CHALLENGES AND OPPORTUNITIES IN LIVESTOCK MANURE MANAGEMENT

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Summary

Livestock production, including hog, will continue to be a very important component of Canadian agriculture and environmental issues and will play an increasingly important role in the continuous and sustainable development of this industry. Despite of all the recent research, development and extension efforts in that area, manure management will likely continue to be the top environmental issue facing pork production in Canada. Anticipated challenges and opportunities in the area of swine manure management research in Canada include topics related to in-barn manure collection and handling, manure characterization, manure treatment, odour control, handling and land application of solid and semi-solid manure and the development of a systems analysis approach to manure management. This last issue has a strategic importance for the purpose of integrating research results and individual expertises in order to identify optimal manure management systems that are adapted to the specific needs and constraints of different hog operations.

Introduction

Livestock production will continue to be a very important part of the global agricultural system on the planet in the future. In a recent report, the Council for Agricultural Science and Technology (CAST) of the United States of America predicted that meat consumption in developing countries would more than double by the year 2020 while it would approximately follow the population growth in developed countries (CAST 1999). As a result, the global demand for meat products is expected to reach 160% of the actual level of consumption by the year 2020. It is also likely that the world demand for other animal products, especially milk and eggs, will follow similar trends. Canada continues to offer many comparative advantages for livestock production: availability of land (for unconfined (pasture) livestock production and for the production of forage and grains); competitively priced feed products; competent workforce; education, research and development capabilities; livestock production efficiency; reduced incidence of disease; transportation networks; processing industries (meat, milk, eggs and other animal products) that yield high-quality products. These advantages place our country in a very competitive position to benefit from the expected growth in the global market for animal products.

AAFC (1998b) identified five major issues related to the development of the pork industry in Canada : environment, financing, labour, foreign investment and export marketing. Environmental issues were considered the most important as they also have significant impacts on many of the others. The Canadian pork and livestock industries will thus need to continue to take into account a number of environmental and societal issues related to changes in livestock farm sizes and structures, increasing non-agricultural uses in rural areas, nuisances from livestock operations, human and animal health concerns and protection of ground and surface water in order to develop and expand in an orderly fashion. Many of those issues have already

important impacts on livestock production in Canada and it is most likely that the environmental and social pressure on the future development of this important agricultural sector will continue to increase.

Optimal management of livestock manure remains a major challenge for the continuous and sustainable development of the livestock industry in Canada. In 1996, the Canadian Pork Council (CPC) acted as a leader of the Canadian livestock industry when it published the *Canadian Code of Practice for Environmentally Sound Hog Production*. This set of environmental guidelines leaves a large place to manure management issues : storage, land application and treatment (CPC 1996). Only a few months ago, the Canadian pork industry initiated a very challenging project related to the development of a National Standardized Environmental Management System (NSEMS) program for Canadian hog producers.

Despite of all the past and on-going research and development work in that area, the national research priorities identified by the Canadian Agri-Food Research Council (CARC) for the year 1999 – 2000 still identify manure management as a top issue in relation with the environmental sustainability of livestock production in terms of odour reduction, optimal timing and amount of manure applications, alternative storage methods, alternate uses, noise and dust abatement, particularly with reference to large, intensive livestock operations such as swine barns, cattle feedlots, poultry and dairy industries. According to CARC, "managing manure remains a significant deterrent to the expansion of the livestock industry" (CARC 2000). The research priorities of the CPC for 1999 – 2000 also made a large place to the continued development of sustainable manure management practices in terms of building design and management, feeding management, manure storage, treatment and land application, as well as the identification of alternate uses for swine manure (CPC 1999). Many of those issues could be found within the recommendations that the Steering Committee of the National Workshop on Land Application of Animal Manure made to the Canadian Agricultural Research Council back in 1990 (Cock et al. 1990). This does not imply that nothing has been done in the area of livestock manure management in Canada during the last decade; it rather demonstrates that much remains to be done; especially in the light of the establishment of a NSEMS for the pork industry.

The purpose of this presentation is first to briefly review some of the major milestones in livestock manure management research and development in Canada since 1996 and then to share some views and perspectives about what lies ahead in that area for the coming years.

1. R&D in livestock manure management in Canada since 1996

Even today at the beginning of the 21st century, many individuals and organizations, both inside and outside of agricultural and agri-food communities still consider manure as a waste product that must be disposed of. The origins of this widespread attitude can be traced back to the approach to manure management research conducted in the 1960's and 1970's that focused almost exclusively on the disposal of manure-associated nutrients to soils and crops without much concern for the environmental impacts of excessive application rates or of improper modes of application. According to Hatfield and Stewart (1997), this has played a major role in the current generalized misunderstanding of manure issues.

Nowak (2000) has placed the evolution of that situation in an interesting perspective. He refers to it as "The Transformation of Manure" in which animal manures were first considered as a most valuable resource in the pre-industrialized age, such a perception being still predominant in most remaining pre-industrialized societies around the planet, even today. The industrialized age was at the origin of the first transformation of manure, shifting its perception from a valuable resource to a waste product. In today's post-industrialized modern societies, animal manures are currently undergoing a second transformation as they are no longer considered simple waste products (dispose and forget) but rather become environmental contaminants.

This change of perception has not only influenced the way animal manures are considered, it has also had a direct impact on the research and development initiatives in the field of manure management over the last few years. Most research priorities, both at the national and provincial levels, have largely focused on minimizing the impacts of manure management systems on the natural resources and ecosystems (air, fauna, flora, soil and water).

The online database ManureNet presents a partial inventory of the research, development and demonstration projects initiated in the 1990's in the area of manure management in Canada (AAFC 2000). Since 1995, more than 200 different projects have been or are currently being completed across the country. Although this inventory is probably incomplete, it allows for the identification of research areas that have received more attention during that period of time.

This analysis reveals that a large part of the research, development and demonstration efforts have been targeted at treating animal manures and also at efficiently and effectively applying it to soil-crop systems for recycling purposes. Some achievements include:

Land application: gas emissions from land-applied swine manure; fate of nutrients from land-applied swine manure; high efficiency, low disturbance, shallow injectors for liquid swine manure; application of swine manure on different soil-crop systems that can make a better use of manure nutrients (timeliness, rates of application, etc.).

Manure characterization: effect of swine and cattle manure application on incidence of soil borne plant human pathogens with the potential to yield important knowledge about the concentrations and survival rates of harmful micro-organisms in animal manures; modifying feeds and feeding systems to reduce nutrient excretion and/or make excreted nutrients more available to soil-crop systems; methodologies and equipment for the rapid determination of the concentrations of major nutrients in manure.

Manure handling: in-barn options for manure handling (partially vs fully slatted floors, flush vs pull-plug vs mechanical scraping removal of manure, in-barn composting, etc.), flow control systems for manure pipeline systems; in-line nutrient sensing.

Manure storage: operating lifetimes for earthen manure storages (EMS) and long-term performance and safety of these types of storages; coverings for manure storage tanks and EMS; measurement and reduction of

emissions from storage structures; combined storage of manure with wastes from other industries (forestry, food).

Manure treatment: assessment of liquid hog manure treatment and management technologies and pilot-scale evaluation; composting of swine manure with other by-product or waste materials; use of artificial wetlands to filter and polish swine manure.

All these research initiatives have yielded and are continuing to yield valuable information about an expanding set of best management practices (BMP) for swine manure. Thanks to this research effort, numerous options are now available to Canadian livestock producers at every link of the manure management chain: in-barn collection, storage and handling; long-term storage; land application; treatment and value-added processing, etc.

2. Challenges and opportunities for the future

Since the focus of this panel is on swine production, let us concentrate on the challenges and opportunities in the management of hog manure in Canada over the next decade. However, most of these challenges and opportunities apply equally to other livestock productions.

In the past, manure management systems were often considered as externalities to animal production systems, which allowed for the development of highly effective and efficient production systems for livestock (Nowak 2000). Now that manure management systems, with a special emphasis on environmental protection, are increasingly being incorporated into animal production systems, we come to realize that the overall efficiency and effectiveness of the latter are decreasing. This author is proposing to use an agro-ecological approach that integrates biophysical, technological and human considerations across space and time to optimize livestock production systems in which manure management systems are integrated. Such an approach will require that the cost of environmental protection be included into the prices of animal products for the consumers and this will become an unavoidable challenge in the near future (Miner and Moore 2000).

2.1 Nature of the problem

Assessing the exact nature of the problem is an important first step. It is essential to know what quantities of manure are produced on Canadian hog farms. The current total pig inventory on Canadian hog farms may be estimated at about 12.3 million heads, including 1.3 million dry and nursing sows, gilts and boars, 4.0 millions weanlings and 7.0 millions feeder pigs (CPC 2000) and Table 1 presents some estimates of the annual manure production of that national pig herd. More than 50 millions tonnes of swine manure are currently produced on Canadian hog farms, including over 2.5 millions tonnes of solid products. Those solid products include almost 2 millions tonnes of organic materials, 143,000 tonnes of nitrogen, 46,000 tonnes of phosphorus and 93,000 tonnes of potassium. However, it can be seen that swine manure is not a commodity that is produced uniformly across the country. According to McEwan and Patience (2000), the current hog production intensity in Canada ranges from 5.5 (Saskatchewan) to 180 (Québec) hogs produced per year per square kilometre of arable land. These different intensities of production are likely to require different solutions in terms of manure management systems and technologies. Other important factors to consider include the current geographical distribution of swine manure production across the country (Table 1) and also the projected evolution of those

numbers in light of factors such as the expansion of the industry, improved feed and water management in hog operations resulting in reduced manure production, changes in manure management processes and systems also allowing for such reductions, etc.

Table 1. Estimated manure production of the Canadian swine herd on an annual basis.

Province	**Manure production [1] (millions of kg)**			**Solid components of manure [1] (millions of kg)**				
	Total	**Water [2]**	**Solids [3]**	**Organic matter [3]**	**Total N [4]**	**Total P [4]**	**Total K [4]**	**Other Solids**
Alberta	7,464	7,090	374	254	21	7	13	79
British Columbia	601	571	30	20	2	1	1	6
Manitoba	8,498	8,072	426	289	24	8	15	90
New Brunswick	423	402	21	14	1	< 1	1	4
Newfoundland	19	18	1	< 1	< 1	< 1	< 1	< 1
Nova Scotia	581	552	29	20	2	< 1	1	6
Ontario	14,042	13,340	702	478	39	13	25	148
Prince Edward Island	509	484	25	17	1	1	1	5
Québec	15,705	14,920	785	534	43	14	28	165
Saskatchewan	3,928	3,732	196	134	11	4	7	41
Canada (total)	51,770	49,181	2,589	1,761	143	46	93	545

[1] values have been rounded to the nearest million kg and may not exactly add up;
[2] assuming an average solid content of 5% w.b. for all types of swine manure on Canadian farms;
[3] CDPQ (1999);
[4] SAF (1997).

Because of its composition, swine manure can be used in many different ways (Laguë et al. 2000):

- ✓ as a source of mineral nutrients for soil-crop systems (manure as a fertilizer);
- ✓ as a source of organic matter for soil-crop systems (manure as an amendment);
- ✓ as a source of energy for use within the livestock production system or outside (manure as a fuel);

- ✓ as a source of water for soil-crop systems (manure for irrigation);
- ✓ as a source of water for use within the livestock production system (manure as "brown water") or,as combinations of the above.

For each specific situation in terms of location, type and size of production unit, only a limited number of these options may be interesting once all the relevant criteria are accounted for (economical, environmental, technical, societal, etc.). However, because of the diversity in the characteristics of Canadian hog farms, it is most likely that an increasing number of these different manure management options will need to be considered in the future as it has been the case in other hog producing areas around the world.

2.2 Needs identified by different organizations

In 1998, the Research Branch of AAFC published its research strategy for hog manure management in Canada (AAFC 1998a). Five major issues associated with the environmental impacts of swine manure management have been identified: odours, ammonia emissions, soil suitability for manure application, pollution by phosphorus, and sustainability of pork production. Short- and long-term research needs were determined for each of those issues.

Within the development process of the Hog Environmental Management Strategy (HEMS) by AAFC in 1998, a very challenging short-term (1998 – 2001) environmental vision for the Canadian hog industry was developed (AAFC 1998b). It stated that "effective, affordable solutions will be developed and implemented for each of the key environmental issues associated with the industry: odours, soil and water quality, and air pollution". Most will agree that we are not quite there yet, which is why research and development efforts need to be intensified and more closely coordinated.

Provincial jurisdictions have also taken a proactive role in the identification of priorities for research, development and demonstration work in manure management. The province of Manitoba has been very active in manure management research and development since the mid 1990's (Tessier 1999). Fifteen research needs have been identified; for each one, the current status of implementation as well as the remaining outstanding needs are presented. In Saskatchewan, seven key strategic areas have been identified in terms of manure management needs: storage, application and use, odours, handling and transportation, treatment, environmental planning, and communication and extension (SAF 1999). Specific needs for research, development and extension have been identified for each of those areas.

2.3 Selected challenges and opportunities

Challenges and opportunities for an environmentally sustainable management of livestock manure are numerous. Some of these challenges and opportunities are presented in this section. The different topics are organized by alphabetical order and not by order of relative importance, which is a parameter that is very difficult to precisely assess. However, it is strongly believed that the development, validation and implementation of a system analysis approach adapted to manure management problems and issues (sub-section 2.3.6) constitutes an area of major importance that should be addressed very rapidly.

2.3.1 In-barn Manure Collection and Handling

The results from many studies conducted in Canada and abroad confirm that the rapid removal of animal excretions from the production buildings can have positive effects on the air quality within the barns and therefore on the health of the barn workers and of the animals (PSCI 1998). There is thus a need to develop systems for in-barn manure collection and handling that are capable to meet that goal. For example, a recent study conducted in the United Kingdom concluded that the addition of a 3-mm layer of recycled and filtered vegetable oil on top of liquid manure within the barn collection pits could reduce both odour and ammonia emissions by 60 and 50% respectively (Pahl et al. 2000). Other systems could be designed to handle mixed manure (urine, feces and wasted feed and water) or they could provide some primary solid-liquid separation of the manure and direct the two resulting products within two different management streams (ex. use of the liquids for irrigating crops and land application of the solids). Improved solid-liquid separation techniques can now allow for the removal of up to 90% of the total and volatile suspended solids contained in raw flushed swine manure (Vanotti et al. 2000). Production systems based on solid manure management (shallow or deep litter, in-barn composting, etc.) also require improved collection and handling processes and systems. Other more unusual avenues also need to be further explored. The conversion of livestock manures into valuable larval biomass products through the continuous digestion of manure by insect such as the Black Soldier Fly constitutes a good example (Sheppard and Newton 2000).

2.3.2 Manure Characterization

A lot of effort still needs to be put into improving the efficiency of pigs at converting feed nutrients into meat and thus rejecting less of those nutrients in their urine and feces. At the present time, about half of the total nitrogen ingested by pigs is rejected by the animals. Since nitrogen is a high-value material, both in terms of dollars and energy, there is a need to make a better use of it. At the same time, it is also necessary to better understand the fate of the excreted nitrogen, especially in terms of reducing the amount of nitrogen-based products that are lost to the environment in forms that can cause pollution (ex. ammonia, nitrates, nitrous oxides) (PSCI 1998). Diet manipulations also offer the possibility of positively impacting on odour emissions (Powers and Van Horn 2000). The value (agronomic, economic, environmental) of manures amended through improved production techniques and feed conversion efficiency will also need to be determined.

The addition of foreign materials to manure (ex. mineral nutrients, other types of organic wastes or by-products) in order to improve its end-use value or to make it better suited to further processing or treatment is another potentially interesting area that should be further investigated (Casey et al. 2000; Hobbs et al. 2000). Some recent work even suggests that the composting process of biological materials such as livestock manures could be used to accelerate the degradation process of biodegradable plastic materials (Kimura et al. 2000).

2.3.3 Manure Treatment

The land base that is required to apply increasing quantities of swine manure in an environmentally sustainable way and the associated increased hauling distances that are associated with larger hog operations are likely to make manure treatment a more interesting option for those operations in the future. Larger operations concentrate larger volumes of manure and larger quantities of nutrients at a given location and therefore increase the risks of

point source pollution (Miner and Moore 2000). Research should be targeted at developing, validating and optimizing systems and processes that allow for reducing manure volumes and concentrating nutrients through improved water management inside and outside the production buildings, more efficient use of feed materials by the animals, separation of the liquid and solid phases of the manure, manure aeration, etc. Systems and processes that make use of the volatile solids for the production of energy could also become interesting and viable options for larger hog operations. Moser and Mattocks (2000) have reported that various types of anaerobic digesters for livestock manures have been efficiently and effectively operating on livestock operations of all sizes in the United States of America over the last twenty years. In a related study about a 16-year old anaerobic digester installed on a dairy farm in California, Moser and Langerwerf (2000) reported that this system had generated revenues in excess of US$700,000 for the farm while the total capital and operating costs of the system during that period of time amounted to less than US$400,000. Another potentially interesting area is the thermochemical conversion of animal manures into oil products (He et al. 2000).

2.3.4 Odour Control

Scientific evidence is increasingly suggesting that the manure components that cause odours can affect human and animal health in addition to be responsible for nuisances (AAFC 1998b). Guidelines and regulations related to the control of odours from livestock operations are also becoming more stringent (PSCI 1999). A survey completed in the United States of America reveals that 44 states do enforce regulations on odour emissions and that those regulations are becoming more and more objective, relying more on odour measurement rather than on odour perception (Redwin and Lacey 2000). Control of odours and of odour-generating substances, including dust, at the different stages of the manure management chain (production buildings, manure storages, land application operations) is thus likely to be a major issue in manure management over the next years. Technologies and management techniques that reduce odours at the source should be preferred to odour abatement methods (PSCI 1998). Improved methods for objectively assessing odour intensity and offensiveness as well as the dispersion of odours in the atmosphere are also required in order to improve the regulations and standards related to separation distances (Vozzo and Chen 2000).

2.3.5 Solid and Semi-Solid Swine Manure

Handling and land application systems for solid and semi-solid manure have experienced much less technical research and development efforts than comparable systems for liquid manure and slurry over the last thirty years or so. The net result is that the number of technological options for solid manure handling and land application, as well as the efficiency of the systems currently available for these purposes, are very limited. As an example, the coefficient of variation for the manure application rate delivered by modern solid manure spreaders can range anywhere between 20 and 180% (Nowak 2000). Achieving controlled and constant application rates under such highly variable conditions of equipment performance becomes a very difficult task. However, many organizations are identifying solid manure as a potential alternative to liquid manure systems in terms of reducing environmental and societal problems that may be associated to liquid manure management. Innovative building designs such as the High-Rise^{TM} concept developed in the United States of America try to combine the advantages of liquid manure for in-barn handling with those of solid manure (Menke 2000; Stowell et al. 2000). As a result, a number of research initiatives related to the management of swine and other animal

manure as a solid or semi-solid are currently underway in Canada (AAFC 2000). Although a number of those initiatives call for some sort of value-added processing of the solid end product (ex. drying, screening, packaging, etc.), there also exists a need to investigate the technological requirements for handling and land application systems for bulk solid and semi-solid swine manure. This type of research could also directly benefit other livestock industries (ex. cattle, poultry) that manage manure as a solid or a semi-solid product.

2.3.6 Systems Analysis

The development of a framework of analysis for livestock manure management based on a systems analysis approach is urgently needed (Laguë et al. 2000; Nowak 2000). This strategic issue has also been identified as a research priority both by AAFC (AAFC 1998) and the CPC (CPC 1999). Such an approach involves the definition of manure management systems in terms of inputs (urine, feces, wastewater, etc.), processes (collection, handling, storage, treatment, etc.) and outputs that become inputs into other systems (e.g. nutrients for soil-crop systems, energy for livestock production operation or for outside uses, "brown water" for livestock buildings or for irrigation of soil-crop systems, etc.). It allows for the integration of expertise and research results from different disciplines for the purpose of defining, as completely as possible, all the internal and external processes that make up a particular manure management system. By doing so, it then becomes possible to compare different manure management systems in order to select those that allow for an optimal use of the manure (maximum benefits and minimum inconveniences) under specific conditions (type, location and size of livestock operation; manure characteristics; environmental and societal issues, etc.).

Conclusions

A lot of work has been done but a lot more still lies ahead. This sentence summarizes in itself the essence of this presentation about the challenges and opportunities in livestock manure management research, development and extension in Canada since the mid 1990's. Not so long ago, animal manure were considered as a most valuable resource for agricultural systems. As agriculture moved into the industrial age in the 20th century, this perception rapidly changed as manure became a waste product that needed to be disposed of. Environmental concerns that emerged in the latter part of the 1900's changed again that perception to a point where animal manures are now often considered as dangerous environmental contaminants or hazardous products. Future research, development and extension work in livestock manure management must focus on strategies, systems and techniques that allow for maximizing the benefits of manure uses while minimizing the impacts of those uses on the natural resources and ecosystems. The integration of agronomic, economic, environmental, societal and technical considerations by means of a systems approach constitutes one of the best methods for achieving that goal.

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ABOUT THE SPEAKER

Since January 2000, Claude Laguë is the chair holder of the Sask Pork Chair in Environmental Engineering for the Pork Industry at the University of Saskatchewan. Dr. Laguë is also professor at the Department of Agricultural and Bioresource Engineering of the University of Saskatchewan and adjunct rersearch scientist in engineering at the Prairie Swine Centre Inc.

Before moving to Western Canada, Claude Laguë obtained his bachelor's and master's degree from Laval University and his doctorate from the University of California in 1990. He worked as a project engineer for Urgel Delisle et Associés inc., an agricultural and environmental engineering firm located in the province of Quebec. He then became professor of Agricultural Engineering, Department Head and Associate Dean for Research at Laval University.

Claude Laguë is member of many agricultural engineering associations. In 1998, he received the "Young Engineer of theYear Award" from CSAE.