of the greatest threats to their continued integrity. Bromegrass responds strongly to nitrogen fertilization

(Lamson-Scribner 1899; Paulsen and Smith 1968), while prairie grasses such as big and little bluestem (Andropogon gerardii and Schizachirium scoparius) are highly efficient nitrogen users (Tilman and Wedin 1991; Wedin and Tilman 1990). In experiments with nitrogen gradients, big bluestem and little bluestem were capable of reducing soil nitrogen levels below that of nonnative cool season grasses. The native prairie grasses dominated low nitrogen plots, but virtually disappeared from high nitrogen plots (Wedin and Tilman 1990). In related experiments conducted over 11 years (Inouye and Tilman 1995), plots were nitrogen enriched by just 0.1 kilograms/hectare/year to 2.7 kilograms/hectare/year. As little as 0.34 kilograms/hectare/year added nitrogen caused major shifts in plant communities and reduced species diversity. It seems likely that increasing rates of atmospheric nitrogen deposition caused by high density livestock operations will disrupt any low fertility natural ecosystems nearby.

EFFECTS OF OPERATION SCALE AND REGIONAL CONCENTRATION

Question # 13. Do contaminations vary by the scale of confinement operations? What are the implications for increased size and concentration?

There have been no studies to systematically survey the waste management operations of farms and swine production operations. For small and medium size operations in particular, the expense and difficult logistics of such a survey have been prohibitive.

However, as the discussions above demonstrate, as the scale or intensity of an operation increases, the complexity of waste management increases, and the consequences of an accident become more serious. The complexity and cost of waste management is further magnified by regional concentration of livestock when the land available for waste disposal becomes limiting.

Question # 14. What is the impact of the proliferation and concentration of large-scale confinement production facilities?

Typically, questions of management and regulation of farms have been addressed at the scale of the individual operation, but not at the community, county, or watershed level (O'Neill et al., 1986). Short-term and long-term effects-that is, temporal scale-should also be considered.

At the scale of the individual operation, the environmental effects of large hog confinement production facilities, or any livestock facilities, depend upon the design, maintenance and day-to-day operations; and the storage, treatment and distribution of wastes (manure, urine, carcasses, water used to flush the system). The effects also depend on local soils, underlying geology, groundwater patterns, and climate of the region in which the facility operates. At larger, regional scales, the environmental effects of the proliferation of hog confinements depend more on the net nutrient and carbon balance for the region, regardless of how well individual operations are managed. An excess of nutrients entering the region in the form of fertilizer and feed, over those exiting the region in the form of feed, meat or other products, regardless of the size of individual operations, will place stress on the ecosystem. This large-scale effect has already occurred in the Netherlands where livestock densities are among the highest in the world, and 80 percent of the feed is imported (Vos and Opdam 1993). As stated above, about one million hectares of land in the Netherlands is saturated with phosphorus, and livestock wastes must now be trucked long distances to avoid further phosphorus pollution (Reijerink and Breeuwsma 1992; Vos and Zonneveld 1993).

CONCLUSIONS

1. There is a surprising lack of population/field survey data on actual performance, e.g., water use, lagoon performance, pit performance, field application of waste, stream and groundwater quality, of swine facilities in contrast to the large amount of information about how they are designed. Anecdotal information about individual farmers, corporations, or facilities is the rule rather than the exception.

2. Where facilities have become larger, livestock have become more concentrated, and management of nutrients from livestock waste has become more complex. At some undefined loading rate, the local ecosystem can handle leakage, accidents, etc., but as the loading rate increases, the ecosystem's capacity to absorb pollution without serious damage is surpassed. This scale has not been determined in any systematic way for any region.

3. There are several unknown but potentially devastating risks associated with human pathogens and antibiotic resistant organisms in swine waste that we currently lack the techniques to assess.

4. Several known, foreseeable problems associated with long-term, high density livestock systems, such as atmospheric deposition of nitrogen and accumulation of heavy metals and phosphorus in soils, have received little attention in this country even though their causes and consequences are well understood.

5. The ratio of animals to land on which their manure can be applied is the ecological bottom line. If the ratio in a region is too high for any given nutrient (N, P, K) then there will be no way of preventing waste management problems, only methods of coping with them. This problem cannot be addressed only at the level of the individual operation, but rather must be addressed regionally. Regulations and standards that have traditionally focused on the individual producer will increasingly need to be rewritten to keep in mind region-wide patterns and the burdens they place on the regional ecosystem.

6. A common assertion made by promoters of large-scale hog confinements, among others, is that industrialization in the hog industry is "inevitable," due solely to economic forces. The implication is that all research should focus on solving the problems of large-scale operations. This widely accepted point of view encourages an unhealthy, uniform research agenda. Specifically, it leads to accommodation and management of the intrinsic problems of industrial livestock production, while

several legitimate research areas remain unexplored. As the above conclusions demonstrate, many problems with large-scale and/or concentrated livestock production are intrinsic and therefore cannot be "solved" in any normal sense; only partially mitigated at some cost. Meanwhile, other important and relevant avenues of research – including the development of alternative methods of livestock and feed production – do not receive adequate funding or sufficient attention from a diverse array of talented scientists.

A major risk of restricting research and research dollars in this way is that the full consequences of land use choices, including the opportunity costs of going one direction and abandoning another, are not made explicit. Researching only industrial livestock production is like offering society the choice of apples or nothing, instead of offering apples, oranges, and bananas, or some combination of the three. Experience with concentrated livestock production has shown that associated environmental degradation can have extremely long-term effects on the resilience and productivity of agricultural ecosystems and the health of human populations (Vos and Zonneveld 1993). Therefore we need to adopt a conservative approach and fully explore all options.

SUMMARY OF RESEARCH NEEDS

1. Based on the questions posed to us by rural citizens, the most pressing need is for local and regional surveys of actual confinement facilities, the performance of their pits and lagoons, their land use practices, waste disposal methods, ammonia emissions and atmospheric deposition, and the chemical, physical and biological integrity of surface and ground waters that they can potentially impact. It is not sufficient to base answers to citizens' questions on theoretical ranges based on state regulations, engineering specifications and waste management plans, because as the saying goes, "the road to hell is paved with good intentions." Studies should focus on the

performance of hog confinements, using stratified random sampling of facilities over a comprehensive range of operation types and sizes.

2. Our knowledge of the performance of conventional livestock production methods is also lacking. Non-point and point source pollution from agriculture is widespread (Iowa Department of Natural Resources 1994) and most of this is from small-scale operations. Attention to large-scale operations, while easier because the production facilities are more obvious and controversial, should be accompanied by a renewed look at conventional or medium- to small-sized operations, which still account for the majority of production systems in Iowa.
3. Direct measure should be made of phosphorus, potassium, copper, zinc and other feed additives in lagoon waste, sludge, and soils where waste is routinely spread. Methods of predicting and assessing long-term accumulation of these elements should be developed, and such estimates should be included in waste management planning.
4. The amount of atmospheric dry and wet deposition of nitrogen compounds should be measured around sources of ammonia release such as lagoons and fields spread with animal waste. Natural areas close to and far from sources of ammonia release should be monitored over the long term for changes in their nitrogen budgets and species composition.
5. It would be useful to develop regional, spatially explicit models of nutrient imports and exports, including fertilizer, crop, soil, livestock, and manure pools, imports from fertilizer, feed, animals etc., and losses to ground and surface water, the atmosphere, and other regions (via export of feed or animals). Such models could be used to simulate proposed or predicted changes in the density and distribution of livestock production on a scale relevant to the functioning of regional ecosystems. Alternative trends could also be modeled: dispersal of livestock onto more farms, diversification of crops and livestock, spatially closer links between nutrients, feed, and livestock; and increased reliance on endogenous (on farm, as opposed to purchased off farm) sources of

nutrients (biological nitrogen fixation, more efficient nutrient cycling, mycorrhizal enhancement of phosphorus uptake[3]) for crop production. These models could also be tied to information on surface waters, geology, groundwater systems, and drinking water supplies to assist in predicting impacts of accidents on particular human populations. An overall ecosystem management approach to agricultural landscapes will require these models.

6. The burden of excess animal waste in a region could be relieved by developing alternative methods to handle and process the animal wastes to create economically transportable forms. The regional/transregional nutrient imbalance could be lessened if wastes could be transported back to feed production areas, or at least used to replace purchased fertilizer in the region. The nutrient imbalance created by the extreme concentration of animals, with current, local disposal of wastes, cannot be sustained without serious environmental damage.
7. Continued research is needed on human pathogen transmission from field application of animal wastes and transfer of antibiotic resistance. The spread of strains of common bacteria, whether or not they are pathogenic, which posses broad-spectrum resistance to antibiotics, is a potentially serious effect of swine confinement proliferation that deserves close monitoring and intensive study.
8. If market mechanisms could reward farmers who practiced more environmentally responsible forms of crop and livestock production, much environmental damage and expensive government regulation could be avoided. Economic research should focus on ways that this could be accomplished.

[3] Infection of the roots of crop plants by specialized fungi creates a mycorrhizal association in which fungus provides the plant with more phosphorus than would normally be available under low phosphorus conditions.

9. Currently, ecosystems are being “managed” by default, by a social, political, and economic system which is largely unaware of ecosystem constraints or consequences. Increasingly, other sectors of the economy, e.g., timber and fisheries, are beginning to realize the value of ecosystem services and the prudence of managing whole ecosystems, rather than individual resources. Social and economic research in agriculture could benefit from the “ecosystem management” philosophy now embraced by the U.S. Forest Service and other federal agencies.

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Question #1. What is known about the content of air surrounding swine confinement production facilities?

Shortly after confinement swine production became popular in the mid- to late-1960s, researchers began to identify gases present in swine confinement buildings. Merkel et al. (1969) published an early list of contents by selectively absorbing airborne components in an enriching solution then subjecting that enriched sample to chromatographic analysis. O'Neill and Phillips (1992) identified over 160 compounds. They pointed out that many identified compounds have detectable odors at extremely low concentrations in the air e.g., less than one part per billion, so low that individual compounds are difficult to measure with any degree of confidence. Specific compounds and classes of compounds identified include: mercaptans, sulfides, disulfides, ammonia, amines, organic acids, phenols, alcohols, ketones, indole, and skatole. These compounds arise from the aerobic and anaerobic decomposition of swine wastes.

All of these compounds, and many others, are present in an environment in which pigs are living and where humans are working. The biological breakdown of complex molecules such as proteins, starches and other complex carbohydrates into final products like carbon dioxide, ammonia, and water involves several intermediate steps. Each of these steps allows time for a particular compound to be emitted within the surrounding air. Some of the compounds will vaporize and therefore be detectable with careful sampling.

The air surrounding swine confinement production facilities contains odors, gases, and airborne particles carried from the buildings by ventilated air. Odors emitted from confined swine facilities are primarily derived from the anaerobic decomposition of protein waste material, including feces, urine, skin cells, hair, feed and possibly bedding. Odors are derived from a large number of volatile organic compounds. Although there are a large number of gases, the principle gases generated from pig production include ammonia, carbon dioxide, hydrogen sulfide and methane. Airborne particles make up an organic dust, which includes endotoxin, possible steroids, and gases adsorbed to the particles. This particulate matter is generated from feed, the pigs, feces, and building materials.

Dust particles varying in size from less than 1 micron to 100 microns may be measured in emissions from swine confinement facilities. These may be measured as Total Suspended Particles (Particle Counting), or as weight of dust per volume of air (mass sampling). At least 50 percent of dust emissions are believed to be respirable (less than 10 microns). Odor and endotoxins can bond to these particles, but little is known about their fate and dispersion patterns. Climatic conditions e.g., wind speed, atmospheric stability may determine dispersion patterns of particulates relative to gaseous emissions.

Question # 2. What are the primary odorous substances and what are their sources?

There is no single compound or small group of compounds responsible for the odor from decomposing swine manure in a building or in a storage tank. However, observations suggest that odor is typically associated with ammonia, hydrogen sulfide and heavier compounds, perhaps indole and skatole. Quantitative measurements, however, show that under conditions when an observer detects odor suggesting the presence of ammonia, the concentration of ammonia measured in the air is significantly less than the published odor threshold (Riskowski et al. 1991). This is similarly true for hydrogen sulfide and other typical odorants.

The answer seems to be that swine manure odor consists of a complex mixture of organic compounds. The measurement of easily quantified constituents will not adequately explain odor. This suggests that other chemicals interact with more common odorous compounds in contributing to odor. Consequently, amines, mercaptans, organic acids, as well as indole and skatole are likely primary odorous substances.

The production of these compounds occurs primarily from the anaerobic decomposition of manure. The expected biochemical breakdown of complex proteins and carbohydrates in pig feed indicates these compounds will be formed either as intermediates or as secondary products in the breakdown process. The formation of these materials in an aqueous solution provides them an opportunity to volatilize prior to further decomposition. The environment under which volatilization occurs will influence the mixture of compounds in the air. In a similar manner, the mixture of compounds present in manure will influence the decomposition process and resulting odor.

There are other possible odor sources as well. If dead animals are allowed to remain on the property without proper handling, they will contribute to odor. If wet feed is allowed to decompose on site, it too will influence odor.

Anaerobic lagoons are commonly used to treat swine manure from large scale confinement units, especially in warm climates. They operate with minimum management attention, are inexpensive to construct, and provide storage as well as treatment. Unfortunately, they also release odors from the surface. The compounds are largely the same as listed above. As lagoons increase in surface area the quantity of anaerobic liquid exposed to the atmosphere increases. As a result, odors are detectable over a larger downwind area and at larger concentrations than among smaller lagoons. Piggery wastes are made up of approximately 150 volatile compounds, most of which are presumed to be products of anaerobic microbial degradation of waste constituents (Spoelstra 1980). Spoelstra details the different components identified in piggery air by different scientists. This summary shows that largely the same constituents identified in the air are in the mixed waste. This confirms the general assumption that offensive odors emitted from piggeries originate from the waste. The conversion of feed to waste is described by Spoelstra as occurring in two stages:

> the passage through the animal giving urine and feces; and the anaerobic degradation of the mixture of feces and urine during storage. During storage many constituents are transformed by microbial activity. Examples of such conversions are the hydrolysis of urea to ammonia and carbon dioxide and the reduction of sulphate to hydrogen sulphide (Spoelstra 1980).

O'Neill and Phillips (1992) identify 168 volatile compounds in livestock wastes. Indole, *p*-cresol, phenol, skatol, diacetyl, volatile fatty acids C_2-C_5, and ammonia are suggested as the most important constituents of odor. Ritter (1989) identifies the following commonly odorous compounds as end products or intermediate products of biological reactions: volatile organic acids, alcohols, aldehydes, fixed gases, carbonyls, esters, amines, sulphides, mercaptans and nitrogen heterocycles. A list of specific compounds identified by Ritter is given in Table 1 (page 51).

Question # 3. What are the health effects of swine-related gases and odors on people, including children, living in the vicinity of swine facilities? Is there any evidence that odors may have an adverse physiological and/or psychological effect?

As a result of dispersion, the levels of swine-related gases and odors are considerably lower at neighboring receptors than inside production facilities (Gjerde et al 1991). However, reports indicate that odors may elicit nausea, vomiting and headache, cause shallow breathing and coughing; upset sleep, stomach and appetite; irritate eyes, nose and throat; and disturb, annoy and depress

(Overcash et al. 1984). Some of the gases from a swine confinement building may be harmful and can cause adverse physiological responses if present in sufficiently high concentrations. Ammonia

TABLE 1

Volatile Compounds Associated with Pig Wastes

Methanol	Methanal	
Ethanol	Ethanal	Ammonia
1-Propanol	Propanal	Methylamine
2-Propanol	Butanal	Ethylamine
1-Butanol	Pentanal	Trimethylamine
2-Butanol	Hexanal	Triethylamine
2-Methyl-1-propanol	Heptanal	
3-Methyl-1-butanol	Octanal	
2-Ethoxy-1-propanol	Decanal	
2-Methyl-2-pentanol	2-Methyl-1-propanal	
2,3-Butanediol	Ethylacetate	
	Methanaoic acid	Carbonsulphide
	Ethanaoic acid	Hydrogen sulphide
3-Hydroxy-2-butanone	Propanoic acid	Methanethiol
Propanone	Butanoic acid	Dimethylsulphide
2-Butanone	2-Methylpropanoic acid	Dimethyldisulphide
3-Pentanone	Pentanoic acid	Dimethyltrisulphide
Cyclopentane	3-Methylbutanoic acid	Diethyldisulphide
1-Octanone	Hexanoic acid	Propanethiol
2,3-Butanidione	4-Methylpentanoic acid	Butanethiol
	Heptanoic acid	Dipropldisulphide
	Octanoic acid	2-Methylthiophene
Phenol	Nonanoic acid	Propylprop-1-enyldisulphide
4-Methylphenol	Phenylacetic acid	2,4-Dimethylthiophene
4-Ethylphenol	2-Phenylpropanoic acid	2-Methylfuran
Toluene		
Xylene		
Indone		
Benzaldehyde		
Benzanoic acid		
Methylphthalene		
Indole		
Skatole		
Acetphenone		
o-Aminoacetophenone		
Aneline		

Source: Ritter 1989

and hydrogen sulfide are two examples. Methane is explosive when mixed with air. However, the range of ambient concentrations of chemical compounds that cause odor nuisance are much lower than their respective toxic threshold values; odor is rarely associated with chemical toxicity. Agricultural odors have not caused deaths or scientifically identified physical illnesses.

Animals produce heat and water vapor which must be removed. Ventilation can control the concentration of those gases for which worker safety limits have been established. There are situations in which ventilation systems have failed or proven inadequate. Workers standing over an anaerobic manure storage tank at the time of agitation are in danger of being overcome by a sudden release of toxic or asphyxiating gases. People who enter manure storages by accident or to make repairs enter an unsafe environment. Tragic deaths have been reported that serve as a reminder that certain safety precautions are necessary to protect both animals and workers.

Health effects, including illnesses, physiological and psychological effects, if any, should be examined in light of potential exposure of workers or neighbors to emissions from swine confinement facilities or associated manure and wastewater storage, treatment, and/or land application. Exposure is a function of time and concentration. These differ drastically depending upon whether the exposure is casual e.g., passing motorist, intermittent e.g., nearby resident, or long-term e.g., swine farm manager. Health effect concerns may be categorized as human responses to instantaneous, short-term, or cumulative exposures. Responses to toxic gases in a swine confinement building are separate from the effects of odors on people who may work in a swine building or live near a facility.

We know that people can have strong emotional responses to particular odors. Ackerman's research (1992) demonstrates we have strong emotional and physiological responses to odors based in part on our previous experiences. It is clear that emotional responses are not independent of our physiological responses.

Research by Schiffman (1995) at Duke University shows that people living near intensive swine operations in North Carolina report significantly more anger, confusion, tension, depression, fatigue and less vigor than people not living near intensive swine operations, as measured by an established Profile of Mood States (POMS) assessment. In addition, persons exposed to swine farm odors have more total mood disturbances than control populations not living near intensive swine operations. The scores for six POMS factors and the Total Mood Disturbance (TMD) score were compared for 44 people living near intensive swine operations and 44 controls not living near such operations. Participants were matched by age, gender, race, and years of education. There is clear evidence that certain people have had adverse psychological reactions to the development of confinement facilities in their neighborhoods. It is also clear that some of them demonstrated physiological responses. Physiological and learned responses may have contributed to the mood alterations.

Question # 4. Is it scientifically warranted to further investigate a physiological and psychological basis for reported health problems among neighbors of large scale swine facilities?

It is always scientifically warranted to investigate the cause of reported health problems among any group of people. One response is to examine the physiological effects from odors associated with swine production in much the same way as other industries are monitored. Industrial hygiene professionals have made major contributions to society by identifying concentrations of airborne materials that are considered harmful to exposed persons.

Research Needs

Research should be pursued that concurrently examines odor concentrations using sensory odor methods (human-based) and mechanical (compound-specific) methods. This should be conducted both at the swine facility and at appropriate downwind locations, including the neighborhood residences. These studies should be coupled with meteorological observations prior to and throughout the period of research as validation of exposure.

A study such as the one above was conducted on a cattle feedlot in eastern Australia (Walsh, Lunney and Casey 1995). In this study, a group of neighbors living within a five kilometer radius of the feedlot were surveyed to calculate Odor Annoyance Indices (OAI). Concurrent measurements of odor emissions from sources within the survey area, downwind odor concentrations, and meteorological observations were taken. Researchers were able to identify an average measure of acceptable odor among neighbors of a particular feedlot. This study followed a general method set out by researchers (Koster et al. 1985; Miedema and Ham 1988; Punter et al. 1985).

Question # 5. Is there any evidence for airborne microbial, including viral, contaminants that may affect human health?

Goodrich et al. (1975) reported high numbers of colony forming units (CFU) per liter of air inside a confinement beef building, a turkey house, as well as downwind from an irrigation sprinkler. Donham (1991), Reynolds et al. (1994), and Thorne et al. (1992) have investigated swine and poultry houses, finding microbes 1000 times higher than outside measures. However, the microbes found generally are not infectious, but may induce inflammation. In their studies, the number of bacteria carried in the spray tended to decrease rapidly with distance.

A related problem was described by Kass (1975). He suggested it is more likely that problems with downwind airborne contaminants are related to allergic reactions to the inhalation of organic dusts. The antigenic material in a majority of those cases was fungal spores, but protein materials have been implicated in others. Individual responses to organic dust particles is quite variable and depends on a person's immunological reactivity. Hypersensitivity of certain individuals is frequently associated with some adverse reactions. However, many researchers have shown that workers with symptoms are not allergic, and the response is induced by the inflammatory nature of the organic dust.

Exposure to airborne particles is the most documented issue related to health and safety of workers in the swine industry. These particles, consisting of organic dust, gases and endotoxins, exist within confined swine housing in far greater concentrations than in the external environment. Respiratory disease in swine and humans develops primarily through increases in concentration of aerosolized particles (Pickrell 1990). These particles are predominantly under five microns in diameter, remain suspended in the atmosphere, and may not be visible unless associated with smoke, fume, mist, or bright sunlight. Aerosol particles may be solid or liquid and can contain microorganisms, and in some cases carry odors. Donham (1986) provides an evaluation of aerosols present in a piggery, listing a diverse mixture of substances including feed partials, pig protein (urine, dander, serum), feces, mold, pollen, grain mites, insect parts and mineral ash. Like aerosols, harmful gases are produced primarily from decomposing animal wastes, but can also be byproducts of animal respiration and faulty heating systems.

Permanent lung damage can be caused by chronic inflammatory and possibly allergic reactions when workers are exposed to organic dust. The rare allergic condition is described as Farmers Lung and manifests as an allergy to feed material (Mahon and Jackson 1995). Subsequent exposures trigger the immune system to work against inhaled foreign material, but permanent scar tissue may form within the lungs and increases with each exposure. The lungs' internal defense system may remove much of the dust before tissue damage can occur. However, the inflammatory and irritant nature of this dust can result in bronchitis and occupational asthma. Organic Dust Toxic Syndrome (ODTS) is far more common and is caused by exposure to large amounts of organic dust. Symptoms of this episodic syndrome include fever, malaise, muscle aches and pains, headaches, cough, and tightness of chest experienced four to six hours after exposure. In a scientific review of studies by Rylander et al.

(1989), findings indicate that "symptoms indicative of acute and chronic airway inflammation were widespread" and that these symptoms were more than twice as common in piggery workers than in control groups.

In a review of intensive animal environments, Pickrell (1990) concluded that swine building environments contained the highest quantities of particles and bacteria (relative to other animal environments) capable of being deposited in the deep lung. These particles consist of feed dust, skin flakes, and animal feces, and are specified by Carpenter (1986) as being less than 5 microns (capable of penetrating the lungs), 5-10 microns (reaching the lower airways), and greater than 10 microns (being deposited in the nasal passage and throat) in size. Particles smaller than 5 microns exceeded 95 percent of total materials using an optical instrument measure and 75 percent using an Andersen sampler in a finisher shed. Therefore most of these particles are capable of invading a human host via the respiratory tract. The settling rate of dust under gravity is described by Carr (1994), who points out that particles of less than 5 microns settle slowly and need only slight air movement to stay aloft. The constant turbulent conditions surrounding intensive animal production will keep these particles suspended while larger particles settle out.

Some evidence exists that some mold spores in the buildings arise from grains used as feed. This may be the result of contaminated grains imported to the feeding facility or from decaying feed in storage on site. Molds from the outdoor general environment may concentrate inside the buildings (Kiekhaefer et al. 1995). Molds can create health problems for certain people.

Research Needs

There is a need for research into the concentrations and compositions of airborne microbial, viral, dusts molds, spores and allergic air contaminants relative to odor and odorant concentrations, both in the vicinity and downwind of confinement and manure handling/treatment facilities.

Question # 6. Odor emissions are frequently correlated with ammonia and hydrogen sulfide emissions. What concerns are associated with these emissions?

Ammonia and hydrogen sulfide have frequently been measured as odor surrogates. Ammonia and hydrogen sulphide concentrations are much more easily measured than are odor emissions. Particularly in research designed to develop odor reduction devices and techniques, a low-cost and quantitative measurement is needed. Ammonia and hydrogen sulfide concentrations serve this function and are indicative of odor intensity so long as a single odor source is being considered. Another reason for interest in a relationship between trace gases and odor comes from the need to predict downwind concentrations of odor from complex sources. The use of ammonia and hydrogen sulfide concentrations in a monitoring situation has the additional benefit of allowing the researcher to gather data within an element of time averaging. When operating at the interface between odor detection and nondetection, measurements over time are required. However, Smith and Kelly (1994) have reported the difficulty in the superposition of odor measurements. Moreover, researchers and regulatory officials need to recognize that neither ammonia nor hydrogen sulfide concentrations are suitable as a regulatory standard for acceptable odor levels.

Both ammonia and hydrogen sulfide are unstable, reactive, readily-oxydizable compounds that are not expected to be persistent in ambient air above odor threshold levels at off-site locations. Emissions of ammonia and hydrogen sulfide are convenient measurements, but do not correlate well with human perception of odor. This is best assessed by human olfactory/sensory measurement methods, except under restricted conditions. There are alternate compounds that are more relevant for off-site odor and health effects. Electronic sensing is a potential tool for quickly measuring relative emissions. This is particularly true if they are coupled with other measures, including instrumental and sensory odor sampling/measurement.

The derivation of correlations between specific compounds and the concentration or characteristics of a odor has been attempted by a number of scientists (Barth et al. 1974; Pain and Misselbrook 1991; Spoelstra 1980; Williams and Evans 1981). Pain (1994) noted that while such relationships may be useful in estimating the offensiveness of an odor from a specific source, no chemical test or marker compound had been identified which is applicable to a wide range of odors.

Question # 7. What is an acceptable odor exposure level for the majority of humans?

Odor can be measured both in terms of intensity and frequency of detection. These measurements can be quantified according to accepted standards. There are also perceptions of "offensiveness." People vary in evaluating "offensiveness," which likely depends on the social dynamics of rural neighborhoods where odors occur.

In many ways, the social norms of a local community establish an acceptable odor exposure level. For example, the odor of dairy manure is acceptable where most of the landowners raise dairy cows. This system may break down when land areas are in transition. Therefore, there is no general standard for odor acceptability based solely on air measurements.

Question # 8. Is there any relationship between swine-related methane and carbon dioxide production and the greenhouse effect? Also is there any relationship between ammonia loss and acid rain?

Methane is the most abundant organic chemical in the earth's atmosphere. Its level is increasing and atmospheric concentrations have reached the highest levels in geological time. Greenhouse gases are important because they tend to absorb longer infra-red radiation. Methane is a much more potent greenhouse gas than carbon dioxide on a molecular basis (21 times) and on a mass basis (58 times). Human activity is the major source for methane in the atmosphere. Total methane production is estimated to be 354 million metric tons (USEPA 1994). This amount is best put in perspective by looking at the global output of methane production shown in Table 2 (page 60). The

U.S. is among the five largest emitting countries at 27 million metric tons per year (ibid). Of that total emission, manure-based emissions represent 2 million metric tons, or 7.4 percent.

The data in Table 2 indicate that livestock manure systems are contributing to total methane emissions. The prevalence of anaerobic manure treatment and anaerobic lagoons highlights the role of confinement livestock production as a greater source of emissions than if the same number of animals were being managed in a less intensive manner. One mediating factor is that methane production during anaerobic treatment/storage of manure is highly temperature dependent. According to Steed and Hashimoto (1994), little methane is formed when liquid temperature is less than 10 degrees centigrade. There is the possibility that global estimates for manure-related methane production are distorted because much of the anaerobic livestock manure exists in areas where temperatures inhibit methane formation for a major part of the year. The proportion of total emissions from this source is small. Consequently, efforts to reduce emissions by changing manure handling practices would be inconsequential. Many of the techniques currently being considered to respond to odor concerns will reduce methane production as well. Aerobic treatment, soil incorporation, and lagoon covering all reduce methane escape.

Ammonia, although produced during anaerobic manure decomposition, is produced in lesser quantities and is a far less important greenhouse issue than methane. In addition, there are mechanisms, such as rainfall and biochemical oxidation, whereby released ammonia is removed from the atmosphere. For these reasons, methane is the byproduct of concern for greenhouse issues.

While ammonia is not a significant factor in terms of greenhouse issues, it is a factor for acid rain. Ammonia is a reactive gas and as it diffuses upwards into the atmosphere it readily combines with acidic compounds such as hydrochloric acid, nitrous acid, and sulfuric acid, to form ammonium aerosols (ApSimon and Kruse-Plass 1991). In this form, ammonia can be transported over long distances making it a pollutant on a large scale. In recent years, it has been accepted that acid deposition of certain ammonium aerosols are potentially more acidifying for soils than strong acids

TABLE 2.

Global Anthropogenic Methane Emissions by Source for 1990

Category	Estimated Emissions Tg Methane
Livestock, ruminants	80
Rice cultivation	65
Natural gas and oil systems	51
Biomass burning	48
Liquid wastes	35
Coal fuel cycle	30
Landfills	27
Livestock manure	14
Minor industrial sources	4
Total	**354**

Source: (USEPA 1994)

such as sulfuric acid (ibid). Deposition of these aerosols has important implications for the critical loads of soil and the health of surrounding vegetation.

The penetration of ammonia into clouds has a marked effect on cloud chemistry. Research in Europe (ibid) has illustrated that the formation of very acidic clouds, which can lead to acid mists over forested hill tops causing foliage damage, is dependent on the presence of ammonia within the atmosphere. Ammonia is a very important atmospheric constituent deserving far more attention with respect to atmospheric chemistry, acidification, aerosol loadings and critical loads of nitrogen deposition.

The adverse ecological impact of ammonia emissions is currently being experienced in the United Kingdom as evidenced by the yellowing of pine tree needles and the increased susceptibility to fungi and insect attack (ApSimon and Kruse-Plass 1991; Roelofs and Houdijk 1991). Ammonia emitted from livestock operations contributes to the problem of acid precipitation and ammonia deposition contributes to excess nitrogen fertilization of natural vegetation and to the leaching of nitrates through soil (Voorburg 1991).

In Europe, agricultural activities are the dominant source of ammonia emissions. Dutch agriculture is estimated to contribute 240,000 tons per year, or 94 percent of the ammonia emitted in Holland. Fifty percent of this amount comes from the land application of manure and 40 percent from confined animal production and storage facilities (Monteny 1994). With animal agriculture being such a significant contributor to ammonia emissions in Holland, it could be concluded that the livestock industry worldwide must also make a significant contribution to ammonia emissions.

Question # 9. What data exist to indicate increased atmospheric nitrogen deposition in precipitation and dryfall?

(See response to previous question).

Prior to 1970, accumulated data indicated that nitrogen as ammonia could volatilize from cattle feedlots and be absorbed on nearby surface waters (Hutchinson and Viets 1969). This was demonstrated by measuring ammonia concentration in nearby lakes and ponds. In subsequent studies, the process was further demonstrated by placing dilute acid traps around animal manure odor sources and measuring the concentration of absorbed ammonia over time. Luebs et al. (1973) measured nitrogen absorption rates in traps located within and downwind of a concentrated dairy area in California. Nitrogen absorption in the acid traps was as high as 8.5 kg per hectare per week within the area. Eight kilometers downwind of the dairy area the absorption rate was an average of 1.4 kg per hectare per week. Anaerobic lagoons are major sources of airborne ammonia as are manure covered surfaces such as pens, feedlots and animals. The matter of ammonia release from livestock production has received limited concern in the U.S. compared to Western Europe where ammonia release from animal manure is believed to contribute to acid rain (Legg 1990).

Research Needs

Research is needed in North America to determine the extent of methane and ammonia emissions from livestock operations and assess their contribution to greenhouse gases and acid rain. Additional research is necessary to determine methods to scavenge these gases on the farm.

Question # 10. What is the impact of the proliferation and concentration of large-scale confinement production facilities on the above issues?

The structure of swine production facilities is changing worldwide, with a change from small- and medium-sized units, to large corporately owned units and multi-site production facilities. At the same time, increasing population pressure, urban sprawl, rural residential development, a declining rural population, and an increasing awareness of environmental issues and demand for a better quality of life have led to confrontation between large-scale production facilities and their surrounding communities.

It may become economically and technically possible to reasonably control odor from pig production. There are now several organizations with access to adequate funding and adequate technological expertise to respond to the need for odor elimination/control. Although research in this area has been generally underfunded over the past 20 years, several alternatives to anaerobic lagoons for lowering odor production have been documented. Despite this, anaerobic lagoons remain the primary tool in some geographic areas because of relatively low construction and operating costs.

This means that neighbors are being asked to assume a portion of the environmental costs of production.

The existence of larger integrated swine production facilities also provides an opportunity to revise design standards developed more than 20 years ago. For example, lagoon loading rates were developed to achieve a moderate level of odor in the countryside. These loading rates were published when a typical swine confinement barn contained 600 finishing hogs and the lagoon was roughly .06 hectares in area. The trend has been to use only slightly adjusted loading rates even though lagoons might be serving 10-50 times the number of animals. As the lagoon surface increases in these ratios, downwind odor concentrations may increase.

If a society plans to respond to global concerns of ammonia and methane as potential contributors to the greenhouse effect, these larger, more technologically sophisticated swine production facilities offer an opportunity to reduce the impact. Similarly, if atmospheric nitrogen deposition in rainfall and dryfall is of concern, these developments offer the opportunity to make meaningful changes in manure handling systems. In short, large-scale swine production operations may better afford odor control technologies than smaller systems. However, incentives to reach a higher level of technology effective in addressing odor and greenhouse gas emissions is not necessarily more evident in large facilities than in the small operations that hopefully will coexist.

The development of any new industrial approach to the production of a major commodity brings a degree of change. Large-scale swine production is one of those changes that has occurred in advance of the technological changes needed to support it. Similar problems occurred in the mid- to late-1960s when confinement swine production was first recognized as economically attractive. The early buildings were poorly designed and required extensive retrofitting. Pioneers who led confinement livestock production made significant contributions to providing a low-cost, high-quality food supply with minimal environmental impact. Perhaps this latest development can become a stepping stone to new opportunities. This will only occur if scientists accept a leadership role in identifying and sharing appropriate responses to new challenges. Also, policymakers must structure a functional policy that enhances appropriate research, and provides guidelines, incentives, and regulations for meeting environmental control.

Increasingly large intensive swine production operations with clustered multi-site facilities will continue to have an impact on the air quality of surrounding communities. The challenge for resource planners, impact assessors, designers and managers is to ensure the sustainable development of a viable, intensive pig production industry without compromising the quality of life for surrounding residents.

SUMMARY OF RESEARCH NEEDS

1. Examine odor concentrations using sensory odor methods (human-based) and mechanical (compound-specific) methods.
2. Research the concentrations and compositions of airborne microbial, viral, dust molds, spores and allergic air contaminants relative to odor and odorant concentrations, both in the vicinity and downwind of confinement and manure handling/treatment facilities.
3. Determine the extent of methane and ammonia emissions from livestock operations and assess their contribution to greenhouse gases and acid rain. Determine methods to scavenge these gases on the farm.

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SOCIAL ISSUES

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INTRODUCTION

Since Thomas Kuhn's seminal 1962 study of the scientific community, it has become more widely understood that the results of scientific inquiry depend on non-empirical assumptions, shaped by extra-scientific social pressures and considerations, which define relevant entities, their relations to one another, and how they are observed and measured. This is an important fact because scientific findings inform policy decisions and often parade as objective, neutral, fact-driven, observational data. Findings may be all of these, but only within the defining parameters of assumptions which are driven by the demands of the wider social milieu, hence neither neutral nor objective.

One powerful way to affect policy is to determine the assumptions of scientific work – the questions asked and the form of the answers. Because the ability to set scientific agendas, fund research, and ratify the findings which inform legislative, judicial, and administrative policy decisions confers political advantage, science has become politically important. This is further exacerbated by a polarizing political process which forces contestants into diametrically opposed camps selecting assumptions and science to fit their political goals. This process defines allies and enemies, winners and losers, but does not resolve disputes or provide neutral scientific work (Durrenberger 1992).

Since the elimination of the USDA's Bureau of Agricultural Economics nearly fifty years ago, the social consequences of agricultural change and research in U.S. agriculture have either been ignored or occupied a peripheral position relative to mainstream agricultural science (Heffernan 1986). It is not surprising that producers and rural residents are currently in the unenviable position of having minimal scientifically grounded guidance to cope with the social consequences of the proliferation of large-scale swine production facilities.

Social issues are personal, family, neighborhood, community, and group relationships, interactions, and values that influence behavior, perceptions, beliefs, quality of life, and adaptation to economic conditions in rural areas. An electronic search on "swine" at Iowa State University library reveals approximately 800 books and over five thousand journal articles on the swine industry. A review of every book title revealed not a single volume on the social dimensions of swine production. A sample of 500 journal articles revealed the same lack. Considerable information is available on the technological and production facets of swine production, but virtually nothing exists on social dimensions. Lack of research and available expertise in this area exacerbates the frustration of producers, rural community members, and production oriented researchers in dealing with non-production facets of agricultural change. This section summarizes social science research relevant for understanding and addressing the social dynamics of swine industry changes. A summary of needed research is included within each section, and a numbered synopsis of research needs is included at the end.

Question #1. ***What are the reported health and quality of life effects of swine-related gases and odors on people living in the vicinity of swine facilities? Is it scientifically warranted to further investigate a basis for reported health problems among neighbors of large-scale swine facilities?***

Question #2. ***Is there any evidence that the frequency of odor problems affects neighbors' quality of life?***

Sources of information on odor, health, and quality of life include experiential reports of people who live near swine facilities, reports of those who attempt to measure the physical or chemical dimensions of air quality, and population-based sample surveys of attitudes. The relationship of these data sources is analogous to a patient who verbally reports experiences of pain to a doctor who attempts to discover the physiological reason for the discomfort in order to alleviate it. Patient perceptions of experiences provide an important array of facts the physician uses as data. The diagnosis could be erroneous if the physician failed to take account of the patient's complaints or experiential reports.

Because the patient is the only one to experience the symptoms, we can say the reports are subjective. In scientific discourse, phenomena that are reliably measured and reported in terms of unquestioned assumptions are taken to be objective, while those that cannot are considered subjective (McNabb 1990). If a patient's symptoms fit a well known pattern of cause and effect, the diagnostician is confident that the patient reported the symptoms reliably and validly. The familiarity of the pattern to the diagnostician removes the reports from the subjective to the objective. The diagnostician who cannot place the complaints must seek additional evidence in the search for pattern (Garro 1986 and 1988; Kleinman 1980).

Judgments of factuality depend in part on the motives of the observer and the observer's employer. If observers have some interest in denying health and quality of life problems to avoid liability, they are interested in styling the reports of neighbors who describe their discomforts as subjective. Given the emphasis in the U.S. courts and legislatures on the scientific status of statements (Durrenberger 1992 and 1996), to characterize a class of phenomena as subjective is to remove them from the realm of rational discourse and thus of legitimization.

Because some feel that quantification assures validity and reliability, it is often used as the measure of scientific status for statements. A current example, which has many similarities with ongoing debates concerning the benefits and problems of large-scale swine production facilities, will show that this is not always true, especially in contentious and controversial cases.

In research conducted for the U.S. Army on environmental, health, and safety effects of chemical weapons disposal in the U.S., Liebow et. al (1995) show that the Army conceptualized chemical weapons disposal problems as solely technical, while communities saw the credibility of the Army, its past treatment of communities, the fairness and appropriateness of decision making processes, and concerns about the adequacy of safeguards and protections as inextricably linked. The different views of the definition and scope of the problem resulted in a cycle of mutual distrust and miscommunication that prevented any constructive dialogue, much less resolution. Some of these same issues are present in disputes regarding large-scale swine production.

The Army saw issues that appeared as political or personal as illegitimate. Their task was "implementing the best technical program and then communicating the results of their technical analyses to the public" (Liebow et al. 1995:12). The only issue from the Army point of view was research to demonstrate that their technical analyses were thorough and correct. They were frustrated that communities saw them as unresponsive, while residents were frustrated that the Army thought that more technical analysis would resolve community concerns.

Technical and quantitative research appears to grant approval to one "side," forcing the other to legislative, judicial, and administrative remedies, prolonging the conflict and further alienating the other. Thus, technical and quantitative research, when presented as the only pertinent information, can be more destructive than constructive, so researchers (Liebow et al. 1995) used detailed personal and group interviews to provide qualitative data on the arguments and the reasons for them from all sides. The researchers purposefully did not quantify this material because they did not want to define winners and losers, but to show everyone what all of the arguments and positions were so that each side could understand the other. The issue was understanding the "reality" and "objectivity" of community complaints. The research team needed a means to understand those realities. They could not define them away as "subjective" because they did not fit the Army's definitions of technical problems with technical solutions.

The issues surrounding community responses to large-scale swine production facilities are similar and call for the same kind of understanding. Neighbors' complaints are themselves facts. It is important to understand those facts, how they relate to one another, and how they relate to political issues. The way to do this is not only through technical research – quantification is but one means that elicits a particular form of data. At issue, rather, are the reasons and warrants behind the complaints, the reasoning involved. That can be established through listening to peoples' reasons and reasonings, and honoring them as facts instead of treating them as subjective or irrational. This is consistent with a 1985 National Science Foundation review of data quality. The validity of quantitative instruments depends on detailed qualitative understanding (McNabb 1990).

Interview data among a nonrandom sample of approximately 100 rural residents[1] in east-central North Carolina known to be experiencing problems reveals a configuration of health and quality of life problems that merit closer scrutiny (Durrenberger and Thu in press, 1994; Thu and Durrenberger 1994a and 1994b). Additional data on the psychological health effects of neighbors living in the vicinity of large operations in North Carolina (Schiffman et al. 1995), as well as community ethnographic data

[1] Interviewees included farmers, hog producers, businessmen and women, retirees, homemakers, factory workers, pastors, construction workers, mayors, and other rural residents.

from Michigan (DeLind 1995a), lend credence to this assessment. A summary of results is provided in Table 1. It should be noted that the nonrandomized nature of interview data is insufficient to label it

TABLE 1.

Summary of Social and Health Consequences

Problem	Reported Consequence
Odor	Alteration of outdoor family activities, e.g., grilling, children playing, friends visiting.
Waste runoff	Contamination of private well drinking water. Contamination of public waterways; fish kills.
Facility presence	Decline in property values, traffic problems, flies.
Concentration of production	Loss of independent hog producers because of market control.
Economic	Job loss and control of economic conditions as the result of by-passing local economic systems.
Political control	Loss of political control and sense of violation of democratic principles and channels of redress.
Loss of community values	Loss of community values of neighborliness that include reciprocity, respect, honesty, and shared identity.
Health	Headaches, cough, plugged ears, watering eyes, runny nose, scratchy throat, tiredness, shortness of breath, nausea, dizziness, and tightness of chest.

unscientific (see Hempel 1965 and Popper 1965 for a review of scientific knowledge and methodology). Rather, such data constitute evidence requiring more systematic research to provide a better framework for understanding its place. This is comparable to the scientifically necessary and responsible reporting of individual community cases of disease outbreaks in order to call attention to the need for more systematic data collection.

Residents interviewed by Thu and Durrenberger represented a spectrum of backgrounds, including African- and Euro-Americans, blue and white collar workers, farmers, wealthy property owners, businessmen and women, clergy, local and state government officials, and retired persons, among others. Interview sites included farms, rural resident homes, churches, diners and restaurants, community meeting halls, local business establishments, and other sites where residents were at ease. Data collection focused on open-ended questions that encouraged residents to tell “their stories.” Recorded narratives were then compared to distinguish common issues.

Results listed in Table 1 revealed a consistent pattern of reported quality of life problems related but not confined to odor. These concerns are intertwined with core family and community social norms that emphasized "neighborliness." A core belief in being an ideal neighbor includes behaviors and attitudes of honesty, reciprocity, respect, and sharing an identity. The emergence of large-scale swine facilities has resulted in affronts to these core values. Such affronts trigger individual and collective responses.

Reported problems can be understood as feedback signals from rural residents that something is wrong. Similar to patients who verbally report symptoms to their physicians, these data are indicators of problems that require closer scrutiny. It is important to recognize that these problems are interrelated. Isolation and treatment of each reported problem, e.g., odor, without data and understanding of its place, importance, and interrelationship in the actual daily lives of rural people results in an institutionalized and often politically volatile misunderstanding of the nature of complaints. Most people voicing concerns do so because of genuine problems, not because of politically fueled agendas or because they are anti-pork, anti-growth, or anti-development.

Consistent with case study findings in Michigan (DeLind 1995a), studies by Thu and Durrenberger show that underlying well-publicized odor issues is a more fundamental problem consisting of a pervasive frustration brought on by the lack of access to adequate means of remediation. This is also consistent with Schiffman et al.’s findings (Schiffman et al. 1995) that loss of control may be an important contributing factor in the development of psychological problems such as depression, anger, and tension among neighbors living in the vicinity of swine production facilities.

Survey evidence concerning the experiences of farm operators relative to livestock operations provides producer perspectives on industry change. In 1992 and 1995, the Iowa Farm and Rural Life Poll asked active farm operators in Iowa about their experiences as swine producers and as residents living near swine operations. For the past 14 years, the Poll has utilized an annual mail-out questionnaire to a statewide random sample of active farm operators. The sample has been representative of Iowa's active farmers when compared with demographic variables of the Federal Agricultural Census. In 1992, 2,370 active farmers returned the mailed questionnaire for a response rate of 66 percent. In 1995, 2,190 active farmers, or 63 percent of those polled, constituted the statewide sample.

Among farmers with livestock enterprises in the 1995 survey (1,380), 82 percent (1,132) said their livestock operation was within a half mile of a neighbor's residence. Only 4 percent, or 57 producers, said they had ever received a complaint from neighbors because of odor, noise, or flies sometime in the past. This is virtually identical to the 4 percent, or 66 out of 1,576 livestock producers, who reported ever having received complaints in 1992. Only 12 producers (less than 1 percent) in the 1995 survey indicated they had received a complaint in the past year.

Farmers were also asked about the distance between their residence and the closest livestock facility (other than their own) and whether its presence diminished their quality of life. Nearly three-fourths (72 percent) reported a facility within a half mile. Two percent of farmers indicated a neighbor's facility detracted from their quality of life "a great deal," while 21 percent indicated it detracted "some." Of those who indicated their quality of life was diminished, odor was the major concern (93 percent). Other concerns were flies (41 percent), manure run-off (27 percent), noise (14 percent), and dust (10 percent). A close (linear) relationship was found between the percentage of respondents reporting a diminished quality life and distance to a neighbor's closest livestock facility. Among those farmers living within a quarter mile from a facility, 25 percent indicated a diminished quality of life. This percentage fell to 15 percent for those living between a half and one mile, and to 9 percent for those living more than two miles from a facility.

Farmers were asked how many days per year they would be willing to tolerate odors from their neighbor's livestock operation before they would consider it a major nuisance. On average, respondents with no livestock enterprise indicated 41 days, compared to 57 days for those with livestock operations. Comparing the 1995 findings with those from 1992 provides evidence of decreasing tolerance. In 1992, 12 percent of producers indicated a tolerance of no more than two days. In 1995, this figure grew to 20 percent.

Attitude questions related to odor and quality of life were included as part of the 1995 questionnaire. Farmers indicated the need for both personal tolerance and producer responsibility. For example, 88 percent either "somewhat" or "strongly agreed" that "if people choose to live in the country, then they should be willing to accept the presence of livestock." Similarly, 83 percent indicated, "I don't care whether my neighbor raises livestock, as long as this doesn't affect my quality of life." By a somewhat smaller percentage (76 percent), farmers agreed that "most livestock producers do a good job of controlling odors and noises from their livestock operations." Differences in attitudes between livestock producers and other farmers were inconsequential.

Farmers were more divided, however, on acceptance of large livestock operations near their residences. When asked if such sitings would be all right if they were guaranteed that property values would not decline, 55 percent answered affirmatively, 30 percent negatively, and 15 percent were uncertain. Under the contingency that owners would be compensated for any damages resulting from such conditions as odor, nuisance or lowering the groundwater, 52 percent indicated a livestock operation would be acceptable near their residence while 30 percent disagreed; 17 percent were undecided. Again, differences between livestock producers and those with no livestock were minimal.

These findings show that the presence of livestock operations receive farmers' attention, but do not presently reflect major problems. However, the possible arrival of new large-scale operations meets with considerable division of attitudes among Iowa farmers.

Research Needs

From a social scientific vantage point, it is scientifically warranted and necessary to investigate the nature of social and health problems linked to large-scale swine production facilities. It is strongly suspected that the physical and/or clinical basis of reported odor problems is closely linked to social factors. Interdisciplinary research is required to unveil the interconnections between social, physical and other factors. Failure to do so reflects and exacerbates the disjuncture between realities created by institutional researchers and the actual nature of rural residents' daily lives.

Question #3. What evidence exists in the following areas to indicate large-scale swine production facilities influence quality of life?

A. Access to political channels to redress problems.

The highly charged political nature of current swine industry research has resulted in significant reluctance among scholars to focus on political issues as an explicit domain of inquiry. This occurs despite the fact that political processes are central to agricultural change and rural response (Adams 1994; Donham and Thu 1993; Goldschmidt 1978; Thu in press, 1995/96, and 1992; Wells 1983). Reluctance among scientists to focus on current political issues in the swine industry reflects a lack of scientific independence from political and special interest influence (Busch and Lacy 1983; Hightower 1973; Lacy 1993). Political involvement in scientific research influences the nature of information provided rural communities (Dahlberg 1986), and feeds a concern among many farmers and other rural residents that they lack independent political and legal channels to redress their concerns.

Some evidence exists to support the claim that local residents are disadvantaged when they seek to redress problems emanating from the operation of large-scale swine production facilities in their communities. This evidence typically comes from individual case studies, industry exposés and investigative newspaper reports (Cecelski and Kerr 1992; Christopher 1994; DeLind 1995a and 1995b; Flansburg 1995; Stith and Warrick 1995; Thu 1995/96; Thu and Durrenberger 1994a; Wagner et al. 1994). There is a need for a more systematic documentation, possibly on a state-by-state basis, of the existing channels of redress and their actual availability and use by a concerned citizenry. Here we highlight examples from Iowa and North Carolina of how political influence shapes rural responses to the encroachment of large-scale swine facilities.

North Carolina

The largest hog producer in the United States is Wendell Murphy, Chairman of Murphy Family Farms. Wendell Murphy is a former state senator and member of the senate agricultural committee in North Carolina. While in the state General Assembly, he played a key role in sponsoring and supporting a series of laws favoring his hog production facilities (see Table 2, page 80).

Despite local pressure, County Commissioners in North Carolina have been reluctant to battle the state because zoning laws designate large-scale facilities as "farming" rather than industrial and exclude them from local control. This law was co-sponsored by Wendell Murphy and passed the state legislature in 1991. Counties are further reluctant to impose local control because of the high cost of litigation and the financial powers they would face. Rural residents have organized various resistance organizations and have vehemently complained to County Commissioners. However, limited county authority fuels frustration among rural residents and county governments alike in being unable to provide a local political avenue for dispute resolution. Consequently, the judicial system has been utilized to seek resolution.

TABLE 2.

Examples of Political Influence in North Carolina

Date	General Assembly Bill	Purpose
7/11/86	Sales Tax Exemption (S488)	Exempts materials used for repairing or improving livestock structures from sales tax.
7/5/88	Inspection Fee Exemption (H519)	Exempts hog corporations from state inspection fees on hog feed.
5/6/91	Zoning Exemption (S148)	Includes corporate hog production facilities within the definition of "farm" to preclude counties from local control.
6/26/91	Exclusion of Hog Facilities From Tighter State Environmental Regulations (S386)	Exempts hog facilities from tighter state regulations that resulted from the repeal of the state Hardison amendments.
7/9/91	Lobbying Money (S669)	Provides hog levy money to be used for political purposes prohibited for federal checkoff money.

A measure of the extent of government influence can be gleaned from communication records between Murphy Farms and state government. Publicly available records indicate that persons in North Carolina's state government placed a total of 4,659 telephone calls to Murphy Farms and its personnel in the two years between September, 1992, and August, 1994. Supposing a working year has 50 weeks of 5 days each, these two years would be a total of 500 working days. The average is 9.3 calls per day from North Carolina's state government to Murphy Farms, or an average of 1.16 calls per working hour. The governor's office made 91 of the calls, an average of nearly one (.91) call per week. During the same time, there were 206 calls from legislators, an average of .5 calls per hour, or one call per two working hours of these two years.

Other dimensions of political influence are evident as well. For example, the North Carolina Pork Producers Association Political Action Committee's report of receipts and disbursements filed on April 17, 1994, reveals that for the Primary Election of March 3, 1994, the Committee contributed to 122 candidates – 12 for the U.S. House of Representatives; 31 for the North Carolina Senate; 75 for the North Carolina House of Representatives; and 4 for county commissioners. The evidence from North Carolina suggests that perceptions of strong connections between industrial swine production interests and state government have merit and foundation.

Iowa

In early spring of 1994, a few local farmers in north-central Iowa organized area farmers, rural residents, and local community members into a group called the Organization for Protection of the Environment (OPE) to protest the influx of large-scale hog production facilities. Approximately three weeks after the group was first organized, a meeting was held on a weekday evening in a high school gymnasium at the county seat to discuss issues and problems associated with intensive swine production facilities. Unexpectedly, over 600 people turned out, including a large number of independent pork producers, packing the gymnasium bleachers. Concerns expressed included potential environmental problems from animal waste, social and quality of life consequences, and the economic impact for existing independent hog producers.

In April of 1994, as a result of OPE's meeting and other activities, a representative of OPE was selected to serve on a state Livestock Task Force formed to investigate problems emerging from the proliferation and concentration of large-scale swine facilities. The purpose of the group was to:

> ...gather facts related to several environmental issues of livestock production, including nutrient management, facility location, design. This includes nutrient application to soils of the state. The committee will also serve as a sounding board for Iowans interested in these topics to present additional information or questions. After collecting good solid facts and public opinion, the members of this committee will develop recommendations on how the state should proceed in addressing these concerns (Office of the Governor, April 4, 1994).

In outlining the scope of the Task Force, social and economic concerns expressed by OPE and a large population of farmers in the state (Lasley 1992 and 1995) were largely ignored. In an interview on Iowa Public Television aired after the Task Force had completed its public hearings and background work (October 30, 1994), the Task Force leader reflected that they should have looked more broadly at the interrelationship between economic and environmental issues.

The Task Force included 21 members, with 9 members from farm organizations and commodity groups (including 2 from the Iowa Pork Producers Association), 2 bankers, 6 state government representatives, 2 university representatives, 1 environmental group, and the representative from OPE. The Task Force was charged with holding 5 to 10 public hearings around the state, conducting “research” on these concerns and suggestions, and developing recommendations to the Governor and the state legislature. However, according to OPE’s representative, the vast majority of problems experienced by the citizens of north-central Iowa went unattended to because of the political composition of the Task Force.

Similar to North Carolina, the direct channeling of campaign support and PAC funds from large-scale swine producers to political leaders has occurred in Iowa. One of the top 10 financial contributors to the Iowa Governor's successful 1995 reelection campaign is one of the largest swine producers in the country (Thu 1995/96). In addition, a number of Iowa legislators returned PAC funds from large-scale swine producers at the beginning of the 1996 legislative session, citing the need to remain independent, while others accepted the contributions (Wagner et al. 1996). Clearly, there have been attempts by large-scale producers in Iowa to influence the political process.

Based on existing data, several patterns emerge. First, the siting and construction of intensive swine facilities frequently occurs without widespread public knowledge or input. When distressed residents seek information and/or corrective action from their township and county officials, the latter often devalue and dismiss their concerns. Likewise, when individual concerns and complaints are taken to the state level they are regarded as being scientifically unfounded and emotional in nature. This judgment has been reinforced by the fact that state departments of agriculture and natural resources have been understaffed and cannot respond in-depth to all queries and complaints. Private citizens find that unless they make "nuisances" of themselves, e.g., dozens of phone calls, their concerns receive little official attention.

While government provides social stability, it also protects the prevailing system – the status quo. The burden of proving that existing agricultural legislation is inadequate or inadequately enforced falls to the private citizen with little experience collecting and interpreting sophisticated scientific evidence. There are problems here, not the least of which are the lack of political experience on the part of most individuals and the power inequities within the agricultural system itself. Agribusiness leaders have political contacts and access to government offices uncharacteristic of the average citizen (Cecelski and Kerr 1992; DeLind 1990; Durrenberger 1995; Krebs 1992; Stith and Warrick 1995). They also have the power to configure public debate (DeLind 1995b), and, as in the case of ex-Senator Wendell Murphy, the power to enact personally profitable legislation (Stith and Warrick 1995).

Receiving little official credibility, concerned residents form grassroots organizations for mutual support and to "fight" the offending swine facility, and the government agencies and/or legislation that enable it. The experience is typically one of mobilizing individual energies against an outside "invasion" rather than organizing proactively to develop internal capacity and a more sustainable and equitable use of community resources. Ultimately, recourse is found not in public testimony, letter writing, or appeals to legislators, but in the courts through the initiation of a lawsuit.

A second pattern that emerges concerns the practicality of seeking redress through the courts. As a solution to local conflict, a lawsuit is a formidable and expensive proposition, an avenue of redress not equally accessible to everyone. In one case, a citizen-initiated lawsuit against a large-scale swine facility was lost due not to any judicial decision, but due to limited financial resources (Durrenberger 1995). In addition, grassroots activism is predicated on volunteered time, equipment, research, and strategic planning. The protracted legal process, conflicting commitments, and associated stress can devastate local leadership and legal campaigns (Cecelski and Kerr 1992; DeLind 1994). Furthermore, a lawsuit and the ensuing court "battle" overtly polarize the local population. This is a debilitating situation within a small community, one that can generate long-term resentment and little enduring social engagement, regardless of who "wins."

Equally problematic is the fact that it is the nature of a lawsuit to repackage a controversy around a "winnable" issue; odor and water pollution are cases in point. As a result, the multiple concerns that local residents have relative to intensive swine production are reduced to a single dimension amenable to discussion in technical terms. It is possible, therefore, that winning a lawsuit can legally advance particular scientifically-sanctioned techniques and technologies while simultaneously bypassing (and further delegitimizing) the many real, though less quantifiable, concerns of local residents (DeLind 1995a).

Third, it appears, on the basis of limited data, that the public controversy surrounding large-scale swine production has resulted in an elimination of, rather than an expansion of, political channels through which citizens can voice their concerns and influence official action (DeLind 1995a; Durrenberger 1995; Thu 1995/96). In Michigan, for example, a nonpartisan environmental review board was eliminated shortly after responding to intense public testimony concerning the regulation of intensive animal agriculture (DeLind 1995a).

Research Needs

These examples clearly show the importance of political processes in shaping community responses to the influx of large-scale swine production facilities. The examples are not to be construed as representative of all cases. There are instances where communities in the Midwestern U.S. have had their concerns successfully mediated by political processes. Nonetheless, the examples clearly illustrate the centrality of researching political and legal processes to fully understand conditions within which rural communities must adapt.

B. Personal job satisfaction among new employees in swine facilities.

Perhaps the most definitive study among employees of hog enterprises was a survey of 18,000 randomly selected producers, employees and consultants sponsored by the National Pork Producers Council in late winter of 1991. The majority of employees in the study (91 percent) worked in operations producing 1,000 or more head of hogs annually, with about half on operations producing over 5,000 head annually.

The survey asked respondents about a number of factors commonly associated with job satisfaction. However, the questions more typically profiled characteristics of jobs such as salary, benefits, incentives, responsibilities, autonomy, having formal job descriptions, working hours, and career advancement, rather than the role of these factors in overall job satisfaction. Exceptions were satisfaction with the working environment and employer sensitivity to employee needs.

Most employees surveyed were satisfied with working conditions: 19 percent rated it as excellent, 58 percent good, and 3 percent poor. Evaluation of the working environment did not differ across types of position, but was more positive as salaries improved. A majority of employees (77 percent) felt their employer was sensitive to personal needs. Again, there was a positive relationship between this evaluation of employer sensitivity and salary.

The report concluded that most employees believe their wages and benefits are competitive with other job opportunities in the community and that employees feel their job provided good training to operate their own operation. Over two-thirds of the employee respondents aspired to own an operation or have a career managing a swine operation.

Among employee respondents in the study, about half (52 percent) had been with their current employer one year or less, and most worked in operations with three or fewer full-time employees. The study does not answer the question of whether this short length of tenure could signal an abnormally high employee turnover rate and therefore a concern about job satisfaction.

Research Needs

In light of recent changes in the swine industry, replication of this 1991 survey would provide important information to the industry and rural communities, especially since employment opportunity is an economic benefit often cited in support of large operations. It is not clear to what extent the study represents operations using latest industry production standards. Most respondents (64 percent) were employed in farrow-to-finish operations, and only a few (less than 4 percent) were associated with contract operations. Also, the analysis does not answer questions about whether employees from vertically integrated operations differ in job satisfaction. This is important given the growth and significance of this sector of the industry.

Another area of inquiry for future studies is occupational satisfaction of formerly independent producers who have entered into contract arrangements. Historically, a primary appeal of farming has been the independence it offers. Depending upon the contract, a measure of independence is exchanged for other considerations.

C. Sense of neighborhood identity, neighborliness, trust, and honesty.

"It's all been very secretive. We've been lied to, we've been deceived and no one's being honest with us" (June 15, 1995 Des Moines Register). This comment from an Iowa rural resident describes her view of a company that is building a five thousand to nine thousand head swine production facility near her residence. The comment encapsulates the views of many rural residents toward the encroachment of large-scale swine production facilities.

Interview data from residents in areas with the most intense growth of large-scale swine operations in North Carolina (Thu and Durrenberger 1994a), Iowa, and Missouri, clearly reflect a sense of violation of core community and neighborhood values. When asked to describe what it means to be a good neighbor, rural residents indicated it means a sense of trust, reciprocity, honesty, and an understanding that you will help in times of need. Rural residents repeatedly voiced concern that violations were occurring across virtually all of these core values (examples in Table 3 below).

TABLE 3.

Conflicts with Core Rural Values

Core Value	Meaning	Violations by Swine Production Facility
Honesty	Do not deceive neighbors.	Promises that facility will not stink are broken. Construction begins without notification.
Respect	Listen. Neighbors' concerns are significant and valid.	Complainants' concerns are labeled emotional, perceptual, and subjective. Such concerns are dismissed as unscientific and invalid.
Reciprocity	When problems arise, neighbors help each other.	Burden of problems and burden of proof concerning the validity of those problems is on the complainant. An economic and political basis of neighborhood relationships replaces the social basis.

Research Needs

Research utilizing on-site, personal interview and participant observation methods is needed to identify the personal, social, and cultural values of rural life. Comparative case control research should be conducted to examine the social cost of large-scale swine production facilities on these core rural values. An examination of the place and importance of rural cultural values relative to traditional measures of economics should be included in such research.

D. Social and ethnic divisions.

Interview data from North Carolina (Thu and Durrenberger 1994a), reflect conflicting reports of the role of ethnicity, race, or social standing in swine industry changes. A nonrandom interview sample included a cross section of rural residents, including poor, middle class, affluent, African- and Euro-Americans, and a spectrum of educational and occupational backgrounds. Questions were specifically posed concerning the purposeful exploitation of poor African-American and Euro-American communities. While several African-Americans framed swine facility siting issues in terms of environmental racism, a number of other African-Americans downplayed or dismissed race as a factor.[2] In addition, interviews among middle class and prosperous Euro-American and African-American rural residents revealed concerns similar to those from people of lower socioeconomic standing. These conflicting reports make unclear the role of ethnicity and/or socioeconomic standing. Such issues warrant further research.

E. Community social, civic, and religious activity.

The most widely known scientific approach for assessing community impacts of agricultural structure is the methodology used by Walter Goldschmidt (1978). The "Goldschmidt hypothesis" has spawned numerous scientific studies on the social impacts of farm size and other agricultural structural variables. Goldschmidt has lamented that most of those studies used secondary data, rather than generating the type of firsthand information collected in his original community based study of the influence of differing types of agriculture on the California communities of Arvin and Dinuba (presentation by Walter Goldschmidt, Iowa State University, March 1995).

A central finding of Goldschmidt's research was that measurable social problems in one community (Arvin) are directly attributable to absentee-owned large-scale agriculture in which labor

[2] It should be explicitly noted that the interviewers for this sample are white, and responses to questions of racism are sure to be influenced by ethnicity, both in terms of behaviors and the perception of persons being interviewed. However, most interviews were conducted in residents' homes or a location nearby (e.g., church or community center) which appeared to have facilitated open communication.

is largely provided by hired workers. This contrasted with another community (Dinuba) where a richer civic and social fabric were connected to farms that were smaller, more likely to be owner operated, and primarily utilized the labor of the operating family. Clearly, social class differences were much greater in Arvin than in Dinuba.

Goldschmidt's analysis of social participation shows that in both Arvin and Dinuba, farm workers tend to participate less in civic affairs than farmers and white collar workers (the exception is in church participation, where farm laborers are more active than are white collar workers). However, as measured in virtually all types of civic activity, "the participation levels for each occupational group is higher in Dinuba [family farms] than in Arvin [industrial] " (Goldschmidt 1978:363-369). In Dinuba, churches were more multi-class than in Arvin, where workers were more segregated from middle class church goers (ibid:372).

Goldschmidt's seminal scientific research identifies the following interrelated reasons for differing social quality of life between these contrasting communities.

1) Because of their socioeconomic status, farm workers do not participate much in the collective life of the community. They lack resources, have little time for civic affairs, and are likely to be socially stigmatized.

2) Greater social distances exist between workers and others in industrial agricultural community than in the community associated with independent family operators. Greater economic inequalities result in greater social separation.

Research by Martinson, et al. (1976) corroborates Goldschmidt's findings. In a study of incorporated farms in the upper Midwest, 40 percent of which had hired workers, they found that workers are more likely "to feel less powerful and more isolated than are farm owners or managers." Furthermore, in examining the mediating effects of farm size (measured by value of farm products sold), they noted that "as the size of the farm business increases, owners and managers are afforded more and more contact with other people. Conversely, the workers on those same farms probably are not afforded more contact and are not affected by the size of the farm business." These results imply that farm workers are less likely to be involved in informal social networks and community affairs than are owners and managers.

Another factor is duration of residence and worker turnover. It may be that many farm workers do not remain in the community long enough to become socially rooted. Research by Flora, et al. (1978:13) found that high gross migration rates in Kansas communities contributed to low community commitment. Goldschmidt did not attend to farm worker turnover in his research. However, he does point out that "over half the population came to Arvin in 1940 [about 5 years prior to Goldschmidt's field work] or later as against but 23 percent in Dinuba with such brief tenure" (Goldschmidt 1978:313).

Research by Mark Grey (1995) in a rural Iowa community with a meat processing plant confirms the finding that high gross labor migration contributes to community social problems. He found high labor turnover rates in an IBP plant, which precipitated high gross migration rates because other local job opportunities are not available to those who quit or are fired. The impact of two different types of meat packing organizations on social conditions is striking. The Hygrade plant, which closed at the beginning of the 1980s, was generally seen as a boon to the community. It had a high-wage structure, a stable local labor force, and contributed some $15 million annually to the local economy through its payroll. The IBP, plant which replaced it in 1982, had a payroll which grew to double that of its predecessor, but it hired few local people (avoiding them because of their union background), had a starting wage slightly over half that of Hygrade, and actively recruited immigrant newcomers to the community – Laotians, Mexican Mennonites, and more recently other Hispanics. These new community members have imposed considerable costs in education, health care, and law enforcement on the community. The negative impacts were augmented by the high turnover rates at the plant and the resultant increase in gross labor migration in and out of the community. There was an explosion of students whose native language was not English, requiring additional expenditures for English-as-a-Second Language (ESL) instruction. High employee turnover at the plant (as well as low wages and no benefits for the first six months of employment) resulted in major increases in uncompensated health care, especially at the County Hospital, and a doubling of emergency room visits in a 10-year period. In addition, there was an increase in the crime rate and a need to hire additional police force personnel.

Community research demonstrates that an agricultural laboring class is less likely to be actively involved in community affairs than are family farmers or other proprietors (where family producers are some combination of managers, workers, and usually part-owners). If agricultural laborers make up a substantial share of the local work force, there are negative implications for community life and the adequacy of community services. This lack of involvement of a particular social group and the social distance between it and the rest of the community can have a negative effect on the capacity of the community to address local issues (Flora and Flora 1993). The fewer options available to workers (the less bargaining power they have) and the more frequently labor turns over (which usually implies a high gross migration rate), the more likely the emergence of declining social conditions. The case of contract farming and community impacts is less clear. There is some evidence (Heffernan 1995) to suggest that contract growers are likely to feel powerless, although they may participate in community affairs as actively as independent family farmers.

Research Needs

1) Research is needed to examine the extent to which work force changes in the swine industry and their attendant community social consequences are comparable to research findings in meat packing firms or to intensive field-crop production as in Goldschmidt's Arvin and Dinuba study.

2) Research is needed to document the extent to which swine industry changes follow the broiler industry pattern where contract farming is dominant. Community-based research needs to assess this new labor force, including their changing economic and social status, the extent to which they are recruited locally or internationally, and its measurable impact on the community social health both for the laborers and existing community residents.

3) There is a need to replicate the research of Goldschmidt, Heffernan, and Gray in communities with different systems of hog production. Longitudinal as well as cross-sectional research is needed. The Iowa 99-community Rural Development Initiative study may provide some baseline data for subsequently comparing community services and social capital between different forms of swine production organization.

F. Sources and nature of information on events occurring in localities.

Inadequate data exist to address this question. This is an area of needed research.

G. The effects of lagoon closures on neighborhoods and communities.

There is little data available to indicate what effect lagoon closures have on the surrounding community. Large-scale confinement facilities have appeared only recently on the rural landscape. It is not known how many have been closed or abandoned after operating for several years. This may certainly become a pattern in the future and community based studies (ethnographies) are needed to provide in-depth, diachronic accounts of community life prior to, during, and in the aftermath of these controversial enterprises. In addition to giving context and meaning to local lives, such ethnographies would permit an assessment of just how closely the facility met its initial economic and environmental "promises" to the area, e.g., local employment, improved tax base, markets for local grain, lagoon clean up, restoration of waterways and farmland, and how equitably the resulting costs and benefits were distributed. According to one of the few case studies that exists, the impact of a facility/lagoon closing on the community was less overt than covert (DeLind 1995a). The local conflict and legal "battle" that surrounded the siting, operation and regulation of the facility was intense and did ultimately cause its closure. The residual anger and emotional baggage created by the struggle, however, were responsible, at least on one occasion, for dissuading a new and more community-minded owner-operator from purchasing the site. As a consequence, a state-of-the-art facility sits unused, generating no employment, paying no taxes, and quickly growing obsolete.

Research Needs

Research is needed to map lagoon closures and assess their effects on surrounding communities. Attention should be given to actual clean-up costs and the social costs to communities involved. Longitudinal community based research should be conducted to assess the social cost of internal struggle over how to approach lagoon closures and related environmental issues.

Question # 4. Have the concerns of rural residents and farmers been treated as equitably as those of large-scale producers by various academic and political authorities? Are there inequitable channels of power to redress problems?

See response to question #3.

Question # 5. Is there evidence to indicate there is inequitable access to markets, credit, and research for various size and organizations of swine production?

See response to questions #1 and #3. There is insufficient research to respond to the issue of markets and credit. This is an area of needed research.

Question # 6. Why are so many local resistance organizations emerging nationwide with the expansion of large-scale swine production?

Resistance organizations have emerged or are emerging to resist large-scale swine facilities in Iowa, North Carolina, Missouri, Kansas, Illinois, Michigan, Minnesota, Nebraska, Utah, Colorado, Ohio, and probably other states as well. Most of these are locally based organizations composed of farmers and rural residents in neighborhoods directly effected by a swine production facility in their area. While some efforts have been made to achieve more regional connections between these groups, they remain largely provincial. Members are often not otherwise politically active, nor do they appear to have particular political affiliations or agendas associated with, for example, animal rights or environmental groups. Connections to these groups do emerge after lack of cooperation is experienced from other channels.

The common denominator underlying the emergence of these local resistance organizations is a view that their rights to enjoy their property and family have been violated. Resistance organizations are formed in response as both a political strategy and as a support mechanism. While odor is a much-cited factor for the appearance of these organizations, closer scrutiny reveals that odor is only one among many interrelated issues these organizations are concerned about (Thu and Durrenberger 1994a; in press). If the odor issue were solved, resistance organizations would not disappear. The core of the problem for rural residents and resistance groups is not a single isolated issue such as odor, property values, health concerns, or water contamination. More fundamental is a sense of frustration at the lack of official respect for their problems, and the resulting skepticism that their situation will be remedied through political and/or legal channels. Currently, the experience of these organizations is that their concerns are being ignored or discounted. This has resulted in an escalating social pathology.

The anthropologist Gregory Bateson astutely described social pathologies arising from situations such as these in which the accuracy and legitimacy of personal experiences are discredited and replaced by interpretations from authorities (Bateson 1972:201-227). It is a phenomenon he called a "double bind" (ibid:26-207). The double bind refers to situations where people suffer for accurately reporting their own experiences to people who provide counterexperiential interpretations. For example, someone who suffers daily from swine related odors is told by authoritative experts that the problem is perceptual, not real; that matters of odor are subjective, not objective. Another example is farmers expressing experientially based skepticism of the local economic benefits of expanding swine production being told by authoritative experts that it really is good for them.

A continual recurrence of these discords leads to a habitual pattern of distrust and eventually the complete breakdown of communication so that fact cannot be distinguished from fiction. This appears to be what is happening in the debate over the direction of the U.S. swine industry. People want to believe authoritative voices. When this means they must disbelieve their own experience, the contradiction between authoritative representations of reality and experience is the double bind that people acutely feel.

Research Needs

Qualitative case study research is needed to examine and assess the response of authorities to complaints and concerns of rural residents. A comparative examination of rural resident and authoritative representations of problems should be conducted. The role of authoritative responses in creation of psychological stress, frustration, and sense of powerlessness should also be assessed. Channels of communication used and responses should be documented.

Question # 7. What are the short- and long-term effects of a conflict generated by siting of swine confinement production facilities in a community?

Several studies have suggested that the conflict itself may have a more enduring effect on the quality of life at the local level than the actual operation of the swine facility (DeLind 1995a and 1994; Cecelski and Kerr 1992; Durrenberger 1995). Because area residents are frequently kept uninformed about the siting of a facility and because their concerns and evidence are routinely devalued by agribusiness, researchers, community developers and local and state officials, the ensuing conflict is charged with frustration, resentment and anger. Challenges to local leadership may be successful in the short term but they can also be accompanied by a sense of conspiracy and deep disillusionment with the political process. There is a growing conviction that government selectively serves the interests of money and power and that no amount of citizen protest will affect meaningful change.

A "we vs. them" mentality produces additional paranoia and distrust both within and beyond the community. The conflict polarizes community residents and tears at the fabric of community life, transforming neighbors into enemies, severely straining friendships and family relationships. In addition, because local activism depends on the mobilization of volunteered efforts and resources, it demands an obsessive identification with "the cause." This contrasts with the purchased manpower and expertise available to large-scale swine enterprises. Not only does this obsession continue to rigidly define "sides" within a small population, but it can also result in the physical and mental exhaustion of heavily committed residents.

As a result, a court-mandated resolution, e.g., new zoning ordinances, modified manure handling practices, or the shutting down of a facility, may have a less lasting effect at the local level than the controversy itself. First, the intensity of conflict leaves behind raw resentments and emotional scars that continue to disrupt community life. Second, local energies are focused against something externally imposed, e.g., an invasion, rather than toward the building of common cause and a more self-reliant use of local resources. Finally, interviews with local activists suggest that they have grown tired and alienated by the struggle (DeLind 1994). Not only are human vitality and creativity being lost, but they are being replaced by attitudes that resonate with isolationism and extremism.

Research Needs

To provide models of constructive action, there is a need to collect examples of community struggles that have been effective in utilizing collective energies to fashion new inter- and intra-community relationships sufficient to reaffirm community identity and self-reliance.

Question # 8. What are the social impacts of having more employed people in a community in place of family farmers?

There is very little direct evidence from swine operations on this question, but there is research on the general question. Since Goldschmidt's landmark study (1978), considerable research has been conducted examining the relationship of farm size and life quality in regions of the country where family agriculture dominates and in which industrial agriculture is of little importance. In contrast, MacCannell's research (1988) included 98 industrial-farm counties in California, Arizona, Texas, and Florida.[3] Using multiple regression, MacCannell found that mean farm size (in acres), gross farm sales, as well as high levels of mechanization "significantly predict declining community conditions not merely at the local agricultural community level, but in the entire county"[4] (ibid:63). These worsening community conditions (which included such things as low median family income, high poverty rate, low retail sales, low housing quality) were exacerbated by the recruitment and attraction of minority agricultural workers (who were paid less than other workers), but, on average, farm, non-farm, and even urban people (regardless of ethnicity) in the more highly industrial-agriculture counties of the sample, experienced worse conditions than residents in counties where agriculture was less heavily dominated by industrial agriculture. These patterns were especially

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[3] The counties were selected in the following fashion: the 43 counties in the four states which ranked in the top 100 U.S. counties in farm product sales, were selected. The 83 counties in the four states with over $2,000 in farm product sales per inhabitant were added, and then 26 Texas counties which were principally grain and livestock producing counties were excluded, since those counties did not conform to the industrial-farm characterization, being more extensive in nature.

[4] The level of mean gross farm sales was positively related to population change, however.

pronounced when rural communities from which agricultural labor was drawn were compared with the nonmetropolitan population of the entire U.S. It is worth noting, however, that percent of farms with full-time hired labor was positively related to community conditions, suggesting that "this group might constitute the base for an emergent middle class in some high-agricultural-influence counties." (ibid:59).

Barnes and Blevins (1992), in a careful study of all non-metropolitan counties in the U.S., separate different factors associated with farm scale and relate them to county-level income – median family income and family poverty rate. Using multiple regression (which allows one to separate out the distinct effects of each independent or predictive variable), the authors find that scale per se is a strong positive contributor to income and a strong negative contributor to the percent of families in poverty. Furthermore, the percentage of the county's labor force which is agricultural workers, independent of the effect of other farm labor variables, also contributes positively to family income and negatively to poverty. However, certain other measures of farm labor contribute positively to poverty and negatively to median family income – percent of farms with hired labor, percent of farms with 10 or more workers, and percent of farm workers hired 150 or more days. These relationships are stronger as farming's contribution to aggregate income in the county increases. Among the three farm labor variables which signal low median incomes and high poverty rates, by far the strongest is percent of farms with 10 or more workers, followed by percent of farm workers hired 150 or more days, with percent of farms with hired labor being the weakest.

Lobao (1990), utilizing a composite index for industrial agriculture in a nationwide study, found it had little impact on life quality variables. In research utilizing the same data, Lobao and Schulman (1991) examined the same variables according to agroecological regions of the U.S., and concluded that industrial agriculture's effects varied more by region than did small-family and large family agriculture: "For example, industrialized farming may have fewer adverse impacts on well-being in the Central United States when compared to the South, because industrialized farms offer higher wages and confront a more organized and skilled work force in the former region" (ibid:596). Thus, we might expect a different relation between large confinement hog operations and local life quality in North Carolina or Virginia than in Iowa or Illinois. It would also make a big difference whether firms in the latter two states, where rural levels of education are quite high, were able to recruit workers locally or relied on immigrant workers, who, although in many cases are well educated, have few options and little bargaining power.

The following conclusions can be drawn regarding the community social impacts of a shift from a predominance of independent farm proprietors to an increased proportion of the farm labor force becoming hired workers and/or contract growers:

• Little research on the impact of changing structure of swine production exists; thus, the best that can be done is to extrapolate from well-documented patterns in other industrialized agricultural commodities.

• Scale itself may not be the key factor related to quality of life in the community or county where production is located. There is evidence that a shift to larger farms diminishes the forward and backward linkages to the local community in the industrialized agriculture counties of California, Arizona, Texas, Florida (CATF), and states in the Great Plains. Flora and Flora (1988), in a study of farming dependent counties of the Great Plains, found that counties which had retained many of their moderate-sized farms were more successful at retaining non-farm population and total population (but not farm population) than were counties which showed sharp gains in large farms. They surmised that this was due to more farmer purchases and product sales being made locally, thereby encouraging more retail trade in the counties which retained their medium-sized farmers.

• Labor force indicators of industrial agriculture affect individual/family and community quality of life in diverse ways. Within the industrial agriculture zone of CATF states, the greater the dominance of industrial agriculture in a county the more negative were indicators of family and community well-being. Studies of all non-metropolitan counties of the U.S. give mixed results, suggesting the patterns vary by region.

Existing research suggests that the life quality impacts of a shift from family swine production to large swine operations depend on a variety of factors. One factor that may be especially important is available labor and its options, which in turn is affected by the skills required, how and where workers are recruited, working conditions, availability of alternative employment, and prevailing wage rates and benefits packages. All of those variables have an impact on stability of employment, which appears to be an important prerequisite for maintaining individual and family quality of life as well as in building community.

Research Needs

Large swine operations are often a form of industrial agriculture. In areas of traditional family-farm swine production, this will involve a shift from family labor to hired labor or contract farming. In general, a predominance of farms which hire labor, particularly large amounts of labor, contributes to a decline in life quality. However, the social impacts of different kinds and aspects of industrial agriculture are sufficiently variable that one should exercise care in extrapolating from one kind to another. It is not clear whether large swine operations will be directly operated by integrators or through contracts with a large group of growers. Since longitudinal macrosocial research like that conducted by MacCannell depend on a long trajectory of experience, by the time changes have occurred there is virtually no chance of altering it. We suggest that case study research using a methodology similar to that used by Goldschmidt be conducted. Variables to be investigated should include labor patterns and scale. In addition, descriptive research on emerging organization of production patterns within the swine industry and of work place conditions would be valuable. This latter approach lends itself well to participatory collaborative research between scientists, producers, and community members (see Flora and Flora 1995). Such an effort would ensure that research, action, and perhaps even policy would be linked.

Question # 9. Have social factors been adequately attended to in local consideration of rural economic development as they relate to large-scale swine production, e.g., importation of labor and changes in class and ethnic structure, demands on health care and educational services?

See response to question 3E.

Question # 10. Are there data from the poultry industry that can be used to assess the efficacy of swine industry contracts? What data exist for the poultry industry generally to assess the future of contract swine production?

In 1968, Heffernan began conducting research on the broiler industry by interviewing all the broiler growers in Union Parish, Louisiana, the parish with the largest number of growers (Heffernan 1972). All of the poultry growers and family farmers in the initial study were interviewed again 13 years later in 1981. The contract production of broilers was new to the area in 1968, much like large-scale swine production is new in many areas today. There were four integrating firms in the parish. The perception and reality at the time was that there was competition in the industry and that the growers could switch from one firm to another, even if it was not done very often. Even though some of the broiler growers also raised cattle or other farm produce, over half referred to themselves as growers instead of farmers. All of those not raising broilers referred to those who did as growers. People in the parish recognized two distinct occupations. About 50 percent of the growers indicated contract production was the only way they could finance a production unit and 25 percent felt the contract would reduce their risk. The remaining 25 percent became growers when they no longer had access to a market (slaughtering facilities) as independent producers.

One of the major consequences of the contract system was the alienation experienced by grower/workers who felt the work they did had little meaning and was not worthwhile because they had little input or decision-making opportunity to determine how tasks might be performed. They had a sense of powerlessness and often experienced social isolation. In the 1969 study, contract growers were compared with family farmers in Union Parish and a sample of workers and managers on larger-than-family farms in the parish and two adjoining ones (Heffernan 1974). No statistical difference was found between the four categories with regard to social isolation, but there were differences with regard to powerlessness and sense of alienation. Contract growers had a greater sense of powerlessness than did either family producers or owners-operators of large farms. In addition, owner-managers had a lower sense of alienation than either family farmers or contract growers and workers.

During the 1970s, several studies assessed farmers' views of the benefits they received from farming. The findings were remarkably consistent. Farmers viewed “doing something worthwhile,” “being one’s boss and making decisions,” “a good place to raise children” and “working outdoors” as more important than “provides a good income.”

In a 1978 study (Kliebenstein et al. 1981), a sample of farmers deemed economically oriented was selected from the Missouri Mail-In-Records cooperators. Within this group farmers who received most of their farm income from cash grain sales were selected. Previous research (ibid) focusing on beef producers indicated that noneconomic factors were involved in decision-making. Interviews were conducted by an economist to ensure economic issues would be underscored. Despite this, farmers ranked income below non-economic factors such as “doing something worthwhile” as the primary benefit of farming. Since all of the respondents were family farmers, the study reinforced the importance of the wide array of nonincome benefits. This is in contrast to the descriptions of workers in poultry, pork, beef and seafood processing industries who indicate the only reason they are working is for the income.

The relationship of income and nonincome benefits of farming to agricultural structure was evident in the 1981 restudy of Union Parish (Heffernan and Jenkins 1983). All poultry growers, including husbands and wives, and farm families with at least 25 to 30 beef cows and/or all other commercial commodity producers were interviewed. In the 1981 study, “provides challenge and opportunity to be your boss” was the base assessment item. The respondents were divided into the three categories: poultry growers only, beef producers only, and both poultry and beef producers. All producers ranked “sense of security” as the most important benefit they receive from farming. This was followed closely by “good environment in which to raise children.” The third ranked benefit listed by poultry growers was “provides good income.” Beef farmers ranked good income eighth on the list of nine items. Although poultry growers ranked income benefits higher relative to the ranking provided by the beef farmers, the finding suggest that poultry growers have not given up many of the noneconomic benefits often associated with rural living and the raising of plants and animals.

In a 1982 study (ibid), respondents were asked a series of questions about their financial status. Seventy-seven percent of the poultry growers indicated their families’ financial condition had improved in the last 10 years compared to 61 percent of the beef farmers. Poultry growers were more satisfied with their families’ incomes and families’ standard of living than were beef farmers. Those doing the interviewing also indicated than on average, the appearance of the house and farmstead would suggest poultry growers had a higher level of income. This supported findings from the 1968 study which found poultry growers had a higher level of income whether using objective, subjective or observational methods of analysis. In contrast, a higher percentage of beef farmers were satisfied with opportunities for social activities outside the home, people with whom they had contact during their work, and quality of life. Respondents who produced both broilers and beef appeared to be as well off financially as the poultry growers and as satisfied as the beef farmers with the noneconomic dimensions of their life.

Four conclusions can be drawn from these studies:

1) Workers in corporate farmhand operations are much less involved in the formal and political activities of the community than are the workers in family farm operations.

2) Owner-managers in corporate farmhand operations are much more involved in the formal and political aspects of the community than workers in the family farm operation.

3) The first two conclusions clearly suggest that the corporate farmhand operation, relative to the family farm operations, begins to emphasize the two extremes with regard to community political involvement. This type of agricultural structure suggests the development of two rather distinct classes for rural Americans which undermines the traditional American ideal of equality.

4) There is little difference between workers in the corporate-integrated operation and workers in the family farm operation with regard to community involvement. In the 1968 study, the workers on corporate-farmhand operations were usually the respondents who were less involved in informal social activities, had less satisfaction with social relationships, and were less integrated into the community. Although the differences between those on family farms and broiler growers were not large in 1982, the differences were greater than they were between these two categories in 1968.

In 1968, broiler growers were concerned about the debt on their buildings and the imbalance of power between the grower and the integrating firm. With four firms operating in the parish to create competition and a relatively good wage, the growers were optimistic they could repay the loans for their buildings and equipment. Fourteen years later, only two of the 80 broiler growers were debt free. One grower had sold his dairy operation when his sons decided “to work on off-shore oil rigs” and the other grower had received a significant inheritance. Those who had initially set up for a seven to fifteen year repay period had refinanced. Over 50 percent responded that they were very concerned with their debt. Growers were reluctant to talk about their debts because they preferred not to think about it. When they did discuss it, they indicated that the integrating firm had all the power.

The major problem of the contract was that the growers' repayment schedule for their loans covered a period of years, but the contract with the integrating firm was from one batch of birds to another; a period of about six weeks. The integrating firm did not break the contracts; they simply did not need to renew them. Sometimes the integrating firms would allow the buildings to remain empty for a period of time between batches. The integrator loses little because most of their capital is in variable costs, but most of the growers' capital is in fixed costs.

By 1982, only two integrating firms remained in the parish and within a year they merged. Thus growers in the parish experienced the same limited access to markets experienced by most growers. At that time, there were about 60 firms that owned about 137 processing facilities in the U.S. They would sign contracts with growers who lived within 25 to 30 miles from the facilities. By 1982 there were few areas in the country where growers lived within 30 miles of the facilities. The growers either worked for the firm in their area or closed their buildings. The buildings were so highly specialized that there were no viable alternatives for their use.

Growers were required to meet one at a time with firm officials to sign contracts. They did not have access to any other contract and had very limited information about the market. We received reports from this area and others that if growers tried to cooperate and share information or meet to share information, their contract might not be renewed; they might be given a "poor doing bird" rating for their next batch of chickens or their chicks might receive inferior feed.

Since the last study, several court cases on misweighing feed or birds have been settled in favor of the growers. An increasing number of growers across the producing regions are joining the National Poultry Growers Association in an effort to equalize the power relationship between growers and the firms. However, growers are quick to describe the discrimination against those who have challenged the system. The major inequity continues to stem from the fact that the duration of the loans on the poultry buildings exceeds by many years the period covered by the marketing contracts. A second issue is that during the early phase of the restructuring, competition existed between firms in the geographic areas. In some areas then, as now, competition between firms can be intense. But over time, the older production areas are "sub-divided" into areas where only one company dominates. There is every reason to believe the same will occur in pork production.

Question # 11. How has and will the privatization of information affect the family farm swine producer?

Typically, information generated for production and marketing in agriculture, including the swine industry, has been available through publicly supported institutions or associations of independent producers. Government statistical reporting services, market services, and the Land Grant college research and extension activities, and the National Pork Producer's Council are examples. Often, information from these sources is dispersed both directly to farmers and indirectly through private agricultural media (magazines, newspapers, radio) and industry associated service industries (feed and pharmaceutical companies, veterinarians, and consultants). Some discussions of privatization center on reducing the role of the public sector in dispersing information, i.e. less significance for extension services. But other, perhaps more speculative discussions, center on changes in generation of and access to new knowledge. These discussions point to the shift in the sources for new knowledge and the proprietary rights of privately funded research findings. One concern is that the cost of contemporary research may outstrip the public willingness to invest. Increased research investment by private firms contributes to the fear that products of proprietary investment will not be size neutral or equally accessible to all producers.

Privatization of information also relates to the restructuring of market information and market access. If changes in the swine industry should happen to follow the poultry industry, the fear is that open markets might disappear, and independent producers would be become residual suppliers. In that context, reported market information would become meaningless because it would not take into account the bulk of pork production. Presently, there is little research on the effects, if any, on the privatization of information and whether it has placed independent producers at a disadvantage.

Research Needs

Research is needed on the production of knowledge related to the swine industry. The role of public versus private research is changing and the potential exists for proprietary rights to information to assume greater significance, especially in the areas of genetics, nutrition, and health.

DISCUSSION

The social consequences of large-scale swine production may be treated as externalities within dominant paradigms of agricultural research, but they are the realities of life for most rural residents. Because social consequences are often negative, many researchers and industry representatives prefer to ignore or dismiss them. The social consequences *are* often negative, not because of researcher biases, but because such issues have been left untreated by most agricultural researchers, industry planners, and policy makers.

The swine industry is an important part of the U.S. agricultural economy and a critical part of the farm economy in Iowa and other Midwestern states. However, as recent events amply demonstrate, an economy does not exist in a social vacuum. If agricultural research and the swine industry does not acknowledge, understand, and embrace social agricultural research, then problems will persist and researchers will continue to be seen as working against each other. However, if social impact assessments become components of swine industry change, and social factors are seriously considered, then social scientists can provide critical information to nurture a truly thriving swine industry and reduce the social consequences and costs of widespread conflict.

We should recognize that local questions and complaints against large-scale swine production facilities actually represent healthy feedback signals. They represent a call for closer scrutiny and understanding, without which we would not be able to make corrections before unalterable pathologies develop. The sustainability of the system requires scientists, policy makers, and industry leaders to recognize that such signals represent a wide range of valid concerns that can help identify common interests and develop alternatives that work for everyone.

SUMMARY OF RESEARCH NEEDS

1. Investigate the nature of social and health problems linked to large-scale swine production facilities.
2. Research political and legal processes to fully understand conditions within which rural communities must adapt.
3. Conduct survey of employees in hog operations to provide comparative information on job satisfaction between different forms of swine production.
4. Research the personal, social, and cultural values of rural life, utilizing on-site, personal interview and participant observation methods. Conduct comparative case control research to examine the social cost of large-scale swine production facilities on these core rural values.
5. Examine the extent to which work force changes in the swine industry and their attendant community social consequences are comparable to research findings in meat packing firms or to intensive field-crop production.
6. Document the extent to which swine industry changes follow the broiler industry pattern.

7. Replicate the research of Goldschmidt, Heffernan, and Gray in communities with different systems of hog production. Longitudinal as well as cross-sectional research is needed.
8. Research sources and nature of information on events occurring in localities.
9. Map lagoon closures and assess effects on surrounding communities. Conduct longitudinal community-based research to assess the social cost of internal struggle over how to approach lagoon closures and related environmental issues.
10. Research whether there is inequitable access to markets, credit, and research for various sizes and organizations of swine production.
11. Examine and assess the response of authorities to complaints and concerns of rural residents.
12. Provide models of constructive action by collecting examples of community struggles that have been effective in utilizing collective energies to fashion new inter- and intra-community relationships sufficient to reaffirm community identity and self-reliance.
13. Conduct case study research to document organization of production forms in the swine industry, with particular attention to labor patterns, and their impact on rural social health.
14. Research the role and impact of private versus public knowledge production in the swine industry.

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ECONOMIC DEVELOPMENT

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INTRODUCTION

There have always been competing visions for agriculture. Dating back to the nation's settlement period, consensus on major policies has never existed on the desired or preferred structure and organization of agriculture. Much of the debate has resulted from disagreement over what types of farms would produce the greatest amount of benefit and who the beneficiaries of agricultural development should be. Many of the questions posed to the economic development panel reflect the historical debates over the goals and vision of farming and the methods to achieve those goals. What likely has changed is the widening gulf between advocates of competing farming systems. On the one hand, advocates of small-scale or family farms argue that current trends in swine production are harmful to rural communities, while advocates of large-scale units argue that society benefits by increased pork output and lower consumer prices. It appears that there is little middle ground between the two dominant views of farming that, for convenience, we refer to as industrial versus sustainable farming. This tension often places researchers and extension staff in the difficult position of being viewed as either friend or foe of a particular farm type.

Agriculture is in the midst of a paradigm shift, and it is the ambiguity between traditional industrial agriculture and an emerging new paradigm that we have labeled “post-industrial agriculture.” Many of the tenets of a post-industrial agriculture are congruent with sustainable agriculture. Perhaps a better description of modern agriculture is that multiple models exist, and much of the controversy over changes in livestock is the lack of middle ground between the paradigms. Are large-scale livestock production facilities beneficial to healthy and prosperous rural communities? Are these facilities more efficient? What is the relationship between farm size and sustainability? How should efficiency be measured? Which farming system provides the most benefits to consumers? Many of the questions posed to the economic development panel reflect values and beliefs inherent in each of the two dominant and competing paradigms.

Asking the right questions is often the most difficult part of finding a solution. However, the queries often reflect the bias and values of those posing them. Inherent in several of the questions are implied issues about what these trends mean for the type of agriculture that is evolving and the yet to be discovered consequences. As the panel struggled to provide answers, it was evident that much is yet to be learned about the long-term impacts of these trends. A second frustration was the inability to synthesize the responses. The panel pondered the dilemma of focusing on specific issues at the exclusion of addressing macro-level trends. This problem is summed up by the phrase "seeing the trees rather than the forest."

Several themes emerged in the panel's deliberations that provide context for the responses to the questions:

1. Many of the questions raise doubts about the responsiveness of university researchers and extension staff to the many pressures felt by producers. Several questions implied a lack of confidence in university research and extension programs designed to serve producers. In part, the questions reflected a widening gulf (either real or perceived) between scientists and the public they

are intended to serve. In other cases, producers and scientists either assign differing priority to the issues or frame the research agenda from differing perspectives.

2. Perhaps related to the lack of confidence in university research is the lack of reliable and valid data on various farm types. The lack of good data and information on such fundamental concepts as long-term efficiency and sustainability, and the failure to have comparative longitudinal data on farms of differing sizes, makes impact statements highly subjective. Some of the data necessary to make direct comparisons are held by private interests and are not available for analyses. A central theme from the panel is the need for additional case studies of differing farming systems that would provide depth of understanding and insight that is currently lacking. While case studies would provide more detailed knowledge of how livestock fits into sustainable farming systems, comparative longitudinal studies that would permit trend analysis are also needed.

3. Given declining research and extension budgets reported from several states, it appears that more efforts should be made to involve producers in data collection and interpretation. Involving clients in the research process (participatory research) may help offset some of the losses that have resulted from declining budgets. Iowa State University and the Leopold Center for Sustainable Agriculture's collaboration with Practical Farmers of Iowa was cited as an example of an alternative model of farm level research and extension.

4. Many of the questions posed did not fall neatly within traditional disciplinary boundaries. Several of the questions reflected an ambiguity between accounting practices, economic and financial analyses, and legal dimensions. Our panel lacked an accountant and an attorney versed in agricultural issues. However, the panel recognized that many of the troubling issues combine elements from each of these disciplines. For example, conclusions on the issue of economies of scale can be highly influenced by accounting and computing methods. In reading the responses to other examples, it became apparent that more interdisciplinary efforts are needed to adequately address the questions.

5. Many of the conclusions can be influenced by the unit of analysis selected. Some issues focused on producer concerns, others on community impacts, and yet others were concerned with societal issues. For example, whether off-site environmental damages are considered in the total cost of production greatly influences statements about the full cost that consumers pay for pork. The availability of state incentives for expansion, use of tax increment financing, property tax abatements, and other tax incentives may serve to underestimate the true cost of production.

6. There is a need to differentiate between economic growth and economic development. The panel noted that there seems to be considerable misunderstanding between these concepts. Economic growth tends to focus on short-run, verifiable impacts that can be quantified or measured. Often jobs, incomes, and prices are used as indicators of economic growth. However, economic development is a broader concept of economic activity and generally focuses on long-term outcomes and products. Many of the questions reflected an interest in understanding the economic development aspects of swine expansion, but were phrased in terms of economic growth. Some might ask whether the panel was splitting hairs by inquiring into the relationship between economic growth and economic development. However, the hog industry may represent a case study of where there is substantial economic growth (jobs, payroll), yet this growth may contribute little to long-term economic development (investment, education). Some would argue that, in the extreme, one could have economic growth in livestock to the extent that it results in thwarting economic development, leading to stagnating rural conditions.

7. Throughout its deliberations, the panel was concerned with broadening traditional measures of efficiency and cost/benefits ratios to consider dimensions that have often been ignored. Externalities such as social costs, quality of life, resource depletion, and other observable costs that are difficult to measure and quantify are often left out of cost-benefit analysis. Many of the questions

reflect an interest in a holistic assessment of trends, suggesting that future analysis should be sensitive to comparisons based upon incomplete information.

8. The panel was frustrated in trying to provide succinct, cogent responses to complex issues without appearing flippant or taking sides on a particular issue. In some cases, it appears that responses were being sought to bolster existing beliefs or positions. There are numerous examples of misuse of data or using selected portions of data to substantiate existing positions. The panel struggled to provide balanced views and analysis. Where conflicting data exist, the panel attempted to note that the evidence is unclear. This workshop points out the importance of having clients involved in setting the research agenda.

There was agreement that a key factor in the future of farming, regardless of organizational structure, is the need to emphasize human capital development. Many of the identified problems are viewed as requiring major investments in human capital, regardless of whether the industry becomes further concentrated into fewer and larger units, or whether it remains a dispersed industry comprised of small to medium production units. Futurists such as Peter Drucker, Alvin Touffler, and Daniel Bell suggest that the post-industrial world, or the information age, will require more investments in human capital. In the knowledge-based era, people will become the central focus. The ability to synthesize, integrate, and develop knowledge will become increasingly important to the wise use of natural and human resources.

It is evident that more research and information is necessary to answer the questions posed. A major limitation of much social science research has been its reliance upon cross-sectional data and, where trend data are available, it tends to cover relatively short time spans. In order to answer the questions with some degree of certainty, more time-series data over longer periods will be necessary.

A final theme identified by the team is the lack of valid and reliable data on the costs and benefits of technological change. What are the appropriate measures, what should be considered, and over what time period are major limitations of existing knowledge. Many of these questions suggest the need for more longitudinal data collection and at the same time the need for more intensive case studies focusing on particular issues. The inability to generalize from existing data presents serious limitations to responses. Findings from one region or one community may not be very informative or useful for others. Contextual factors, situational differences, and diverse socioeconomic conditions across communities and regions have a major influence on the issues raised and on alternative solutions. Local property values, overall economic conditions, employment levels, alternatives for economic development, and other such factors are important dimensions that restrict generalization. These represent a unique set of characteristics for each community.

The panel recognized the urgent need to develop data sets and appropriate analytical models to answer the questions. There is a danger in waiting to get answers after no one is asking the question, or in getting answers when it is too late. Recognizing that all the information needed to fully answer the questions is not available, the panel "rolled up its sleeves" and offered its best response to the complex issues and questions posed. In several instances, the responses should be interpreted as preliminary, based upon current information.

Question #1. What evidence exists to indicate large-scale swine production operations are more efficient forms of sustainable food production? How is efficiency measured?

Central to this question is how one defines efficiency and sustainability. The typically quoted measure is a financial accounting approach that places a monetary value on resources used. These are valued at their market-based monetary cost. Monetary returns to the owner are revenues minus these accounting costs. While this measure of efficiency is important for the short-term viability of a firm, it does not account for resources external to the firm (externalities) that are used in production. To be sustainable over time, production systems must cover all costs: economic or accounting, as well as environmental and social.

Little valid data or information exists to measure the efficiency or sustainability of swine operations of differing sizes. Available public and private accounting data and economic modeling indicate that approximately 40 percent of traditional Midwest producers are competitive with large-scale production units (ISU Extension 1992,1993,1994). With corn prices where they have been in recent years, total (economic) cost for the large-scale units is approximately $36-$38 per hundredweight (Good, et al. 1995; Boehlje, et al. 1995). The top one-third of Iowa Swine Enterprise Records cooperators have costs in the $35-$36 per hundredweight range, while the average is nearly $40 per hundredweight.

One advantage often attributed to large units is reduced variability in product, productivity, and returns. By their industrialized nature, standardized facilities and production practices, and information feedback systems, large units may experience less variation in production. Research has shown traditional operations experience a great deal of performance and cost variation from year to year. Bruns et al. (1992) (also see Shaffer 1994) showed that 73 percent of Iowa farrow-to-finish producers were in the top one-third for profitability at least once in six years. The same producers were in the bottom one-third approximately the same amount of time. Langemeier and Schroeder (1993) report greater variability in cost of production between operations of the same size than between large and small producers. This greater variability may be linked to the demands on an owner/operator of the diversified farm and their personal life compared to the large specialized units with multiple employees and centralized management.

Question #2. Are there data from the poultry industry that can be used to assess the efficacy of swine industry contracts? What data exist for the poultry industry generally to assess the future of contract swine production?

Contract production in the pork industry has seen recent dramatic growth. In 1992, an estimated 15-16 percent of the U.S. domestic slaughter was from contractors in their own facilities or contract facilities (Rhodes and Grimes 1992). This compared to 11-12 percent in 1989 – a 40 percent increase. The primary reason for growers entering contract production was risk reduction. Lack of capital followed as the second reason for entering into contract production.

There are numerous types of pork production contracts, and the pork contracting industry is still young. Contracts can cut across input supply, production, and marketing agreements. To be effective, each should specify the responsibilities of each participant. For long-term effectiveness, the arrangements will need to maintain or improve the participants' competitive position. Moreover, each contract needs to be evaluated on its own merits.

While the poultry industry can be used to gain insight into potential development patterns of the swine contract industry, there are differences. First, hogs and birds are different, e.g., live birth versus hatching; individual birds have relatively little value compared to pigs. Thus, greater emphasis is placed on stockmanship or the quality of the grower in the swine industry. Second, unlike the broiler industry, the pork industry had an extensive infrastructure in place before development of the mega-operations. This will allow for more varied forms of industry adjustment to enhance competitiveness. Third, the pork industry is unlikely to see the dramatic increase in U.S. per capita consumption which has been enjoyed by the poultry industry over the past 20 years. Finally, hog producers can learn from the poultry industry, leading to a shorter learning curve and avoiding some mistakes.

A key in contract development will be the balance of power between industry participants: input supplier, grower, banker, packer, etc. Without a balance of power between sectors, those with the most bargaining power will be able to extract the most from the arrangements. A related issue is whether smaller producers can enforce compliance with a contract. Better and more public information is needed on contractual arrangements such as payment rates, payment conditions, etc. This would assist in equalizing the balance of power. In its development phase, the poultry industry had contracts which were quite favorable to the grower. The industry needed more growers. However, after the industry reached maturity, the balance of power shifted and the number of favorable contracts declined leaving many producers in precarious positions. The pork industry needs to be cognizant of these shifts. As contracting becomes more prevalent, all participants need a better understanding of contract law.

Contract production in the pork industry began initially in the southeast U.S., primarily North Carolina, and has moved in a west-northwesterly direction (Wind-Norton and Kliebenstein 1994b). The poultry industry was fully developed in the Southeast, and pork production in that region was a diversification movement. Contract hog growers also show differing patterns of other employment. A larger percent of the growers in the Southeast viewed contract production as the primary source of income. In the Midwest, most growers had sizable enterprises in addition to contracting.

Within a coordinated pork production system, contracts enhance system coordination. They can also reduce the risk of some participants. Hillburn (1993) has shown that while level of risk can vary dramatically between contracts, they tend to reduce the level of risk and expected incomes over sole proprietorships.

Question #3. What evidence exists to assess the following consequences of large-scale swine operations both in the localities where they are located and in other localities where family farm swine production is present?

A. Family-based hog producers and their markets;
B. Rural employment, including displacement, job distribution, income levels, and job security;
C. Tax bases and support for local institutions and services, e.g., schools and health care facilities;
D. Local businesses;
E. Demand on local services, e.g., schools and health care

There is a dearth of reliable and valid information on the impacts of large-scale swine operations. The most recent case study by DePietre and Watson (1994) explored the impacts of Premium Standard Farms (PSF) on the local economies of north Missouri. A review of this study by Ikerd, however, questions how many independent producers may have been displaced by the expansion of PSF.

Beyond this study, little quantified research has examined impacts specific to the swine industry. However, within rural sociology there are a number of studies that have explored the consequences of replacement of independent producers with large-scale farms. Referred to as the Goldschmidt hypothesis, there are a wealth of studies that have explored the social costs of industrial agriculture. A number of these studies have been reviewed by Lobao (1990), Buttel, et al. (1990). A review article by Lasley, et al. (1993) attempts to frame the recent controversies of sustainable versus industrial agricultural paradigms. The literature suggests that the movement towards larger scale operations poses a number of important considerations about rural quality of life and socioeconomic conditions. The most recent study in this tradition is by Durrenberger and Thu (forthcoming) and uses census data to test the relationship between large-scale hog facilities and rural socioeconomic conditions. They conclude that the number of swine producers in Iowa is more important than the number of hogs produced for rural economic health.

Research by Chism and Levins (1994) and Lawrence et al. (1994) confirm previous research that larger scale units are more likely to travel further for inputs and bypass local community suppliers. To the extent that large firms bypass local suppliers, this may have a negative impact on the number of local businesses and the economic viability of main street. Beyond the case study conducted by Chism and Levins (1994), we are unaware of any research that has explored how changes in the structure of agriculture affect the demand on local services.

Question # 4. Is there evidence to indicate a difference in the extent of local purchases between various sizes and organization of swine production?

In theory, if producer purchasing patterns are the same regardless of organizational structure or farm size, the economic impact of livestock production on rural communities would be the same. In reality, community economic impacts are directly related to factors such as purchasing and marketing patterns and location of profit centers. For example, purchasing and marketing arrangements that bypass local communities do not add economic activity for that portion of the purchase or marketing function. Moreover, profits earned by outside interests such as contractors are less likely to be retained in the community than profits earned by community residents.

A Minnesota study showed that on average about two-thirds of all farm expenses were made locally (Chism and Levins 1994). However, there was substantial variation between farms. Of the 30 farms surveyed, one purchased 92 percent of its products locally while one purchased less than one-third locally. In general, smaller farms purchased a higher percentage of goods locally than did larger farms. Local expenditures declined dramatically for livestock farms as compared to crop farms. Crop farms of all sizes tended to purchase more locally. Only 11 percent of livestock purchases, and 59 percent of purchased feed was acquired locally. Purchases of feed ingredients, antibiotics, protein, vitamins and minerals lend themselves to discount pricing from distant dealers. Thus, 41 percent was not purchased from the nearest town.

Results from a recent Iowa hog operations study (Lawrence et al. 1994) showed similar results (see Table 1 below). Smaller hog operations (those marketing less than 700 head annually) purchased 69 percent of their feed within 10 miles of the operation. This compares to 42 percent for the large operations (marketing 2,000 or more hogs per year). While the proportion of locally acquired feed was smaller for the larger-sized units, they may actually spend more money overall. An important issue is whether these trends continue as operation size increases to the 50,000 or more head marketed. To date there is little empirical evidence on firms of this size. About 11 percent of the large operations purchased feed from operations located 50 or more miles from the hog operation; for small operations this was 5 percent. Only 15 percent of the large operations purchased equipment within 10 miles of the operation, while 35 percent went 50 miles or more for

TABLE 1.
Distance from Operation for Input Purchases by Hog Operation Size

	Operation Size and Percent		
Input and Miles	**Small**	**Large**	**All**
Feed			
≤ 10	68.8	41.7	59.1
50 +	4.6	10.7	6.7
Hog Equipment			
≤ 10	42.7	14.8	30.8
50 +	2.8	34.6	16.6
Building Supplies			
≤ 10	49.1	27.6	42.5
50 +	2.7	11.5	7.2
General Supplies			
≤ 10	59.3	44.3	53.4
50 +	0	0	.3
Banking Services			
≤ 10	65.5	56.7	65.1
50 +	0	0	0
Accounting Services			
≤ 10	42.6	26.7	39.5
50 +	3.7	14.4	6.0

Source: Lawrence et al. 1994

equipment purchases. In comparison, only 2.8 percent of the small operators went 50 miles or more for equipment purchases. Patterns similar to equipment were found for building supplies. Distances for banking services were similar for all farm sizes with the majority within ten miles.

These studies raise concerns for rural communities. Larger livestock producers have a greater tendency to bypass local communities and travel longer distances to purchase inputs, and indeed, local suppliers may be bypassed. However, it may be that suppliers in the next community have benefited; not all bypassing goes directly to factories located in some distant city. As the hog industry moves to larger and fewer operations, these pressures on rural communities will continue to grow. Rural communities, too, need to become active in livestock production networks, coalitions, cooperatives, etc. These forms of organizations which help keep the small- and medium-sized producers competitive are also vital to keeping the small- to medium-sized community competitive. Coordinated efforts may represent the lifeblood for both the livestock producers and the rural community.

Question #5. How do large-scale swine facilities influence the distribution of income locally, regionally, and within the swine sector?

We are unaware of any study that has systematically explored how changes in the swine industry influence the distribution of incomes. The wide range of variability in terms of wage rates, benefits offered, and competitive structure across states and regions makes comparisons difficult. One major concern is whether profits from the enterprise remains in the community or are siphoned off to investors living beyond the community. This argument was a major consideration in several states that limit absentee ownership of farmland, especially in the case of absentee ownership by foreigners (aliens).

Question #6. What is the relationship between the local impact of large-scale swine facilities and the economic health of the industry regionally, nationally?

Initial economic impacts of the construction and operation of large-scale swine facilities on the local community, county, or multi-county area are likely to be positive. Obviously, the magnitude of initial impacts will depend on size of the hog operation relative to the local economy. However, construction and operation of several 1,000-sow production units could be expected to have significant positive impact on total economic activity, employment, personal incomes, consumptive spending in a rural community or county (DePietre and Watson 1994). Impacts will be considerably greater during the construction phase than after the facilities are in operation.

Initial local impacts may not be perceived as positive by all concerned. Increases in local employment opportunities may raise local wage rates and increase labor costs to other farm and non-farm employers. Increased demand for housing by people coming into the community to work for new hog operations may increase local real estate values and property taxes, even though values of land and houses surrounding hog farms may decline (see question 15). Local procurement of production inputs may temporarily drive up prices for feedstuffs and other inputs and attract suppliers away from traditional purchasers.

Regionally, the increased concentration of hog production in one locality may make it more difficult for smaller, independent hog producers to compete. Greater demand and higher prices for feedstuffs, labor, and other production inputs may be a regional as well as local concern. A long-term concern is the potential loss of market access for smaller, independent operators. Large hog operations may bring new processing facilities to rural communities. But over time, as processing firms supply more and more of their own needs from either owned or contracted production, "outside" hogs may become discounted or not accepted by the processor.

With respect to long-term impacts on the hog-pork industry, the increased production brought about by large-scale production units will result in lower farm level prices and ultimately in lower prices to consumers. The farm value of pork is about one-third of total retail value. It is impossible to predict the precise market impacts of recent structural changes in the hog industry. However, current evidence indicates that increased numbers of large operations will reduce the average cost of producing live hogs by a small amount. With the projected increased supply of pork, it will be critical that new markets for pork be developed to avoid falling pork prices. Increased numbers of large production units concentrated in specific regions seem likely to displace a large number of independent hog producers elsewhere in the industry. The planned expansion of the 57 largest hog operations between 1993 and 1996 would produce twice as many hogs as Missouri's 12,000-plus hog farmers in 1993. Unless demand for pork increases, the expansion of these 57 largest operations could display many small-to-moderate-sized hog farms.

Question #7. How adequate are the economic input-output models, particularly frequently used models from the U.S. Forest Service (IMPLAN), in analyzing costs and externalities associated with large-scale swine production facilities? Do these economic models provide adequate information to local and state economic development agencies?

None of the more frequently used input-output models, including IMPLAN, deal with external ecological or social costs or benefits of economic activities.

IMPLAN provides estimates of direct economic effects (first-round impacts of input purchases and commodity sales), indirect effects (impacts of direct purchases and sales on local manufacturing, wholesaling, and service activities), and induced effects (impacts of consumptive spending made possible by increased employment and incomes derived from estimates of direct and indirect effects).

Estimated economic impacts in the IMPLAN model are based on default data which reflect historical relationships between local economic activity, employment, incomes, and spending in various sectors of the local economy during the period reflected by the default data base. The underlying assumption is that impact relationships within and among various economic sectors in the future will be like those observed in the data base period. Such an assumption may not be valid for assessing situations where the basic structure of an industry is changed by the economic development activity, as in the case where a hog sector characterized by independent, family-sized hog farms is displaced or augmented by large-scale corporate or contract operations.

The relationships between total value of production and local input procurement, local employment in hog production, employment in local manufacturing, wholesaling and service sectors, and local spending all would be expected to be quite different. For example, production of a given number or market value of hogs, might be expected to employ two to three times as many hog farmers and generate two to three times as much gross farm income on small-scale independently owned hog farms than would be supported by the same level of output from large-scale, corporate or contract production units (Ikerd n.d.). Relationships between total direct economic impacts and local versus outside procurement and marketing activities may be quite different for small and large hog farms (see question 3). Thus, input-output models such as IMPLAN, that are run using default data bases and coefficients, are not likely to accurately reflect the economic impacts of large-scale hog operations on local, regional, or state economies (Ikerd, et al. 1995).

Another shortcoming of such models is that they do not account for additional capital expenditures required to support indirect and induced effects on the local economy. For example, if new jobs result in more children in school and more patients in local health care facilities, the model would account for increased employment of teachers and health care workers, but not for the public capital outlays to build more or bigger schools and health care facilities. Likewise, the model may account for increased law enforcement officers, but not account for facilities or equipment required to support these officers or for the economic costs of crime. Nor is there any accounting for economic impacts of the changing nature of the local society. Increased employment from outside the local community may change the basic relationships between local employment and the demand for public services such as welfare benefits, education, health care, crime prevention and other factors which can have both economic and non-economic impacts on the local community.

Economic input-output models such as IMPLAN can be a useful tool for local and state economic development agencies, but their limitations in addressing the specific issue of large-scale hog production at the local level should be recognized and accounted for in the impact assessment process. The inherent inability of such models to address environmental, natural resource, and social resource impacts should be explicitly recognized.

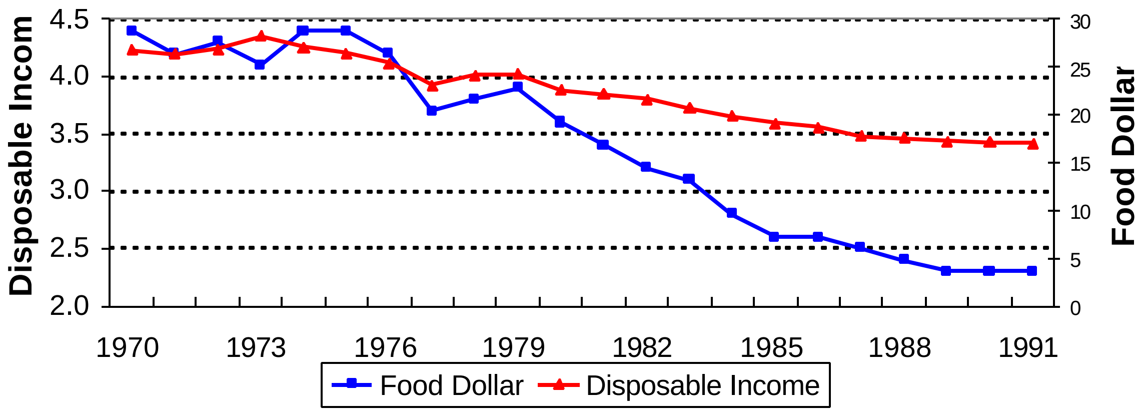
Question # 8. How does international economics, trade, and agricultural policy influence local changes in swine production?

Our panel was not qualified to respond to this question other than to note that U.S. attempts to encourage free trade with other countries opens the possibilities for additional exports of meats. China and Pacific Rim countries are viewed by many as potential major meat importers if world trade negotiations are successful.

Question # 9. What portion of the retail swine dollar do farmers receive and how has it changed? Are there any data on the viability of alternative farmer-owned and controlled swine production and processing organizations? How do different production, distribution, and marketing arrangements affect the farmer's shares?

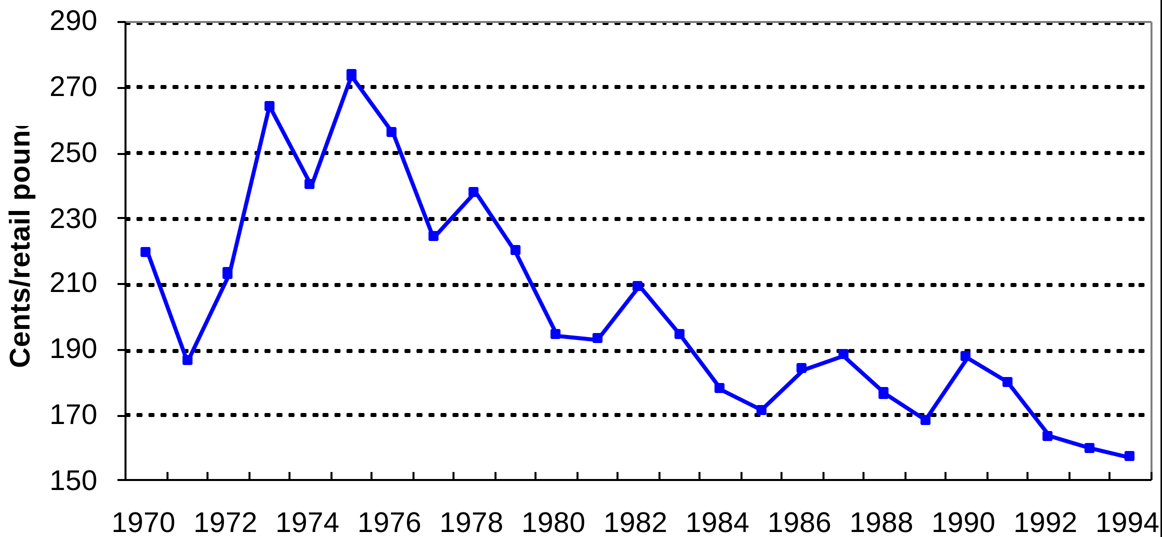
Consumers' meat expenditures as a percent of disposable income or as a proportion of the food dollar have declined over the past 20 years (Figure 1, page 134). At the same time, real (adjusted for inflation) retail pork prices have declined since the mid-1970s (Figure 2, page 134), and the farmer's share has also declined over the past 20 years (Figure 3, page 135). In 1994, farmers received about one-third of the retail pork price compared to more than 50 percent 20 years ago. The farm-to-wholesale margin (the portion most closely related to the packer's share) has remained relatively stable since 1975 in nominal terms (Figure 4, page 136), but has declined in real terms

Figure 1. Meat Expenditures as Percent of Disposable Income and Food Dollar



Source: U.S. Departments of Agriculture and Commerce

Figure2. Real Retail Pork Prices: 1987=100

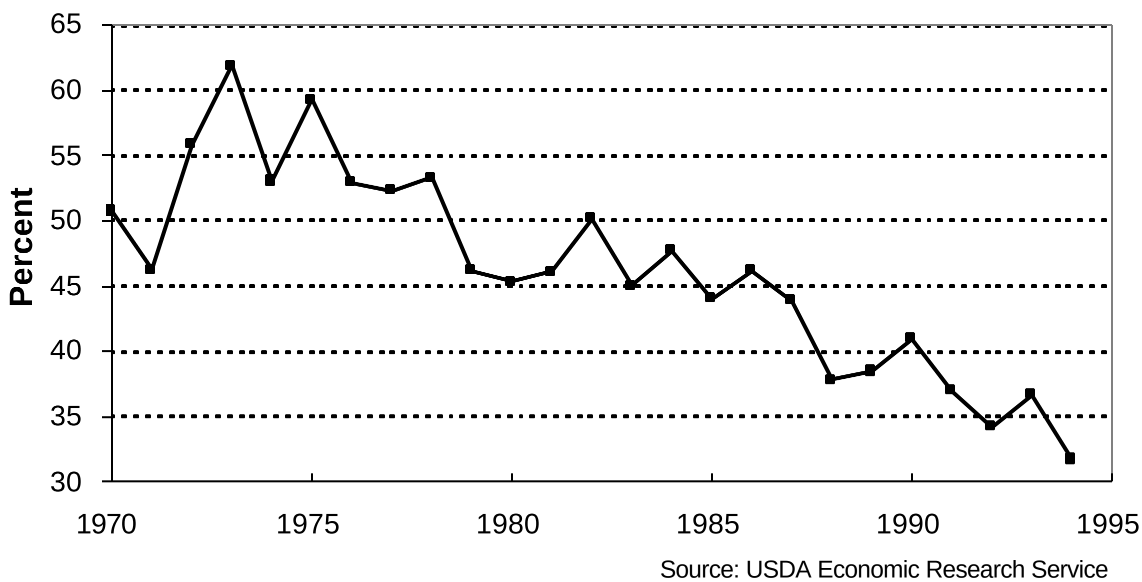


Source: USDA Economic Research Service

(Figure 5, page 137). Retail margins have grown faster than the rate of inflation (Figures 4 and 5). The product consumers buy, however, has changed. Nearly all of the value-added activity (trimming, deboning, packaging, seasoning, etc.) occurs beyond the farm gate.

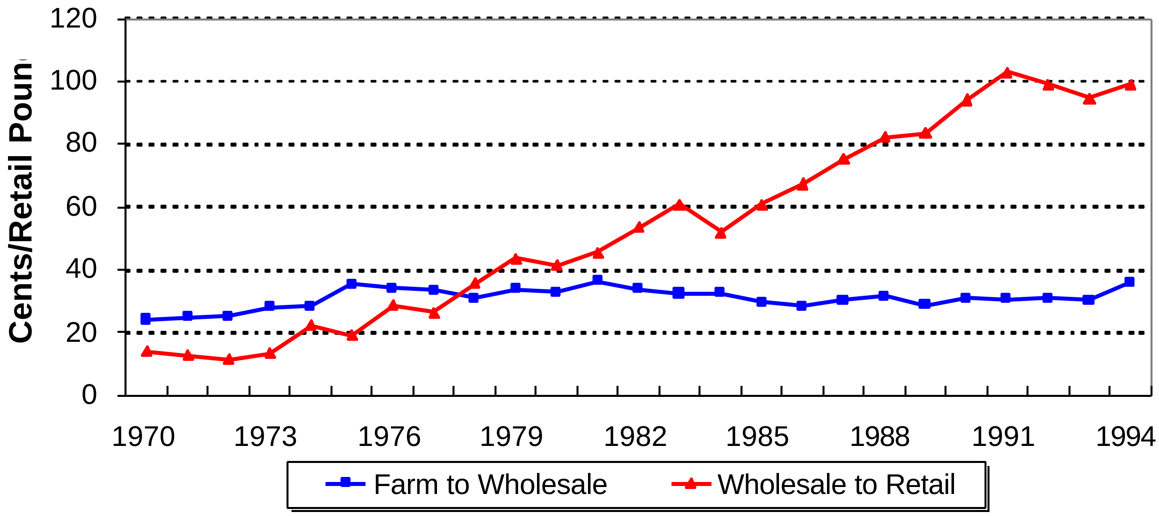
Individuals can be replaced in the production-to-consumer marketing chain, but the function they perform cannot. Producers may integrate forward into retailing, but they will have to perform or pay for all of the marketing functions between the farm and consumer. If producers enter the processing and distribution sectors of the existing market chain, they must compete against specialized large-scale firms in these industries.

Figure 3. Farm Share of Retail Pork Price

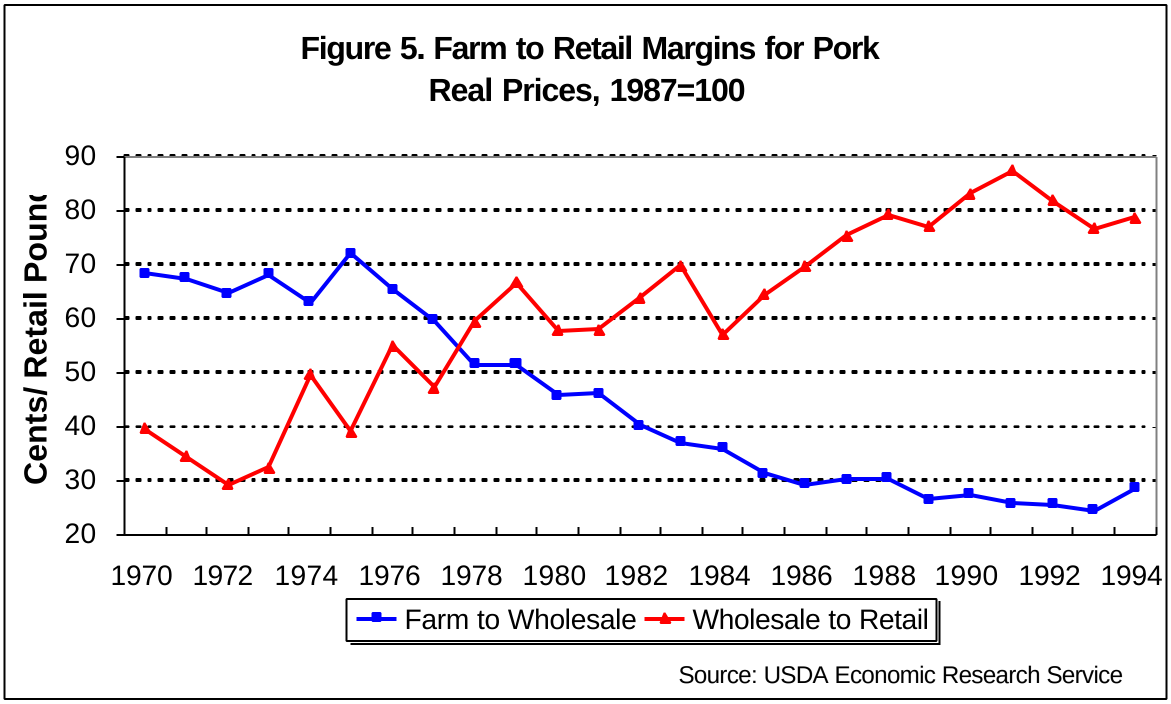


While there are examples of alternative farm production and processing arrangements, little is known about their competitiveness. Private entrepreneurs have tried with varying degrees of success to establish niche markets to differentiate their product based on production methods. Coleman's Natural Beef and Pastureland Pork are examples of labeled and branded products. Meeting government standards and regulations on niche market meat products can be costly and presents barriers for many producers (Black 1990; Coleman 1990). Niche markets for specialty meat products are increasing (Johnson 1990), but require entrepreneurial talent from the producer/retailer to succeed. Lawrence (1990) describes alternative marketing channels to access these markets. By its mass production nature, industrialized pork production systems are often at a disadvantage to smaller producers in serving these niche markets. However, in the brewery industry, the major breweries produce and sell more micro-brewed specialty beers than all the micro-breweries combined. It is likely that major pork production systems will develop the capacity to respond to niche markets in ways similar to the major breweries.

Figure 4. Farm to Retail Margins for Pork Nominal Prices



Source: USDA Economic Research Service



Question #10. Is there any evidence to indicate policy factors, e.g., taxation, antitrust, create uneven economic conditions for various sizes and organization of swine production?

Question #11. What are the costs and benefits of various tax abatements and subsidies used to attract large-scale confinement production facilities and who do they affect?

Both questions deal with essentially the same topics: policies and their benefits and costs. We are unsure of general policies specifically for pork, therefore, the following discussion will have a broader focus.

One major issue addressed in the introduction is particularly relevant here, namely, growth versus development. Most of the tax abatement and subsidies and other policies in place are for growth (job numbers) not development (job quality). The creation of jobs generates economic activity, but it is the quality of the jobs that determines whether this development is desirable.

The purpose of antitrust legislation is to prevent companies from acquiring undo economic or market power. The lack of enforcement of antitrust laws has led to increasing concentration and high concentration ratios in the food production and processing industries (Heffernan 1994). This is particularly worrisome when one looks across the industry in a vertical fashion and across related industries.

Corporate policies, although available across a broad spectrum of farming operations, tend to favor larger operations. One of the primary reasons for this is access to information. Large operations can devote more resources to information gathering, e.g., consultants, on-farm research, and legal interpretations. The corporate structure also tends to favor larger operations through limiting personal liability. This is especially critical if actions cause major environmental catastrophes; the owners' liability is limited. An individual farmer, or even a Subchapter S family farm corporation, does not enjoy the same degree of protection.

Enforcement problems and policies on leveling fines for infractions also appear to favor larger units. For example, in a recent Iowa case, a large producer was fined $5,000 for improper waste disposal. For large operations such fines are more of a nuisance than a deterrent. For smaller producers such fines could be financially disastrous.

Large companies appear to get preferential treatment in direct proportion to their economic power or potential for job creation. This is particularly true when one examines the concessions given to attract new companies to a community.

Three major problems need to be addressed in conjunction with this policy discussion. First, the issue of growth versus development and who really will benefit needs to be considered. Some policy options put forth in the interest of the community at large seem to benefit a narrow range of people at the expense of many. Second, there are size related issues that need to be considered. Many of the policies have unintended consequences that favor larger farms or operations at the expense of the smaller units. A final problem is the lack of data and solid evidence and studies. Many questions exist with few answers.

Question #12. Is there any evidence to indicate there is inequitable access to markets, credit, and research for various sizes and organizations of swine production?

Some evidence suggests that differences exist between size of operation and input purchase cost. An Illinois study showed quantity discounts for volume purchases and premiums paid for volume sales (Polson and Hudson 1990). However, the bigger question is whether these discounts and premiums are inequitable. In the case of market access, inequitable treatment or discrimination not based upon quality is a growing concern. Quality, as currently measured, refers to lean content (backfat thickness or percent lean) and carcass weight. Some packers have set acceptable minimum standards for leanness that some producers fail to meet. This is not a size criteria. Some producers have received warnings or “pink slips” for delivering low quality hogs. Some packers will buy any hog, but only on a carcass basis, so the value can be determined before the price is established. We are not aware of Midwestern producers being denied access to markets because of the numbers of hogs delivered. The second question regarding market access is the availability of long-term, price-risk share agreements for all producers. Some packers have indicated that the cost to establish and monitor these agreements on a small number of hogs is prohibitive. This would indicate that size has an impact on price received and ability to transfer risk. (See two publications by the National Pork Producers Council: *Pork Chain Quality Audit* and *NNPC Market Access: Situation Analysis*).

Credit availability relates to the ability of the borrower to repay debt. Evidence suggest that large-scale operations have a greater list of alternative credit sources. For example, Rabobank of the Netherlands is financing large-scale U.S. hog operations, but is only interested in any operations that want to borrow at least $5 million. This is beyond that needed by small producers. Some lenders favor contract production over independent production because the contractor (large-scale producer) has a proven track record and the lender perceives better odds of having the loan repaid – his first objective. Additionally, some bankers also view the contract relationship as providing management expertise and discipline to the operation. Some lenders are also concerned about the future of independent producers in this dynamic industry, and thus contribute to a self-fulfilling prophecy: "Small producers can't compete, so I won't loan them the funds to acquire the technology they need to compete." Finally, just as the quality of hogs differs, the quality of producers differs as well. Nearly half (48 percent) of Iowa hog producers surveyed in 1993 indicated that they did not have sufficient information to calculate their cost of production (Lawrence et al. 1994). In spite of poor records, only 15 percent of producers reported that their lender had limited their ability to expand.

Access to research is a key question because information is one of the determinants for effective management decisions. Traditionally, research was performed at agriculture experiment stations and made publicly available through the extension service to everyone at the same time. Partly due to budget cuts and shifting priorities, the creation and dissemination of publicly available information regarding modern pork production has fallen behind that of the private sector. Private sector firms – particularly those large enough to justify a research and development staff – are generating their own research and, because of their extensive information system, can almost instantaneously adopt research throughout the operation. Moreover, this information remains in private hands. Many allied industries (feed, genetics, facilities, health) are directing research to their most important customers which, increasingly, are large-scale firms. In some cases, research at public institutions is funded by private sector firms that are given early and, under some agreements, exclusive access to these new technologies.

Question #13. What evidence exists to assess the economic impact of the loss of market share of swine production in traditional family farming states such as Iowa to an emerging large-scale production stat, such as North Carolina? What evidence exists to indicate the likelihood of this? Would this be lost economic activity to a state such as Iowa?

Question #14. How does the economy of a highly concentrated hog production region compare with that of a region producing a comparable number of hogs in less concentrated facilities?

Although North Carolina has increased its market share since 1989, Iowa's share of the breeding herd first showed a sharp decline in December 1994 (USDA Hogs and Pigs). Iowa will likely lose market share to other states because of growth in those states and because of fewer hogs being produced in Iowa. Expansion is coming from highly specialized, capital-intensive production units. Facilities built outside Iowa or other traditionally family-farm states will stay in production until the assets are sufficiently depreciated. While the next generation of facilities may be built in Iowa, those being built in other states will be difficult to displace.

Even if Iowa does not lose market share, hogs will be less profitable than they have been due to larger pork supplies from outside of Iowa, and there will be fewer dollars of disposable income and less economic activity. Economic activity comes from production and purchased inputs including hired labor and proprietor income (unpaid family labor, return to owner equity, and profits), and from secondary effects of wages and income generated from the former being spent on consumer goods. If profit margins are tight due to large hog supplies, economic activity may still rise because the amount of inputs needed increases as hog production increases. However, if the growth in supplies comes from other states and Iowa has the same or fewer hogs and less profit, there will be less economic activity in the state from the pork industry.

The economic impact in the local community from diversified family farms is greater per hog produced than it is in large-scale units because they add greater value to the inputs they purchase (crop inputs and equipment). They also tend to spend more of the return locally from resources they provide, e.g., capital, labor, management. Although the IMPLAN model discussed in question 7 likely underestimates the difference between the two industry structures, it can be used to compare the Iowa and North Carolina hog production sectors. Table 2 below shows the economic impact of the two states on a 1,000 head marketed basis. Note that the IMPLAN coefficients used here were based on 1988 relationships, prior to the rapid expansion in North Carolina and large-scale units in Iowa. Iowa's hog industry generates more economic activity, jobs, and personal income per head than does North Carolina. The difference comes primarily from beyond the farm gate as the jobs created on the farm do not greatly differ. Iowa's extensive infrastructure supports local communities by creating jobs in the wholesale, retail, and service sectors that producers in North Carolina have internalized. However, from the perspective of a pound of live hog, carcass pork, or retail cut produced, North Carolina is carrying less baggage and has fewer salaries and profit centers to support.

TABLE 2.
Economic Impact per 1,000 Head Marketed of Two Industry Structures: Iowa and North Carolina

	Iowa	North Carolina
Total Economic Activity	$258,000.00	$141,000.00
Personal Income	$83,840.00	$37,500.00
Employment (full-time equivalent)	2.28	1.18
In Production (FTE)	0.794	0.629
Beyond Farm (FTE)	1.489	0.553

Question # 15. What is the impact of large-scale swine facilities on neighboring property values?

Large-scale swine facilities can affect neighboring property values in several ways. The negative externalities commonly associated with such facilities would tend to decrease values. Conversely, some positive impacts may be associated with neighboring land values.

A recent study in North Carolina provides one of the few detailed studies of the impacts on neighboring property values (Palmquist et al. 1995). This study examined the impact of the facilities on residential housing values. It found two major factors influencing property values. They were hog density already in an area and distance from the facility. Hog density was a reflection of the number of existing facilities in the neighborhood. The maximum predicted decrease in value found in the North Carolina study was 7.1 percent for a house within one-half mile of a new facility in the lowest hog density area. The decrease in the predicted value for a new facility was less than one percent, regardless of the distance from the facility, for areas where the highest concentrations of hogs were examined.

In Iowa, impact on farmland values can be inferred from the ISU land value survey (ISU Extension 1995). In this survey, respondents were asked to list positive and negative factors affecting land values. Several of the respondents listed the expansion in the swine industry as having a localized, positive impact. Swine producers new to an area bid up land values in an effort to secure a land base for a facility and manure disposal.

Hard evidence examining the impact of the large facilities on the value of neighboring property is scarce. The North Carolina study appears to be the only detailed study and it only examined residential property. From what evidence does exist, it appears the new facilities have a negative impact on the rural residences. This negative impact decreases with the distance from the facility and in areas with higher hog numbers. The impacts on farmland values appear to be positive but this would be a one-time change associated with the increased demand for construction and disposal sites.

Question 16. What evidence exists to assess the probability packing plants will leave states with anti-corporate farming laws, environmental restrictions, and the absence of large-scale swine production facilities? What evidence exists to assess the impact should packing plants leave?

Iowa's fed cattle industry may provide a model to study. From 1968-1971, Iowa was the leading cattle feeding state, marketing over 4 million head a year, for an 18 percent national market share. Iowa processing plants were approximately in balance with production. By 1994, Iowa fed cattle marketings had declined to 1.46 million (5 percent share) and the state's processing and production sectors were approximately in balance. New processing facilities were built near the supply of fed cattle in the High Plains region. Packers will locate where it is most profitable to operate. While labor costs, distance to retail markets, taxes and utilities, etc. represent production costs, the largest single cost item for a packer is the cost of hogs, and they will want to be near a competitively priced supply of hogs. IBP, Inc. is considering a new plant in North Carolina because of the large supply of hogs available (North Carolina exported over 4 million hogs in 1993) (USDA Hogs and Pigs and Livestock Slaughter). The age of the packing plant also enters in the decision to close a plant. The future supply of livestock in the region weighs heavily on the decision of whether to reinvest in an existing facility or build a new plant elsewhere.

CONCLUSIONS

This panel was asked to reflect on the economic consequences of restructuring swine production for family farms, the environment, and the viability of rural communities. It was not clear if the panel was to address sustainable agriculture. However, simply trying to stop the industrial system will not bring back the past nor preserve the present. It is clear that production is undergoing a significant structural change, and with this change comes many important long-lasting consequences. It is insufficient to only criticize what is happening; the panel concurs that we should be proactive in offering alternatives to the industrial model that has dominated agricultural development over the past 50 years.

Sustainable agriculture, or what some prefer to call "post-industrial agriculture," views farming as part of an integrated food and fiber system. Sustainable farming calls us to address holistic systems rather than simply looking at the food system as an aggregation of parts. Sustainable agriculture has been and will continue to be value-laden, controversial, and subject to many interpretations. The definition in the 1990 Farm Bill (U.S. Congress, Food, Agriculture, Conservation and Trade Act of 1990, Title XVI, Research, Subtitle A, Section 1602) is *"an integrated system of plant and animal production practices having a site-specific application that will, over the long term (A) satisfy human food and fiber needs; (B) enhance environmental quality and the natural resource base upon which the agriculture economy depends; (C) make the most efficient use of nonrenewable resources and on-farm resources and integrate, wherever appropriate, natural biological cycles and controls; (D) sustain the economic viability of farm operations; and (E) enhance the quality of life for farmers and society as whole."* This definition reflects the commitment to view farming as a set of integrated practices throughout the food chain, from the natural resource base to the consumers. However, many have trouble with the restrictive nature of a definition framed by practices. Sustainable agriculture should be defined as a vision for the long-term future of agriculture and society. Recognizing the diversity within agriculture, the large number of special interest groups, and the heavy reliance upon short-term economic benefits, sustainable agriculture as a vision may never be defined to the satisfaction of all stakeholders. However, the dialogue that emerges out of the debates about the future of agriculture is not without merit. In trying to come to grips with the future of farming and rural society, we increase our understanding of the complexity of the issues and slowly move to consensus.

A sustainable agriculture vision would likely have the following features: a diversity of livestock and cropping systems that builds the natural resource base of the soil, water, and biological systems while providing a stable economic base for the local, state, and national economies. To achieve this vision, agriculture will have to produce a variety of value-added products in harmony with the best use of the land and natural resources, while providing a diversity of income sources and sustaining a strong rural economy and the family farm structure. Essentially this means continued emphasis upon human capital development as opposed to the industrial model of placing emphasis exclusively upon productivity and narrowly defined efficiency.

In considering this vision, the panelists recognize the great need to broaden traditional definitions of efficiency and productivity. Historically, econometric models were developed with little attention to externalities, and often were designed to maximize short-term profits. However, world population pressures, growing scarcity of natural resources (particularly fossil fuels, arable lands, and potable water) and other environmental constraints are reshaping how we view the world and the food system. Structural change in agriculture is not new, nor is it complete. However, it is during occasions such as this that we should step back and contemplate whether these forces of change are leading toward systems of farming that will be sustainable over time.

SUMMARY OF RESEARCH NEEDS

1. Support for a strong, adaptive research program that provides alternative management systems that permit family farmers to compete with highly capitalized industrialized systems.
2. Learning links that transfer information from farmers to researchers and allow researchers to interact directly with farmers.
3. Promote integrated farming systems that permit high returns on labor, maintain and enhance productivity and maximize profits while increasing the quality of soil, protecting ground and surface water supplies, enhancing biological and physical diversity of the landscape, and permitting easy access to land by those who want to enter commercial agriculture.
4. Develop and support policies for providing diverse opportunities for high value employment in rural places.

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OCCUPATIONAL HEALTH

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INTRODUCTION

The sustainability of an industry depends on a host of factors, most especially economic factors. However, the health of those doing the work is a very important aspect as well. Whole industries have changed drastically or gone out of business because of occupational health hazards. Examples include luminescent watch dial manufacturing (radium paint-induced lung cancer) and the fire proof fabric industry (asbestos-induced fibrosis and cancer). An industry is no more healthy than its workers (Donham 1995). Therefore, there is a need to explore the occupational health aspects of swine production and recommend corrective actions where warranted (Strange 1984).

Agricultural production has historically been an occupation with notable health and safety hazards. In fact, Lineus in the 1500's and Ramazzini at the turn of the 18th century wrote about the health hazards of agricultural workers. Regarding occupational health in more modern livestock production, Preuschen (1974), a German physician, reported that there was a significantly increased physiologic demand on the respiratory tract for farmers working inside livestock confinement buildings compared to other farmers. In the late 1960s, and early 1970s, swine production came "indoors" in the United States. This led to the first description of health hazards to people working in these facilities in 1977 (Donham, Rubino et al. 1977). This study revealed that over 60 percent of veterinarians were having one or more respiratory health symptoms associated with their work in animal confinement facilities. This report led to more than 25 subsequent studies in the United States, Canada, Sweden, Denmark, Netherlands, Germany, and England (Donham 1990). In addition to respiratory illnesses, other occupational health concerns have been documented, e.g., traumatic injuries, noise-induced hearing loss, needle sticks, hydrogen sulfide (Donham, Knapp et al. 1982) and carbon monoxide (Anonymous 1993) poisonings, and infectious diseases (Donham 1985).

Several authors of this section have been contacted frequently over the past decade from throughout the United States and Canada by concerned swine workers experiencing adverse health effects associated with their work. The interest among our producer population is very apparent. They want to know what the health hazards are and how to prevent them. In order to understand the full range of their concerns, we recorded questions from participants (producers and the interested public) at a conference on concentration of the swine industry held in Kansas City in 1994[1]. Additionally, we consulted a previous survey of participants who attended a conference in Nebraska in 1993[2]. Additionally, questions were derived from a mail survey conducted of a random sample of producers in Iowa (N = 200). Finally, several new occupational health questions were collected from the National Pork Producers Council Ad Hoc Committee on Occupational Health. Together, these questions offer a broad representation of producers' and the general public's concerns regarding occupational health of swine workers, and provide a framework for addressing them.

[1] Livestock Production for Sustainable Rural Communities, Kansas City, Missouri.
[2] George A. Young Swine Conference, Lincoln, Nebraska.

It was the intent of this workshop to answer these questions to the extent available scientific data allowed and to note areas where research is needed to answer questions. A 2nd goal was to create a body of information that may assist development of preventive programs that will keep swine production workers healthy. As the industry changes, new questions will arise. In the future, more swine workers are likely to become employees of a larger producer or employers of additional hired help, raising legal issues. It appears that more workers are going to spend longer hours in animal confinement buildings. This will likely lead to increased exposure and risk of adverse health effects.

The Occupational Health Group of this conference was assembled to characterize the range of occupational health hazards associated with swine production and to suggest ways to reduce the morbidity and mortality associated with swine production. Through this process gaps in the understanding of these hazards were identified and ways to fill some of those gaps were suggested. There were 11 specific questions the Occupational Health Group was charged with addressing. These are listed below in bold type followed by our answers.

Question #1. What are the health risks for persons working inside swine confinement production facilities?

A. What types of problems and symptoms develop?

The Occupational Health Group first identified four time frames for adverse health effects: immediately dangerous to life and health (IDLH), acute, subchronic, and chronic. Other classification schemes besides time frame of the injury were recognized: those based on agent classification, those based on the disease or the target organ, and those based on the task that poses a hazard or is associated with a particular disease. In Table 1 (page 153), we list major categories of hazards and then further classify diseases or health outcomes within those categories. The order does not necessarily relate to incidence, prevalence, or severity. We have further described inhalation

TABLE 1: Major Hazard Categories in Swine Production.[1]

Hazards	Subcategories	Examples
Chemical Hazards	asphyxiation	carbon monoxide
	lung injury	nitrogen oxides, ammonia
	contact dermatitis	allergic, irritant
	poisonings	pesticides, fuels, cleaning agents
	intoxication	solvents, silo gas, substance abuse
	immunomodulation	adjuvants: biocides, phytotoxins
		immunosuppressants: pesticides
Biological Hazards	microorganisms	pathogenic
		non-pathogenic
	organic dust	bacterial toxins: endotoxins, exotoxins, enterotoxins
		fungal toxins: mycotoxins, glucans
		phytotoxins
		inflammatory agents
	aeroallergens	arachnid detritus
		animal proteins
		allergenic fungi
Infectious Hazards	zoonotic	systemic
	non-zoonotic	lung
	antibiotic resistance	skin
	emerging pathogens	ocular conjunctivitis
Biomechanical Stress	trauma	animal bites
		falls
		needle sticks
		punctures, lacerations, abrasions, burns
		crushing injuries
		repetitive trauma
	noise	noise-induced hearing loss
		reduced safety from impaired hearing
Thermal Stress	heat stress	
	cold stress	
Emotional Stress	occupational	suicide
	marital	depression
	financial	anxiety
Drowning		lagoons
		pits
		farm ponds
Fires/explosions	chemical	methane in pits
	electrical	ignited building materials or feed
	welding	ignited building materials or feed
	organic material	grain, grain dust, compost, hay
Electrocution		faulty wiring
		water associated
Chronic pain	biomechanical stress	arthralgia
	arthritis	myalgia
Fatigue	sleep deprivation	planting, harvesting
	chronic fatigue syndrome	chronic endotoxin exposure

[1] References for above table results: Auger 1993; Bar-Sela, et al. 1984; Donham 1991, 1989, 1985; Donham and Thu 1995; Donham, Yeggy et al. 1988; Donham, Yeggy et al. 1985; Randolph and Rhodes 1993; Slesinger and Ofstead 1993; Stanford and Ross 1986.

exposure and respiratory disease by region of the respiratory tract and various diseases. We have also described symptoms and specific agents for each disease in Table 2 (page 155).

The Full Spectrum of Health Risks

The principal health risks for swine workers (Table 1) result from a wide range of hazards. Chemical, biological (non-infectious), and infectious hazards have received considerable attention. In addition, noise, trauma (Randolph and Rhodes 1993), fires, explosions, electrocutions, thermal stress, poisonings, and drownings are important causes of morbidity and mortality. Often overlooked are emotional stress, chronic pain, and fatigue, which can lead to significant impairment and put the worker at additional risk. Most of these are readily understood, e.g., fires, drownings, electrocutions, and preventive measures are established and available, but often not implemented. Respiratory disease in swine confinement workers receives even less preventive attention.

Respiratory Diseases

Inhalation exposures are common and lead to significant morbidity among swine farmers. Lung diseases from the multitude of exposures have been difficult to characterize, in part because they are often not discreet conditions and there is considerable overlap in symptomatology. There are confined space entry hazards in swine farming and related deaths from hydrogen sulfide are not uncommon (Anonymous 1993; Donham, Knapp et al. 1982; Osbern and Crapo 1981). Other lung injuries result from exposures that are not immediately dangerous to life and health. Lung disease in swine confinement consists of acute lung insults that may lead to chronic declines in lung function (Bongers, et al. 1987; Choudat et al. 1994; Cormier, et al. 1991; Crook, et al. 1991; Donham, Zavala et al. 1984a). Respiratory problems associated with this environment are listed in Table 2 by upper respiratory tract, airway, interstitial, and mixed airway and interstitial lung diseases. Classical (IgE-mediated or IgG) hypersensitive disease appears to be uncommon in swine workers. The pathogeneses is primarily acute to chronic inflammation.

TABLE 2.

Respiratory Diseases Associated with Swine Production[2]

Upper Airway Disease

- Sinusitis
- Irritant Rhinitis
- Allergic Rhinitis
- Pharyngitis

Lower Airway Disease

- Organic Dust Toxic Syndrome (ODTS)
- Occupational Asthma
  - Nonallergic asthma, hyperresponsive airways disease, or reactive airways disease syndrome (RADS)
  - Allergic asthma (IgE mediated)
- Acute or Subacute Bronchitis
- Chronic Bronchitis
- Chronic Obstructive Pulmonary Disease (COPD)

Interstitial Disease

- Alveolitis
- Chronic Interstitial Infiltrate
- Pulmonary Edema

[2] References for above table results: Donham, Zavala et al. 1984b; Dosman, et al. 1988; Haglind and Rylander 1987; Harries and Cromwell 1982; Heederick, et al. 1991; Holness, et al. 1987; Iverson, et al. 1988; Jones, et al. 1984; Leistikow, et al. 1989; Lenhart 1984; Rylander, Essle et al. 1990; Rylander, Peterson et al. 1990; Thelin, et al. 1984; and Turner and Nichols 1995.

Upper Respiratory Tract Disease

Frequent upper respiratory tract problems include sinusitis and rhinitis. Several studies have referred to these collectively as mucus membrane irritation (MMI) (Rylander 1994; Rylander, Donham et al. 1989). MMI may be attributable to the combination of bioaerosol, endotoxin and ammonia exposures (Donham 1986; Donham, Scallon et al. 1985).

Sinusitis is often chronic in confinement workers. They complain of a continual or frequent cold that "they just cannot shake." They complain of a stuffy head, difficulty in breathing through the nose, headache, and "popping ears." These symptoms are a result of a noninfectious inflammation and swelling of the mucus membranes of the sinus cavities in the head and the eustachian tubes leading to the middle ear. This is often accompanied by an irritant rhinitis (nasal passages) and pharyngitis (sore throat).

Allergic rhinitis (also called hay fever) has rarely been attributed to confinement exposures. These persons have a specific allergy to some component of the swine environment. These symptoms may be similar to irritant rhinitis, except it usually comes on after only brief exposure to the environment, and may be accompanied by itchy, watery eyes and possibly acute chest tightness (allergic asthma).

An asthma-like syndrome reminiscent of byssinosis (a condition of workers exposed to cotton dust) is apparent with swine workers. This condition is characterized by acute onset of chest tightness and wheezing cough on return to work from two or more days of work absence (Monday response) and mild acquired airway hyperresponsiveness and cough. It can occur on first exposure to the swine confinement environment and is therefore not a hypersensitivity disease. It was documented in 11 percent of a population-based study of Iowa swine confinement workers (Donham, Merchant, et al. 1990). Byssinosis is often associated with chronic bronchitis and includes chronic airways obstruction with progressive decline in pulmonary function.

Bronchitis is the most common complaint of workers, effecting as many as 70 percent of exposed persons. This is an inflammatory-induced irritation of the airways. Acute/subacute bronchitis is a dry cough associated with exposure to the swine facility. It occurs for usually less than a year, and will usually dissipate within a year with decreased exposure. However, it may lead to chronic bronchitis, a condition with chronic cough and phlegm production, that occurs at least three weeks out of the month for two or more years. This condition effects about 25 percent of swine producers in confinement. It may be accompanied by occupational asthma.

Occupational asthma includes periodic airways obstruction, chest tightness, wheezing, and dyspnea, but does not occur on first exposure. Workers with existent asthma typically experience often severe asthma upon first exposure to swine confinement facilities. These workers usually select themselves out of these jobs. Occupational asthma is associated with repeated exposure to the work environment. It has two basic causes: 1) allergic, or 2) chronic irritation. Rarely has there been documented allergic (IgE) mediated causes for swine workers' illnesses. These "susceptible" workers more than likely leave the work force early because they can be affected by exposure early in their work history and the condition is very difficult to manage. Nonallergic occupational asthma, or reactive airways disease, is common (20 percent) of current swine workers. This condition is caused by long-term inflammation of the airway epithelium, and responses by tissue-associated white blood cells containing certain mediators resulting in a constrictive response of smooth muscle in the airways. This condition may lead to chronic obstructive pulmonary disease, which is a permanent, possibly disabling condition.

Occupational asthma is distinct from organic dust toxic syndrome (ODTS) in that ODTS results in a flu-like spectrum of symptoms with headache, joint and muscle pain, arthralgia and myalgia, fever, fatigue and weakness, and irritation of the airways and the cells lining the small sacs of the lung. ODTS may be mistaken clinically for farmers lung disease (FLD), as they have nearly identical acute symptoms, e.g., a severe, influenza, delayed onset following exposure. However, FLD is rare. It is caused by a certain type of allergic condition (hypersensitivity pneumonitis) seen in a variety of farming operations, but has not been documented in swine workers (Rylander 1994). It is established from agricultural exposure assessment studies that airborne thermophilic organisms most commonly associated with FLD (*Saccharopolyspora rectivirgula, Thermoactinomyces vulgaris,* *T. saccharii*) are present in significantly lower concentrations in swine barns than in dairy barns (Kiekhaefer, et al. 1995). Since swine farmers are exposed to higher levels of inflammatory agents such as endotoxins and ammonia, these may alter the processing of inhaled bioaerosols. On the other hand, 33 percent (Donham, Merchant et al. 1990) of swine producers have reported episodes of ODTS, that is an influenza-like illness followed by exposure to a higher than usual dust load, e.g., moving and sorting hogs, and is marked by headache, fatigue, muscle aches and pains, fever, low work/exercise tolerance, and possibly a pulmonary infiltrate.

A chronic or subacute condition (a variant of ODTS) more frequently seen in swine workers is marked by chronic fatigue and possibly persistent mild pulmonary infiltrates (Auger 1992). This may represent a similar syndrome caused by simultaneous exposures to bioaerosols and irritant gases. However, there are only anecdotal cases observed and no human studies that have been conducted (Donham 1993). In addition to anecdotal case reports, evidence for a persistent pulmonary infiltrate comes from an animal study (Donham and Leininger 1984).

Acute respiratory distress syndrome (ARDS) or pulmonary edema can result in swine workers from acute or chronic exposure to hydrogen sulfide (H_2S). There have been at least 19 acute deaths in workers resulting from sudden H_2S exposure of above 500 ppm secondary to liquid manure agitation. These people will collapse and stop breathing with only a few breaths at this high exposure. Severe pulmonary edema and death may result. Longer term lower exposure may lead to ARDS at an unpredictable time during or following an accumulative or multiple period exposure (Donham, Knapp et al. 1982).

It is recognized that several of these conditions may occur in an individual swine worker and they may occur at the same time. It is likely that an individual worker may have signs and symptoms of an asthma-like condition, bronchitis, and episodes of ODTS. This produces an interrelated group of conditions (a syndrome) of illness caused by exposure to the swine building environment (illustrated in Figure 1. Page 161).

Research Needs

- What is the extent of disabling conditions?

There is relatively little information to indicate the extent that workers are forced to quit because of respiratory or other conditions. Furthermore, there are no economic data available to elucidate the cost of these conditions to the industry. This could be answered by a prospective epidemiologic cohort study. A prospective study could follow several possible study designs. One study design would be to follow a group of producers over a five- to ten-year period, documenting their health status and outcomes over time. A secondary prospective design would be to conduct a follow-up study on a previously studied cohort.

A third study design could involve studying the health history of the employees of large companies where the number of workers range from 200 to 300. Health and economic data including lost work time, medical expenses, training expenses of new employees, etc., could also be included as part of the study designs.

- What are the end stage or permanent conditions that may develop?

This is a very important question that can best be answered by the long-term prospective epidemiologic study mentioned above. Separate studies by Dosman (1996) and Schwartz et al. (1995) document that accelerated progressive lung function decline occurs over time in swine confinement workers. This suggests there is a risk for chronic or permanent disease with long-term exposure. However, this evidence needs more clarification.

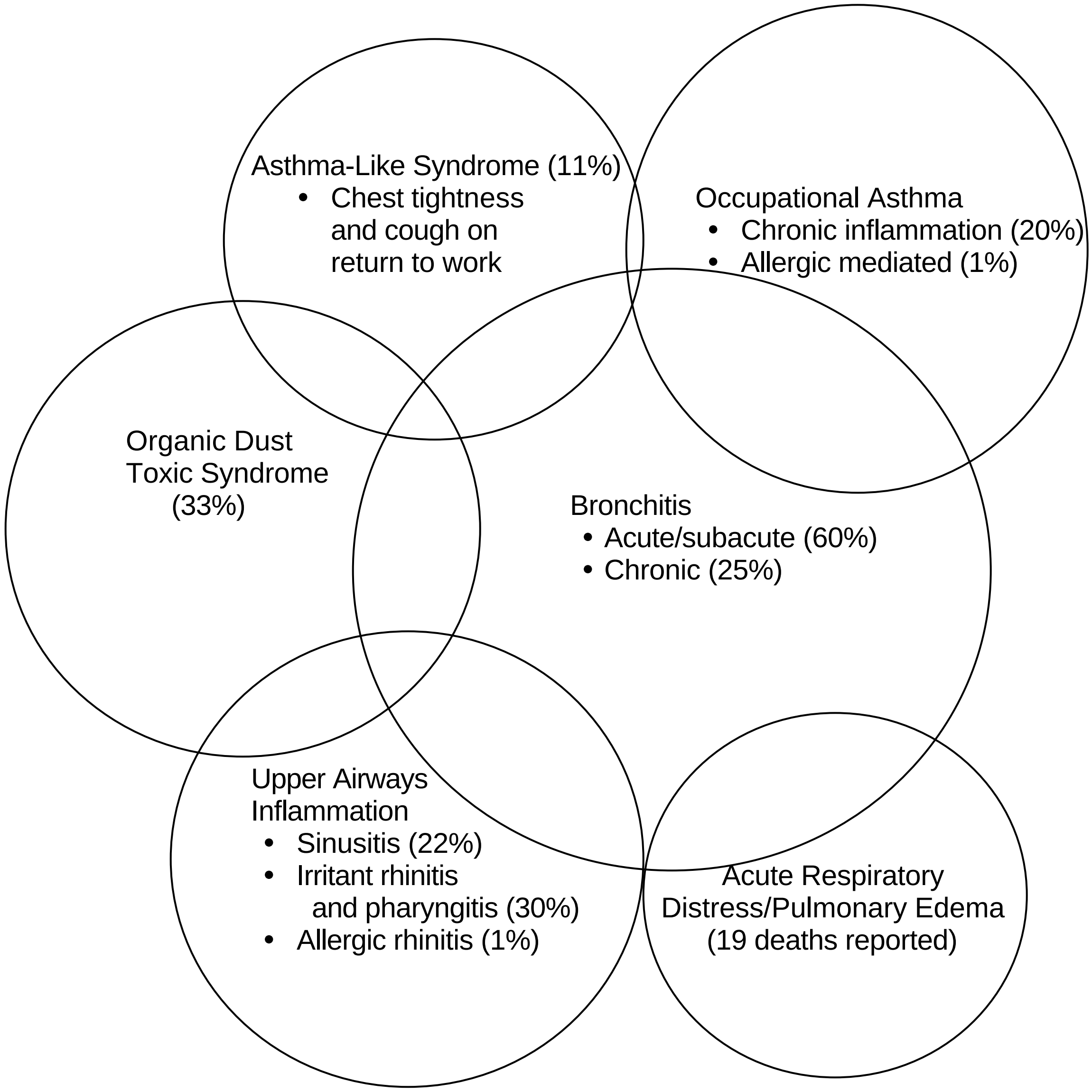
B. How long does it take for symptoms to develop?

According to several studies of comparison groups and swine producer cohorts, it is fairly clear-cut that as little as a two-hour daily exposure may initiate acute symptoms (Donham and Gustafson 1982), and six or more years of exposure increases the risk for chronic symptoms. However, prospective studies of newly hired workers have not been followed over time. Donham and coworkers studied previously unexposed (naive), nonatopic individual response to swine confinement exposure. Their pulmonary (breathing) function was assessed every 30 minutes. Their pulmonary function declined when measured at 30-minute intervals to a maximum at two hours (ibid). Three different studies have shown chronic bronchitis and reactive airways disease is much higher in the six and over exposure years (Donham and Gustafson 1982; Donham, Haglind et al. 1989; Donham, Reynolds et al. 1995). Certainly there are variabilities among individuals with regard to time for symptom development. This may be because of differential exposures and susceptibility, and early selection out of this occupation. For individuals with underlying pulmonary disease, e.g., asthma, only a few minutes may be sufficient exposure time for symptoms to develop (Donham and Gustafson 1982). It is believed that if these individuals elect to work in swine production at all, they will leave this occupation in the first three months of employment. For less susceptible individuals with no underlying disease one must rely on existing evidence that chronic symptoms develop within a 6- to 14-year time frame (Donham, Reynolds et al. 1995). How quickly one becomes symptomatic may depend on episodic high exposures to organic dusts leading to recurrent ODTS (Malmberg and Larsson 1992).

Research Needs

Although there are at least three cross-sectional epidemiologic studies that indicate a six-year exposure leads to increased risk of respiratory illness, additional data would be helpful. The long-term prospective study outlined in question 1A above would be the best way to answer this question.

FIGURE 1. The Spectrum of Respiratory Disease in Swine Confinement Workers



The circles indicate overlapping symptoms and conditions. The percentages indicate approximate rates of swine workers who experience these conditions.

C. Are there some people who have more problems or are at higher risk?

There is evidence to suggest that atopic individuals and others with symptoms or history of asthma, emphysema, myocardial ischemia, or other cardiopulmonary conditions are at greater risk of developing symptoms (Donham and Gustafson 1982). Exposures to irritant particles and gases in swine farming may encourage early selection out of the occupation when compared to grain farming or cotton dust exposure environments. It may be that farm children who are susceptible to respiratory problems learn this as children and choose occupations other than farming from early on. Smokers appear to experience respiratory symptoms indicative of bronchitis and reactive airways at 1.5-2 times the rate of nonsmokers (Donham, Haglind et al. 1986; Matson, et al. 1983).

There also appears to be a great deal of variability of individual susceptibility that has no obvious explanation. Some individuals never have complaints, while others are severely affected for no apparent reasons. Those working in total confinement compared to conventional housing seem to have more frequent and severe symptoms (Donham, Merchant et al. 1990). There is also evidence that the greater the dose of dust, ammonia, and number of years of exposure, the greater the health problem (Donham, Reynolds et al. 1995). The quality of the environment does relate to the health of those persons who develop symptoms.

Research Needs

A prospective study of new workers entering the field would be very helpful in answering this question (similar to that described in question 1A above). For example, new graduates of training schools or new employees coming into the field could be screened for a variety of conditions, e.g., atopy, asthma, allergic rhinitis, bronchitis, etc. These individuals could be followed over time to see if they are more susceptible than others.

D. What are the early signs or indicators of impending more serious health problems?

There is sufficient evidence that acute cross-shift change in lung function is predictive of longitudinal lung function decrements (Schwartz et al. 1990). Additionally, at least two studies have shown that lowered baseline pulmonary function is associated with declines in pulmonary function over a work period (Donham, Merchant et al. 1990; Donham, Reynolds et al. 1995). There is conflicting evidence as to possible residual effects from repeated ODTS episodes. There is subjective evidence that episodes of ODTS may lead to more severe cases subsequently with less exposure (Malmberg et al. 1985).

Although there have been few longitudinal studies to answer this question precisely, medical judgment based on case information would suggest the following as warning signs of impending health problems:

1. Persistent cough with production of phlegm that persists for more than three months out of the year.
2. Chest tightness or wheezing associated with working in the building that occurs most of the time.
3. Persistent fatigue, lowered work tolerance that may or may not be associated with difficulty in breathing (dyspnea), muscle/joint aches and pain, and headache.
4. Symptoms of a persistent cold, e.g., stuffy nose, headache, “popping” ears (like when traveling in the mountains in an automobile).
5. Pulmonary function tests that reveal one or more of the following:
    - A *decrease* from normal *baseline* values of volume measurement of 20 percent, e.g., FEV_1 or FVC.
    - A decrease in baseline flow rates of 30 percent, e.g., FEF, FEF 25-75.

- A decrease in volumes, e.g., FEV_1 over a work period of 5 percent.

These recommendations are made with the recognition that “well” farmers generally have higher pulmonary function values than standard comparison populations. This means that the prevalence of respiratory dysfunction may actually be underestimated.

Research Needs

This question could be more fully elucidated by the long-term prospective cohort study mentioned in question 1A above. Some particular areas to follow would be those developing symptoms of an asthma-like syndrome, or decreased lung function over a work period, and episodes of ODTS. Presently, we can only speculate on these as signs of impending danger. Furthermore, a pulmonary function study of “normal farmers” needs to be completed in order to establish an appropriate comparison group.

E. Are the damages or health problems reversible?

It is likely that some of the lung problems experienced by swine workers do cause irreversible damage since there are longitudinal declines in lung function in some of these workers (Dosman 1996; Schwartz, et al. 1990). However, there are unpublished anecdotal cases observed by the authors that some acute lung illnesses are probably reversible. It should be realized that reversible health problems should still be prevented.

Similar to the answers provided for question 1D above, there are insufficient long-term studies to provide validated answers to these questions. However, based on anecdotal case experience, applying information from other work exposures and clinical judgment, the following recommendations are made:

1. Simple bronchitis, e.g., dry cough for less than three-month duration in a year, is likely reversible without further occupational exposure.

2. Chronic bronchitis (cough with phlegm persisting more than three months for two years) may improve with elimination or reduction of exposure, but may be a permanent condition.
3. Chronic bronchitis that has progressed to chronic obstructive pulmonary disease may improve with exposure control, but will not reverse to baseline.
4. Hyperreactive airways (asthma) will improve with exposure control, but will likely persist, even after cessation of exposure. In fact, the condition is likely to occur with irritant exposures to other than the swine facility, e.g., other dusty environments, solvents, detergents, perfumes, exercise, cold.

Research Needs

A large-scale prospective study (as described in question 1A above) would also help to more fully answer these questions. Individuals who developed problems would be followed over time to see if the conditions were reversible. This would include use of medications to manage the symptoms, as well as management of the workers' exposures.

F. When do you know it's serious enough to quit?

The major concern for work restriction in swine confinement workers are periodic acute airways obstruction, progressive decline in lung function, and episodes of reactive airway disease. Whether to restrict exposure to swine barns is an important issue for employers, the independent farmer, and his/her health professional. Some respiratory conditions have a significant risk for disability or may be life threatening. These conditions require special consideration. Medical practitioners should advise use of improved environmental controls, personal protective equipment, appropriate use of anti-inflammatory inhalers and bronchodilators, and restriction from high hazard areas and sometimes from all areas of livestock production. Farmers should be advised to leave swine farming when these measures cannot control serious symptoms. Conditions for advising restriction from working in swine confinement facilities follow.

Asthma:

Asthma marked by severe airways obstruction, chest tightness, wheeze, or dyspnea is grounds for restriction from exposure and work in swine confinement buildings. This is particularly true if the condition does not improve with environmental and personal control measures. As this is a drastic step for many farmers, particularly owner-operators, this should be discussed thoroughly with the patient and his/her family, so they understand the severity of the condition and the likelihood of progressive asthma and airways obstruction.

Restriction from work in cases of mild asthma depends on several important factors. If the asthma can be managed with environmental controls and respiratory protection, restriction from all areas may not be necessary to keep the farmer working. Use of respiratory protection with a high protection factor, such as a powered air purifying respirator, and implementation of improved exposure control measures may allow that farmer to continue working. In most cases, this will require that the patient be committed to continuing work in this environment and be willing to fully implement these changes. It is recommended that medical surveillance be conducted annually, and every 6 months if the patient experiences a repeatable cross-shift reduction of FEV_1 of greater than 5 percent, and his/her before-work FEV_1 is less than 80 percent of predicted. Progressive loss in FEV_1 is grounds for restriction from livestock production. Farmers with an FEV_1 of 60 percent or less require a detailed pulmonary evaluation with evaluation for possible disability benefits.

Asthma-like Syndrome:

It is likely that use of respiratory protection for those activities that are most hazardous and general operational improvements to reduce exposures to bioaerosols and irritant vapors will allow continued work in swine production. Again, if symptoms worsen especially with protective measures, one should consider changing to a reduced exposure job and further medical surveillance.

Chronic Bronchitis:

It may be acceptable for the farmer to continue work in swine confinement with chronic bronchitis. However, in some cases this will make respirator use difficult and may cause sleep problems for the worker. Progression of symptoms, especially if accompanied by a loss in lung function, should result in transfer to lower exposure and further medical evaluation.

Research Needs

To provide professional advice regarding medical management of workers with work-related respiratory disease, the health professional needs to know more about the progression and end stages of the disease. Again, a long-term prospective study as described in 1A would help to answer this. Additionally, clinical studies on severely affected persons as mentioned in 1A above could also help more fully answer this question.

Question #2. Are worker health risks being contained through monitoring, engineering, personal protective equipment, health assessments, and management practices?

The authors of this report believe that worker health risks can be significantly reduced through a comprehensive program of environmental monitoring and control by use of management practices, engineering controls, judicial use of personal protective equipment, and health surveillance. However, such programs are exceedingly rare in today's swine industry. There is little to no exposure monitoring except for research purposes, and routine health assessment in this worker population is rare. Engineering controls are generally implemented if they will benefit hog production but rarely with worker health as the principal motivation. There is some evidence to suggest that healthy swine confinement workers usually can tolerate the following exposures without experiencing acute respiratory symptoms (Donham, Haglind et al. 1986; Donham, Merchant et al. 1990; Donham, Reynolds et al. 1995; Reynolds et al. 1996):

2.5 mg/m^3 total dust
0.23 mg/m^3 respirable dust
7 ppm ammonia
100 EU/m^3 endotoxin
10^5 micro-organisms/m^3.

It is important to recognize that swine workers are a survivor population**,** meaning that the most severely affected leave the environment early. In addition, there is evidence that workers exposed to inhaled endotoxin develop a tolerance (at least to acute symptoms) to this toxicant. However, long-term exposure may lead to chronic conditions even in the absence of acute symptoms. Previously unexposed persons would be expected to react acutely to lower exposure concentrations.

Management practices and engineering controls can significantly reduce exposures to inhaled toxicants. These include frequent facility cleaning (power washing from floor to ceiling at least every three weeks); addition of extra fat and a urease inhibitor, e.g., microaid, to the feed; self-cleaning flooring; and improved lagoon operation (Mutel, et al. 1992). The ventilation system cannot necessarily assure a healthful environment by itself. Management procedures mentioned above must also be implemented. Also, the ventilation system must be properly engineered and maintained; very often, higher cool weather exchange ventilation rates are needed; and lower animal density (swine mass per unit of barn volume) is required.

Personal protective equipment should not be considered an effective alternative to good management practices and engineering controls. It is very difficult to assure that exposed personnel wear the right respirator, and that it fits properly, functions properly, and is worn at the appropriate times. Respirators are not well tolerated, especially for strenuous work in a hot environment. The

Occupational Safety and Health Administration (OSHA) requires that if respirators are worn to protect workers, they must be worn at all times, and be fit, maintained, and stored properly. Because of health or improper fit of other filter respirators, some workers may require a powered air purifying respirator, e.g., Racal's air stream helmet. However, these respirators are often viewed as too costly unless the swine worker is already impaired. Few physicians are aware of the range of respirators available and their proper selection and use (Donham, Ruskin et al. 1995). Many, but not all, insurance programs will provide reimbursement for respirator purchase. We recommend use of respirators as an adjunct to management practices and engineering controls, especially for specific tasks that result in higher-than-normal exposures or which have historically caused respiratory problems for the worker. We recommend against the use of one-strap masks since they do not seal well around the face, and thus, offer only minimal exposure reduction and give a false sense of protection. A National Institute for Occupational Safety and Health (NIOSH)-recommended 2-strap mask with high-efficiency particulate air (HEPA) filtering can be expected to reduce exposures 10-fold when used properly. A good respirator for swine workers who may already have a breathing problem is a powered, air-purifying respirator with a HEPA dust filter and an ammonia cartridge. This type of respirator carries an assigned protection factor of 50, is more comfortable to wear (for some swine workers), can be worn by workers with existing airway or heart disease, will function if the wearer has a beard or other facial feature preventing a good seal, and also provides protection against head trauma and eye exposures. They require use of a rechargeable battery pack and cost about $500.

Special attention should be given to pregnant women who work in swine confinement facilities. Aside from increased susceptibility to carbon monoxide and potentially other gas and vapor exposures, pregnant women may be at increased risk for spontaneous abortion if they work in swine barns. A specific mechanism for this increased susceptibility includes carbon monoxide exposure and risk of accidental inoculation with prostaglandin. More exposure control and surveillance is appropriate for this group of workers.

Noise-induced hearing loss is a problem in this occupation since the sound pressure levels of squealing sows in swine barns routinely exceeds 100 dBA. This noise is compounded by that emanating from ventilation equipment and feeding systems. Reduction of noise exposure through engineering is difficult in this setting because animals, rather than machines, are the primary source of the noise. Use of absorptive materials and baffles is impractical due to the need for surfaces to be cleaned with high pressure spray equipment. Thus, the simplest approach to prevention of noise-induced hearing loss in this environment is through the proper use of protective devices such as ear plugs or semi-aural caps. These can provide noise attenuation in excess of 30 dB at frequencies most common in swine barns.

Research Needs

To fully answer this question, a prospective study would be helpful. One could identify several facilities that were monitored and kept within recommended exposure limits, and follow a specified occupational health program. The worker health in the facilities could be compared to facilities not following this program.

Question #3. Can risks associated with persons working inside swine confinement facilities be extrapolated to exterior environments?

There is limited utility in attempting to extrapolate occupational health risks from inside swine facilities to community health risks outside swine production. Although there is discharge of airborne particulates and vapors from the swine barns to the outside environment, the aerosols differ considerably in composition and concentration of specific agents. As aerosols and vapors emanating from a point source travel downwind in a lower concentration atmosphere, the aerosols disperse and adsorbed vapors may be stripped from particles. There may also be photochemical reactions and ground deposition. Most swine confinement facilities are surrounded by other buildings, row crops, and trees which can influence dispersion of effluents. These make the indoor exposures vastly different from those outdoors. Odoriferous volatile organics present in the outdoor air in the vicinity of a swine production facility may arise from the lagoon or outdoor manure piles as well as particulate and gases in air discharged from the barns.

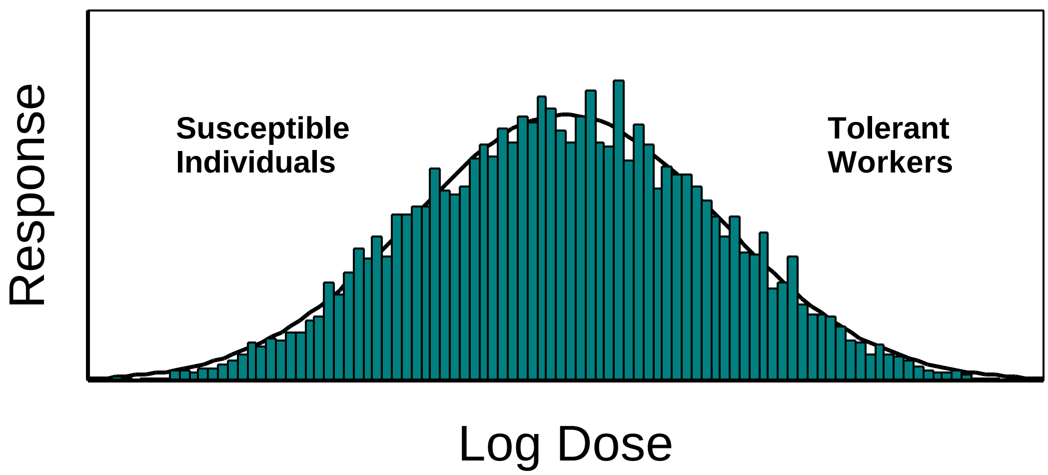
Although there is theoretically a definable dose-response relationship for respiratory diseases by individual compound, the exposures inside are unique and are quite different from those outside. Perhaps equally important is the fact that the exposed populations are quite different in terms of susceptibility factors. Figure 2 is an illustration of the general concept that, whereas workers may require a high dose to develop a particular response, the general population includes children, the elderly, asthmatics, and other susceptible individuals who would be expected to develop responses at lower doses.

Perhaps the most significant community concern is swine odor and the perceived adverse health effects associated with the odor. There is some evidence (Schiffman et al.1995) that odors from swine facilities can produce real illness in sensitive populations, such as those with rhinitis or asthma, or in those individuals who have exposure to higher than normal concentrations due to their proximity to swine facilities and micrometeorological conditions. However, a link between community exposure to swine odor and illness has not been scientifically defined at the present time and there is no well-established etiology for such a causal link. At this point there is only anecdotal evidence that respiratory symptoms have been reported (1991 National Pork Producer's Council Report) in the vicinity of pig lots that have been attributed to air contaminants from swine facilities.

Research Needs

Just two studies (a pilot study in Iowa, and a follow-up study in North Carolina) are being conducted in this area at present. The environment in the vicinity of facilities is being studied, as well as the physical and emotional health status of area residents. These types of studies need to be increased to answer this most important question.

FIGURE 2. The Distribution of Responses to Toxicants in Exposed Populations.



Question #4. What evidence exists to indicate changes in the intensity and duration of worker exposures affects the health of swine confinement workers? Is there any evidence to indicate these changes will result in occupational health consequences for more workers?

The intensity and duration of exposure is expected to differ between large-scale swine production facilities, contract grower operations, and owner-operator facilities. The duration of exposure is variable and depends upon the degree of automation, the facility size, and whether or not farrowing and nursery are a part of the operation. Automation tends to decrease exposure time while work at large facilities and operations with farrowing and nursery grower units tends to increase exposure duration. In the smaller owner-operator swine production facilities farmers may spend as little as 10 hours per week in the swine barns and the rest of their time with crop production and other farm work. In some large operations, full-time workers spend 40 or more hours per week in the facilities. Across the industry, time spent inside swine barns is likely to increase with movement toward large-scale swine production. If one applies Haber's law of toxicology, the benefits of lower exposure concentrations (C) may be entirely offset by the longer exposure times (T), or expressed mathematically $C_1 \bullet T_1 \cong C_2 \bullet T_2$ where the subscripts denote different facility types.

The potential exists for improved exposure control in large-scale swine production facilities but whether or not this is being realized has not been documented. Larger facilities may be able to bring greater resources to bear to incorporate advanced control options and are more likely to have incentives to do so. These incentives could include improved worker health and morale, reduced health or liability insurance premiums, reduced worker compensation claims, future regulatory pressure, or fear of litigation. There is concern regarding swine production’s low profit margin, and this is an impediment to improved worker health and safety.

Research Needs

We recognize a need for comparative studies between large-scale swine production facilities and small owner-operator facilities to characterize exposure intensity and duration. In the past, it has been relatively easy for researchers to receive permission to study small operations and quite difficult to gain access to large-scale swine production facilities. We would encourage all producers to cooperate with research studies that may lead to better ways to protect worker and animal health in the swine industry.

Question #5. What is the impact of the proliferation of large-scale confinement production facilities on the above issues?

The Occupational Health Group believes that exposures and related occupational risks will increase with proliferating large facilities. This is mainly due to larger exposure periods. Increased risk does not have to happen if proper controls are implemented. Health and environmental surveillance by OSHA will increase as large-scale swine production expands. At some point, these large facilities will come under federal, state, and/or local regulatory scrutiny. OSHA has jurisdiction if an employer has 10 or more workers on a job site. However, this has not been rigorously applied to production agriculture which has been largely exempted from most aspects of the OSHA Act because of the predominance of owner-operator farms. Potentially applicable regulatory issues are listed in Table 3 (page 178) and illustrate the extent of potentially important regulations. A shift toward large-scale swine production has the potential to greatly improve health and safety and with it come some significant cost benefits. For producers who are proactive for worker health, there are potential rewards including a healthier, more stable work force, lower absenteeism, lower health insurance costs, and reduced worker compensation burden. There is a need for large-scale swine producers to have model surveillance programs they can implement. Respiratory exposure assessments available on a fee-for-service basis through independent parties could help develop guidelines for these producers based on actual environmental conditions in their facilities.

A second important potential impact of the proliferation of large-scale swine production facilities is the impact on public health. It is believed that these facilities will draw laborers from outside the surrounding communities, including immigrant or migrant laborers, and this will have an important impact on social services and health services in these communities. Important concerns that have been raised include the following: utilization of community resources and social service programs, immunizations, bilingual education and language translation generally, potential increase in tuberculosis and other transmissible diseases, further burdens on the health care system because of uninsured status, housing needs, mental health issues, and law enforcement implications. These concerns should be discussed in a broad consideration of the impact of a shift to vertically-integrated systems in agriculture.

Research Needs

An in-depth comparative study of the public health and social consequences needs to be conducted in counties where large-scale swine production has emerged, versus more conventional production areas. Social and public health needs and demands could be readily studied over time with information from the bureau of statistics and public health records.

TABLE 3.

Occupational Health Regulations Potentially Applicable to Swine Production Facilities

Material Safety Data Sheets for Chemicals and Drugs Used on Site
Right-To-Know Rules and Regulations
Confined Space Entry
DOT Placarding Rules
Child Labor Laws
Sanitation Issues
Tuberculosis Screening
Immigrant Labor Laws
Multilingual Training
OSHA Health and Safety Rules
Mechanical Safety Rules
Transportation and Commerce Rules
Community and OSHA Noise Standards
Pesticide Applicator Training
Americans with Disabilities Act

Question #6. What are the elements of a complete occupational health program for the environment?

In Table 4 (page 180), we have outlined the essential elements of a complete occupational health program for large-scale swine production facilities. Elements included in the program are an administrative component; an education and training component; an agricultural hygiene program geared toward recognition, evaluation and control; a health surveillance program; an emergency preparedness program; an employee assistance program, and the staff to oversee such a program. What is outlined in Table 4 represents a comprehensive model program that would serve a large-scale producer with a large number of employees. Smaller independent producers would need to implement a more modest program to meet their particular needs.

Research Needs

The prospective and retrospective studies outlined under 1A will help to confirm the answer to this question.

Question #7. What are the possibilities of insurance reductions if employers comply with an occupational health program?

Insurance reductions for providing a safer work environment can result in a significant cost savings. When combined with health care cost savings, reduced worker compensation costs, lower worker compensation coverage rates, lower absenteeism, and lower worker turnover, these can result in a net savings for the producer (Dr. G. Geiger, National Farms, Hersey, Colorado). Additional reduction in insurance rates can arise from employing non-smokers, good drivers, and for instituting wellness programs. The nationwide shift toward managed health care may increase the emphasis on health promotion and occupational health programs. The Occupational Health Group felt that State and National Pork Producers Council organizations could promote a “good

TABLE 4.
Elements of a Complete Occupational Health Program for Swine Production Facilities

- Administration
  - Right-To-Know
  - Placarding
  - Material Safety Data Sheets
  - Record Keeping
  - Compliance with Child Labor Laws and Americans with Disabilities Act
- Education and Training
  - Documentation
  - Multilingual
  - All Hazards Described: Respiratory, Machinery, Confined Space, Chemical, Animal
- Agricultural Industrial Hygiene
  - Hazard Anticipation, Recognition, Evaluation and Control
  - Exposure Assessment
  - Safety Inspection
  - Inspection of Ventilation Equipment
  - Noise Dosimetry
  - Respiratory Program (Some Operations)
    - Documentation
    - Fit testing
    - Storage and Maintenance
    - Training
- Health Surveillance
  - Pre-Placement Evaluation
  - Periodic Health Evaluation
  - Hearing Conservation program
  - Tuberculosis Testing
  - Trauma and Needle Stick Prevention
  - Reporting System for Illness and Injury
- Emergency Medical Services
  - First Aid Kits
  - Emergency Planning
  - CPR training
  - Self Contained Breathing Apparatus on Site if Confined Spaces
- Employee Assistance Program
  - Mental Health
  - Drug/Alcohol Abuse
  - Health Promotion Programs, e.g., smoking cessation
- Staffing
  - Occupational Health Professionals
    - Company or Contracted
  - Agricultural Hygiene/Safety Officer
  - Administrative Assistance

standards occupational health and safety program" that insurance companies would support and provide strong incentives for.

Research Needs

Additional research demonstrating the cost effectiveness of prevention programs in the agricultural sector would help promote such programs. A model demonstration projection comparing insurance incentives for occupational health programs to operations with no programs is important to effect the health of this industry.

Question #8. What are safe and economically achievable limit values for dusts and gases? What are effective and economically realistic dust and gas control measures?

There are no federally mandated permissible exposure levels for dusts or gases specifically for swine confinement facilities. Further, the American Conference of Governmental Industrial Hygienists, the professional organization that publishes Threshold Limit Values (TLVs), has not issued TLVs for this industry. It is widely held that general industry standards for many individual toxicants are not protective for the complex mixture of inhalation exposures in the swine environment. Exposures of relevance include aerobic and anaerobic bacteria, fungi, viruses, arthropods, animal aeroallergens, grain dust, microbial toxins including endotoxins and mycotoxins, phytotoxins, tannins, ammonia, carbon monoxide, hydrogen sulfide, noise, and heat. Of particular significance is the airborne endotoxin that arises from the cell wall of Gram negative bacteria. Inhaled endotoxin has repeatedly been shown to induce lung inflammation, cross-shift decline in lung function, and respiratory symptoms. Thus far, there are no exposure standards based upon the concentration of airborne endotoxin and it is hoped that standards based upon total dust (particulates not otherwise classified) will provide protection from endotoxin-induced pulmonary injury. Most researchers who have studied the swine environment would agree that existing dust standards do not provide sufficient safety for exposures in swine barns. It is widely held that guidelines from general industry are not applicable in this setting because the toxicants are more complex and represent mixtures of toxicants that act additively or synergistically.

Three dose-response studies have been conducted, attempting to define exposure levels associated with illness (Donham, Haglind et al. 1989; Donham, Reynolds et al. 1995; Reynolds, et al. 1996). These levels are listed under the Donham et al column in Table 5 (page 183). Such levels are practical and achievable, but few facilities meet these recommended levels, especially in winter.

Research Needs

An important research need is the development of better methodology for bioaerosol exposure assessment. It is also important that these services become more readily available to producers. Noise-induced hearing loss is common among swine workers and there is concern that the A-weighted scale applicable for general industry noise exposure may not represent spectral properties of noise in swine facilities.

Although there have been three studies suggesting safe limits for dusts and gases, additional research in this area is extremely important. This type of research is difficult to design because of the multiplicity of variables and exposures. A well designed prospective study is the best way to answer this question. The current recommended limits by Donham, Reynolds et al. (1995) could be tested by comparing the health response in workers and pigs in units that have variable levels of dust and gas exposures. This study would require a variety of facilities where the environment could be monitored and controlled, and have a compliant worker force and manager who would allow environmental testing, and human and animal health monitoring.

TABLE 5.

Exposure Levels Pertinent to Toxicants in Swine Confinement Facilities

Toxicant	Specification	ACGIH TLV[a]	OSHA PEL[a]	NIOSH REL[a]	Donham et al.[a]
Dust -PNOC[b]	total		15 mg/m^3		
	inhalable	10 mg/m^3			
	respirable	3 mg/m^3	5 mg/m^3		
Grain Dust[c]	total	4 mg/m^3	10 mg/m^3	4 mg/m^3	
Swine Barn Dust	total				2.4 mg/m^3
	respirable				0.23 mg/m^3
Ammonia	TWA[d]	17 mg/m^3		18 mg/m^3	7 mg/m^3
	STEL[d]	24 mg/m^3	27 mg/m^3	27 mg/m^3	
Carbon Monoxide	TWA	29 mg/m^3	40 mg/m^3	40 mg/m^3	
	STEL/Ceiling		229 mg/m^3	229 mg/m^3	
Hydrogen Sulfide	TWA	14 mg/m^3	14 mg/m^3		
	STEL/Ceiling	21 mg/m^3	21 mg/m^3	15 mg/m^3	
Carbon Dioxide	TWA	9,000 mg/m^3	18,000 mg/m^3	9,000 mg/m^3	1540 mg/m^3
	STEL	54,000 mg/m^3	54,000 mg/m^3	54,000 mg/m^3	
Endotoxin	TWA				800 EU/m^3
Noise	TWA	85 dBA[e]	85 dBA		
	STEL	100 dBA	115 dBA		

[a]ACGIH TLV is the Threshold Limit Value published by the American Conference of Governmental Industrial Hygienists, OSHA PEL is the Permissible Exposure Limit promulgated by the U.S. Occupational Safety and Health Administration, NIOSH REL is the Recommended Exposure Limit published by the U.S. National Institute for Occupational Safety and Health
Values for Donham et al. were published in Br. J. Ind. Med. 46:31-37, 1989 and Am. J. Ind. Med. 27:405-418, 1995.
[b]PNOC = particulates not otherwise classified
[c]Grain dust applies to dust from oats, wheat and barley only
[d]TWA = 8 hr time weighted average, STEL = 15 minute short term exposure limit, Ceiling = maximum allowable value
[e]dBA = sound level in decibels assessed using a sound level meter on the A-weighted network with slow response

Question #9. What are effective and economically achievable methods of environmental assessment for dusts and gases?

Effective and economically achievable methods of environmental assessment for dusts and gases have been developed by the National Institute for Occupational Safety and Health and are documented in the NIOSH Manual of Analytical Methods (NMAM), 4th Edition, DHHS (NIOSH)

Publication No. 94-113. These have been reviewed in a swine environmental control manual (Mutel, et al. 1992) and an American Lung Association manual (Donham, Ruskin et al. 1995). Total inhalable and respirable dust samplers are widely available and many contract or university laboratories can provide analytical support services. If regulatory compliance is not the motivation for sampling, one can purchase detector tubes (colorimetric) for gases and vapors which can be used as passive approximate assessment of exposure. There are a number of widely available economical methods for determination of ventilation. Personal noise dosimeters are commercially available for determination of A-weighted noise exposure. Bioaerosol sampling to determine airborne culturable organisms is not warranted and grossly underestimates the total microbial exposure. Most of the organisms will not grow under the aerobic culture conditions normally employed.

Research Needs

Research methods are available for the determination of total airborne microbes but are too complex and labor intensive for routine analysis. Several bioaerosol research laboratories are working to improve and streamline these methods. Methods exist for analysis of airborne endotoxins but they are rather expensive and await further validation through interlaboratory comparison studies which are underway at this time. It is hoped that standard methods for endotoxin exposure assessment will evolve in the next several years and that these will be available beyond the realm of research studies.

Question #10. What is an effective protocol and delivery system for this assessment?

There currently is a paucity of agricultural hygiene and laboratory services available to aid swine production facilities in exposure assessment and few producers have the capability to perform these functions in-house. There is a trial in progress to assess the utility of providing simple environmental testing kits that can be mailed to producers with instructions for their use, and then mailed back to a testing laboratory for analysis and interpretation of results. Preliminary results show promise for this approach. A network of regional hospitals and clinics has been organized in Iowa (Gay and Donham 1990) to provide occupational medicine services and such networks could disseminate information regarding where to get help with environmental assessment. There also are new "user friendly" analytical devices coming on the market which function as real time monitors. These are particularly of interest for large-scale producers, agricultural hygiene consulting laboratories, insurance companies, and producer cooperatives. There is a need for NIOSH or perhaps a university-based agricultural research center to issue a current intelligence bulletin addressing medical management, environmental measurement options, and environmental and administrative controls.

Research Needs

Training and certification of veterinarians to provide these services is an important consideration. Model programs such as the Iowa Agricultural Health and Safety Network, private consultants, and the Extension service need to be studied for their effectiveness of service delivery.

Question #11. What are the requirements of OSHA or other regulations and liabilities to employers for worker health in livestock production?

This is a complex issue that differs from state to state. The Occupational Health Group recommends that this question be referred to legal experts aware of federal and state laws pertaining to the strict legal definition of agriculture; Department of Labor and OSHA jurisdiction in agriculture; the workers compensation responsibilities of agricultural employers; protection of workers that are employed less than 100 days, providing bartered labor, or are extended family members; and personal injury law in agriculture. In addition, contract law is an important element because many smaller producers function as independent contractors who own the swine facilities on their property but do not own the hogs. Liability and responsibility under these circumstances may differ from one contract to the next.

Question #12. Are there additional important issues?

The Occupational Health Group sees a need for increased education of primary health care providers in identification, treatment and prevention of lung disease and other injuries in swine production workers. There are many important research questions that need to be addressed in order to improve worker health and the environmental impact of swine production as we move toward the 21st century. Occupational health research in agriculture has traditionally been underfunded compared to other industrial sectors. Solid answers to many of the questions posed to the participants at this conference can only be answered through additional biomedical and environmental research.

SUMMARY OF RESEARCH NEEDS

1. *Epidemiologic Studies*

   A long-term prospective study is the highest research need. Although these are expensive and time consuming studies, they are the best way to confirm answers to many of the questions that presently need confirmation or more complete answers. Questions of particular concern are the long-term health outcomes of workers, economic impact, and insurance incentives for effective health programs. A follow-up study of previously studied worker cohorts also has a high priority to help answer some of the most important questions listed above.

2. *Environmental Studies*

   Highest priority is to confirm the effectiveness of exposure limits by Donham, Reynolds et al. (1995). Before control measures can be prescribed, there must be environmental goals. These can only be confirmed by studying the relations between exposure and health response in controlled environments.

Also, a high priority is to investigate model occupational health delivery systems for the environment. This includes development of assessment methods that are affordable, efficient, and reliable for the producer and environmental consultant.

3. *Clinical Studies*

Treatment regimes including environmental exposure controls, personal protection, and the effectiveness of medical management plans are critically needed. We must be able to appropriately and ethically manage affected individuals in the work force for their own benefit and that of the livestock industry.

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SUMMARY AND DISCUSSION

by Neil D. Hamilton

The goal of the workshop was to generate scientific information to address a range of interrelated issues concerning large-scale swine production. The issues considered ranged from the direct and quantifiable, such as water quality, to the observable but less measurable, such as odor. The study also considered issues that, while more subjective, such as social and neighborhood concerns, are no less factual and legitimate. The issue of health risks to the workers directly involved in swine production were also considered. Part of the success and value of the effort comes from this comprehensive approach which attempted to consider the full range of scientific issues relating to swine production, rather than focusing on discrete issues of economic performance.

As the thoughtful introduction notes, the changes in swine production have resulted in factions within agriculture and society and even within the academic and research community. While academicians have been called on to deal with these questions, it has often been in the context of validating or justifying one or the other piece of the system, e.g., responding to their constituencies. This has made it difficult for institutions to perform their true functions. The natural constituencies that have developed between the swine production industry and the institutions of government and education, and the nature of the current debate have also contributed to this situation. The question in the minds of many observers has been, Where is the objective or neutral scientific appraisal of the issues and the science? How can society adequately address these important policy issues if this information is not available? This challenge, which motivated creation of a process to identify and respond to issues raised by the changing swine industry, faced the participants who are responsible for developing this report.

A central question to ask in this conclusion is, Did the workshop meet the challenge, or at least engage it directly and professionally? The answer is, clearly, yes. While the factions that exist, as noted in the introduction, may react differently to the report, there is no doubt it is a valuable effort and perhaps the most comprehensive attempt to look at this range of questions in a neutral setting. The information it presents about the current state of scientific knowledge for a range of important questions is extremely valuable. This information should be of value to all parties in the debate, whether producers, government officials, or individuals concerned about some aspect of the changing nature of swine production. But perhaps even more important are the contributions of the report on two other fronts – identifying the questions for which we do not have adequate answers and highlighting the range of important research topics that need to be addressed.

The process that generated the study was both sound and, unfortunately perhaps, too unique in the operation of science today. The process, as explained in more detail in the introduction, was to first hold a meeting with the people raising concerns about these developments and ask them to generate the questions they wanted science to be able to answer. This was done at a conference in Kansas City, Missouri, in November 1994. The second step was to bring together scientists in a neutral forum and have them discuss the questions, to consider the "answers" that were available, and then to prepare their own thoughtful reports summarizing the work. The five substantive sections presented in this document are the result. Readers can answer for themselves whether the information in the sections was either "independent" in the sense desired by the workshop organizers, or "scientific" in the manner of what is commonly expected from researchers. From my perspective, both challenges were met.

The study identified a series of important questions on which more and better research is needed if we are to be confident in the adequacy of current production methods and waste handling practices, and even regulatory approaches, to adequately protect both human health and the quality of our natural resources.

Water Quality

The excellent section on water quality raises a series of questions concerning the need for better data. The section begins by observing how the artifice of many efforts to segregate treatment of water issues – ground water from surface water and non-point from point source pollution – makes it difficult to study and address the water quality issue in a comprehensive or systematic manner. An important concern is not the ability to answer the questions we can identify (although even there answers may often be inadequate), but to recognize there may be questions we have not even begun to ask.

This thorough section addresses the issues presented and makes many significant points. Highlights include the need to study the reliability of waste handling systems and how the lack of field survey information on the performance of lagoons raises questions about the sufficiency of current systems. The study also notes that in our efforts to manage land application of waste, the difficulty in knowing the precision of the application or the nutrient content of the wastes raise questions about our predictions of the environmental impacts. In other words, while we may understand the mechanisms for how water pollution happens, we cannot fully evaluate our contribution to it.

This section also notes that the manner of how wastes are utilized as part of a farming operation naturally varies depending on the scale of the facility. The authors conclude that large operations may need regulations to force the most efficient use of waste as a nutrient, due to the amounts available and the costs and requirements of transportation and application. From both a resource protection and an operational standpoint, some issues are naturally affected by the scale of the operation in question. The implication is not that we should regulate large facilities just because we feel we should; we should regulate them because we have to in order to protect water resources.

As these selected observations reflect, this first section report is a comprehensive and thoughtful treatment of the major questions relating to water quality protection. The authors make many suggestions for how we can best address these issues, including how observing the experience in the Netherlands, which has dealt with intensive concentrated waste handling needs, can be useful in predicting the issues we will face. As with the reports that follow it, perhaps the most valuable part of the water quality section is the identification of research needs. This extensive listing, which begins with the dire need for research based on performance of existing hog confinement systems, is an important gauge of what we should know, but yet do not. As a final valuable observation, the section's conclusion includes the thought that our research should be focused on answering real questions, not based on the premise that we should accommodate an existing system of industrializing swine production. In other words, science must have the integrity to let the facts take us where they will, not trim the search or the report to fit what we think is required.

Air Quality

The section dealing with air quality is important because it addresses the feature of large-scale swine production – odor – that is the single most significant factor stimulating societal concerns. While there are a variety of other issues, such as farm structure associated with the matter, many observers believe that if swine production did not stink, there would be little societal attention to these developments. But having confronted this single most important issue, the section authors are left with the reality of our current state of knowledge. This is represented by two simple facts: first, that swine manure odor is the result of a complex mixture of organic compounds primarily produced in the anaerobic decomposition of swine wastes; and second, that while those things we can most readily measure, such as ammonia and hydrogen sulfide, are related to odor they do not adequately explain its presence. The conclusion is perhaps the obvious one: swine waste odors occur for a variety of reasons related to the chemistry of swine wastes produced, the nature of the rations fed, the waste management system used, and the method of disposal employed. The section authors acknowledge that research shows human responses to swine odor are both a function of physiological factors and psychological or emotional factors, and that recent research indicates the two are not unrelated.

The air quality section presents a straightforward response to the many questions raised in the workshop and gives the present state of our understanding on such matters as the possible human health effects of odors and the potential for microbial contaminants to pass into the environment. The greatest value of the section, in addition to presenting current research findings, is in identifying the areas in which additional research is needed, whether on such questions as possible microbial contaminants or the greenhouse gas effects of livestock production in North America. Realistically, the section notes, there is no correct answer to the query, Is there an acceptable odor exposure level? What is an acceptable level will vary by individuals and communities, with the social norm of local communities helping establish what is acceptable.

The section concludes by noting that the current changes in the structure of swine production may present opportunities for scientific advances in the understanding and management of odor and air quality. One opportunity is to revise facility and waste handling design standards, which were developed decades ago for a structure of producers then in place. Whether the issue is loading rates of waste disposal or the effect of the surface area of lagoons on odors, the movement to larger facilities will require new understanding of how to address air quality. This section also observes how the movement to larger facilities may result in producers having access to greater resources, notably financial, which can be used to control odor and air quality. The section optimistically notes the need for society to provide adequate incentives for this to happen. However, the reality of the impact of existing legal and regulatory provisions on such a development must also be recognized. There is little reason to expect that larger scale swine operations will spend additional sums to implement more costly waste handling and odor control techniques, unless they are required to do so, either by regulation or the threat of potential legal liability, such as nuisance suits. Until the market also pays for "clean air," or the lack of odors, it may be overly optimistic to think that community spirit will lead large corporate-owned facilities to spend a portion of profits to make things either safer or nicer for the neighbors. Twenty years of legal and regulatory developments related to swine production, namely society's support for right-to-farm laws and other regulatory protections, may show the fallacy of such hopes.

Social Issues

The section on social consequences, a central part of the proceedings, is both valuable and frustrating. The section is valuable in that it represents a comprehensive attempt to identify and consider a range of social science issues and the research that has been done on them. In doing so, it is possible to consider which questions have been answered and which have not been addressed or even asked. This process contributed to the authors being able to identify a number of concrete areas of needed research. While this effort should prove valuable in helping set the future research agenda, it is frustrating to confront the obvious voids in our current research and understandings.

This section begins by noting that in the mountains of research produced about swine production, little has been written about the "social dimensions" of the sector. This lack of research no doubt contributes to the current difficulties of institutions, both governmental and educational, in responding to the concerns of rural residents and neighbors of proposed facilities. Perhaps more worrying is that this lack of past research may be contributing to the current institutional response to such citizen complaints. As the authors note, this response is typically to treat individual's reports of problems from swine facilities as “subjective” and as not really legitimate concerns. Perhaps the main observation from the section is the need for the scientific community to treat the social concerns that citizens may have about changes in the swine sector as legitimate and worthy of attention. The failure by much of the institutional structure to respect these complaints and investigate their origins has contributed to the sense of frustration felt in impacted communities. It is also a factor helping fuel attempts to use legal remedies for redress, a development which in itself is often ineffective and politicizing for local communities.

The social consequences section systematically addresses the various questions raised and documents the existing social science research and how it might apply. The discussion of citizen experiences in North Carolina and Iowa, and the upsurge in formation of grassroots citizen groups to oppose large facilities, is illustrative of the social dynamics in question. Topics such as the role of core values in helping define the “neighborhood” and the impact of changing agricultural labor relations on rural communities show the range and complexity of the issues involved. Throughout the section, valuable suggestions are made concerning the nature of the research needs in this area. These specific suggestions validate the central conclusion of the section: If we are to develop a truly sustainable swine production system, social science research must be an essential part of the mix. If the institutions of government or higher learning, to which society traditionally turns for answers, fail to adequately investigate and address the concerns of citizens who fear the impacts the changing nature of swine production is having on their communities, these institutions will have failed to fulfill their social function and will contribute to a growing level of frustration and tension that may threaten the performance of agriculture.

Economic Development

By focusing on economic considerations, the fourth major section of this document addresses many of the issues that go to the heart of why the shift toward large-scale swine production may be occurring. It begins by placing the current controversy into the historical context that there have always been debates about the nature of agricultural development and who benefits from changing systems of farming. The authors note the current debate may differ in the size of the gulf dividing the two sides, something reflected in the tenor of the debate. The sharpness of the controversy has many implications, including several important ones for this effort to marshal a scientific approach to the issues. The first is that for many people in the debate, there is little middle ground on most of the issues. This fact is readily apparent, but nonetheless unsettling, to university researchers attempting to address the issues. The second is that for many parties in the debate, though perhaps more so for those who oppose expansion of large units, there is a growing mistrust of the university research community, or at least a lack of confidence in its ability to fairly address these issues.

The authors of this section make valuable observations about the nature of the questions they were asked to address. Most important perhaps is that many of the questions themselves reflect a bias or flow from a given set of values. In addition, the questions generally deal with fairly specific matters of impacts and effects but in so doing, may not provide sufficient consideration of the larger or macro-level developments influencing agricultural production. A final valuable observation was the apparent common confusion that exists about the difference between economic growth and economic development as relates to both the benefits from, and the impact of, changes in the structure of swine production.

After making these important observations about the nature of the controversy and the process being used to generate the report, the section authors proceed to address in turn each of the many questions presented. As with earlier sections, the answers insightfully present the current state of research on the issues and highlight the many areas in which adequate data are not available. The authors attempt to deal with questions that range from which size of facilities are most efficient (it depends on how efficiency is defined and whether externalities are accounted for), to what are the impacts of large operations on the distribution of economic returns in an area (very little research has been completed). These answers provide the basis for many important insights and recommendations, including the need to explore the use of coordination and networking as one response to impacts on local purchasing patterns; the need to develop better forms of economic models to account for the impact of shifts in production structure on local economies; the shifting nature of the access to information and research in an era of declining public resources and increasing private proprietary activities; and the impact of credit availability and other government policies on these shifts.

The section concludes with an insightful discussion of the need to consider not just what is happening (as is the focus of this report) but also the importance of thinking about alternatives for what the future could bring. The authors conclude by presenting a vision for the development of a swine production system based on a foundation of sustainable agricultural principles and offer it as one possible alternative to the current industrial model being promoted and evaluated in many areas. By doing so, the section provides hopeful and helpful suggestions for producers seeking to orient pork production to a sustainable future, and for researchers, especially those at public institutions, considering such alternatives.

Occupational Health

Occupational health concerns relating to swine workers could become one of the most important management and social issues relating to swine production, especially if production continues to move into larger-scale confinement facilities and makes use of more hired labor. The health effects on workers in the swine industry has not received significant attention in the policy debate over the changing structure of the swine industry. However, in recent years, there has been a growing awareness by medical researchers and health providers of the significant health effects experienced by swine workers, in particular respiratory problems. This section is an excellent presentation of the state of our knowledge on swine worker health issues. It does this by attempting to answer a series of focused questions generated from the 1994 Kansas City conference, an earlier conference in Nebraska, an Iowa survey, and a pork industry committee on occupational health.

The section provides a straightforward and powerful appraisal of the potential health effects swine workers may experience. It begins by classifying the range of health risks according to the time frame of their effects. The section then presents a picture of the current state of medical knowledge about health risks on issues such as: What are the indicators of the potential for serious health problems? Are the problems reversible? Who experiences the problems?

The discussion about the range and frequency of respiratory health problems experienced by a significant portion of workers is disturbing. It highlights the need for greater education of both workers and health care professionals about these matters. The discussion also presents a solid justification for additional research, in particular, the priority for a long-term prospective study as called for by the authors. Perhaps as importantly, the section clarifies the need to develop preventive programs to help protect the health of swine workers. To their credit, the authors have attempted to begin the process of creating a complete occupational health program for swine production facilities.

The section addresses a variety of important questions, the most significant of which is: Are worker health problems being contained through current management practices? The authors are optimistic that, in fact, the health risks they identify can be significantly reduced by use of management practices, engineering controls, judicial use of personal protective equipment, and health surveillance. But their disturbing conclusion is that such programs are rarely used in today's swine industry. This observation is perhaps the most important of the section – while we know serious worker health risks exist, we have not adequately addressed them. The main reason is the primary goal of swine engineering has been to focus on the benefits to swine production, not on worker health.

In light of the medical data reflected in the answers in the section, one can only conclude that this must and will change. The proliferation of large-scale units will increase the potential exposure of workers and related occupational health risks. As the awareness of the potential risks increases it can be expected that additional regulatory attention will come from state and federal agencies. It is also likely that the companies involved in swine production will increase their attention to worker health issues, both to improve the performance and safety of their work force and because of potential concerns over liability.

From this basis, the section concludes by presenting the elements of an occupational health program for swine production facilities. This valuable listing will in many ways provide a template for the industry on issues of worker health, for the medical community in shaping needed research studies, and for the government in evaluating the performance of the sector in protecting worker health.

Policy and Legal Issues

The five major sections in this report represent a thorough effort to identify the questions society and the scientific research community should be asking. The previous discussion has highlighted a number of significant observations from the effort to begin answering these questions. This effort also identified an extensive list of issues on which additional research is needed. The challenge now is for the scientific community, with the support of society and the swine industry, to begin the process of carrying out this research. The resources, in terms of funding and personnel as well as institutional commitments to the process, necessary to engage such a broad research agenda are not insignificant. If science is to play the role we expect of it in helping society address the important issues related to the changing nature of swine production, these resources must be forthcoming. While society has a range of other options available to it for addressing the growing controversy, which could include doing nothing or providing unquestioning support for the development of an industrial model of production, these other approaches may not resolve the controversy in a manner that is satisfactory to the many participants, including swine producers, or may only serve to increase the frustration and mistrust growing in some segments of rural society. Another option, which has already been the subject of considerable attention, is use of legal and regulatory approaches, either to establish minimum levels of performance, such as through waste handling guidelines, or to provide protections from liability for qualifying operations, such as right-to-farm nuisance suit protections. While there is an important role for law to play, and resort will no doubt be made of legal remedies and requirements, law should only be one mechanism society turns to for relief. Even then, the societal decisions reflected in the law must be based on something. Our hope is that sound scientific information and research will be a significant part of that basis on which laws are developed.

Any effort to summarize the state of our scientific knowledge on an issue as broad and potentially controversial as this would not be honest it if did not at least ask, Does society really care what “science” says on this matter? To many participants in the controversy, the answer might be, Well, it depends on what the science says or whose science it is. Others might argue we really do not have time to wait for science to provide answers because the developments are underway now and must be resolved in the near future. This concern may be especially pertinent because much of what science provides is not in the form of “answers,” but instead is information upon which society must act to develop its own answers. Clearly, it will not be possible to resolve all concerns people might have about the ability of science to aid society in this controversy, nor will it be possible to make everyone happy. But the scientists who contributed to this effort are committed to their belief that science does have an important role to play. A society that is willing to attempt to resolve social issues as significant as those considered in this report without the use of science is a society that values neither the integrity of its educational system nor is honest about the use of its policymaking processes. More importantly, it is a society that may one day reap a bitter harvest of social strife, resource exploitation, human suffering, and economic dislocation.