Analysis of Extensive Hog Farming in Quebec

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EXECUTIVE SUMMARY

The recent growth of Concentrated Animal Feeding Operations (CAFO's) across North America, leading to an increased agricultural production, has intensified the cost shifting of social problems, health problems, and pollution to surrounding community and environment.

This report provides a synthesis of existing data on water consumption, water contamination and some of the health consequences of industrial hog farming in Quebec and attempts to place a dollar value on several of these costs. However, the current limitations of an economic cost-benefit approach lead to the proposal of an alternative approach involving a precautionary risk assessment.

We were able to calculate an estimate for the cost of water used by the hog industry. We also found that the pollution of water by the hog industry is mainly due to the associated crop production, and the liquid manure disposal. Due to the diffuse nature of this pollution we were only able to place a dollar value on the treatment necessary to make the water potable. It is not possible at this time to derive an appropriate cost for the impact of the hog industry on human health in Quebec, as there is not enough data to make clear links between a source of pollution and the impacts on human health.

Further research and data is needed to better identify both sources of pollution and the subsequent health effects. However, we should not have to wait until there is clear, uncontested evidence that there are negative impacts to health before taking action to prevent it. We recommend several preventative measures to reduce water pollution and to improve the public health surveillance system.

Introduction

The Quebec government plans to double exports from the hog industry by the year 2005, a goal that will be achieved primarily through the expansion of concentrated animal feeding operations. Although these intensive feeding operations are less economically efficient than small operations, they generate high revenue in part due to cost shifting, which reduces their production costs (Weida, 2000). Cost shifting occurs when the costs of health problems, social problems and pollution are transferred to the residents of a region and are neither paid by the company responsible for the costs nor included in the price of the products they market (Wieda, 2000). Public scrutiny of the safety of waste management from animal production facilities has intensified since seven people in Walkerton, Ontario died after drinking water that had been contaminated by microorganisms from animal manure. A better understanding of how water resources and human health may be impacted by hog production is required so environmental risks of the proposed hog industry expansion can be quantified accurately.

Our goal is to provide a synthesis of existing data on water consumption, water pollution and health consequences of industrial hog farming in Quebec to provide our clients with some of the information necessary to perform a cost-benefit analysis. However, most environmental pollution is diffuse and pollution in agricultural regions may originate from many sources. Cost-benefit analyses may not be the most appropriate technique for evaluating the environmental impact of the hog industry of externalities such as health care and environmental costs. Since our clients want to perform economic analysis that accounts for these hidden costs, we propose the use of risk analysis or the precautionary principle as alternative analytical frameworks.

Since the 1970's, there has been a trend towards the industrialization of small, traditional animal farms into large, concentrated animal feeding operations (CAFO's) across North America. Similar expansion elsewhere in Canada has resulted in a significant increase in the national hog production for both domestic and export markets, making hog production a major component of the Canadian agricultural sector. Industry expansion created 29 500 direct and indirect jobs across Canada in 1999, and resulted in an economic spin-off of 3.7 million dollars (Federation du Porc, 2000). At present, Quebec has the highest concentration of large hog farms in Canada with 81% of the farms generating over $250 000 (MAPAQ, 2000). Hog industry revenues were 747 million dollars in 1999, and accounted for 24% of province's total agricultural revenue (Federation du Porc, 2000). The revenue from hog exports has also increased in the last five years and over half of the hog produced in Quebec are now sold on export markets. The value of Quebec's hog exports in 1999 was about 634 million dollars compared to 278 million dollars in 1994 (MAPAQ, 2000).

The trend toward increasing intensification and concentration of hog operations should increase profit for producers, but large operations will be subject to two economic restrictions: diseconomies of scale and diminishing returns. Diseconomies of scale occur when an element in the production process increases faster than the size of the process itself. One element in hog farming is disease; the more concentrated the hogs, the greater the possibility for disease outbreaks. The need to limit shed population sizes, the heavy reliance on antibiotics, the costs of maintaining a sterile site, time limits on site location, as well as the destruction of whole flocks because of outbreaks all increase the costs of the operation (Weida, 2000).

Hog operation size will also be constrained by diminishing returns, which is the "break-even" point where the marginal cost of one additional hog unit exceeds the marginal product of one hog unit. Manure disposal is an example of how hog operations are constrained by diminishing returns. Often, intensification of hog production is not accompanied by the purchase of more land so the agricultural land available for feed production and waste disposal remains the same (Weida, 2000; Fraser, 1985). The costs of disposing animal waste responsibly and transporting feed from locations far from the hog farm, eventually become inefficient.

The diminishing returns on larger farms are illustrated throughout the country where smaller farms have higher profit margins than large farms (MAPAQ, 2000). Profit margins are calculated by dividing the amount of profit, total revenues minus the total expenses, over the total revenue. In Quebec, small farms who declare between $50 000 and $100 000 in revenue per year have a profit margin almost five times greater than that of large farms who declare over $500 000 in revenue per year (MAPAQ, 2000).

Despite diminishing returns, farms who declare $500 000 or more in revenue are growing in number in Quebec and across Canada (MAPAQ, 2000). The apparent inconsistency between the trend in intensification and increasing internal economic inefficiency could be explained in two ways. First, large CAFO's are able to maximize tax benefits and subsidies by employing production practices that allows them to be classified in both agricultural and industrial categories. In 1997, the Quebec hog industry received around 130 million dollars in subsidies from the federal and provincial governments (MAPAQ, 2000). If the hog industry received an equivalent amount of subsidies in 1999, subsidies would have represented approximately 20% of the industry's revenue. We have not included tax rebates or other incentives that hog producers may receive. Second, cost shifting can also reduce the cost of production in hog operations. The costs of health problems, social problems and environmental pollution are paid by residents of the region, and damages are neither paid by the company responsible nor included in the price of the products they market (Weida, 2000).

The increase in CAFO's is also changing the cultural and social systems in small farming communities, and there is evidence that CAFO’s have detrimental effects on the local economies of surrounding communities. Research has shown that independent hog producers create three times as many jobs as contract producers, and for each 12 000 slaughter hogs produced by contract producers there is a net loss of over 18 jobs (Fagan, 1995). Furthermore, independent producers create 10% more permanent jobs, a 20% larger increase in local retail sales and 37% larger increase in per capita income than large corporations (Fagan, 1995).

Water Use

When one considers that only 0.007% of all the water on earth is readily accessible for direct use (Environment Canada, 1996), it is important to evaluate the ways in which we distribute the use of our freshwater resources. Since there is a finite amount of water at our disposal, we should attempt to assign a cost to the amount of water used, especially by its primary consumers.

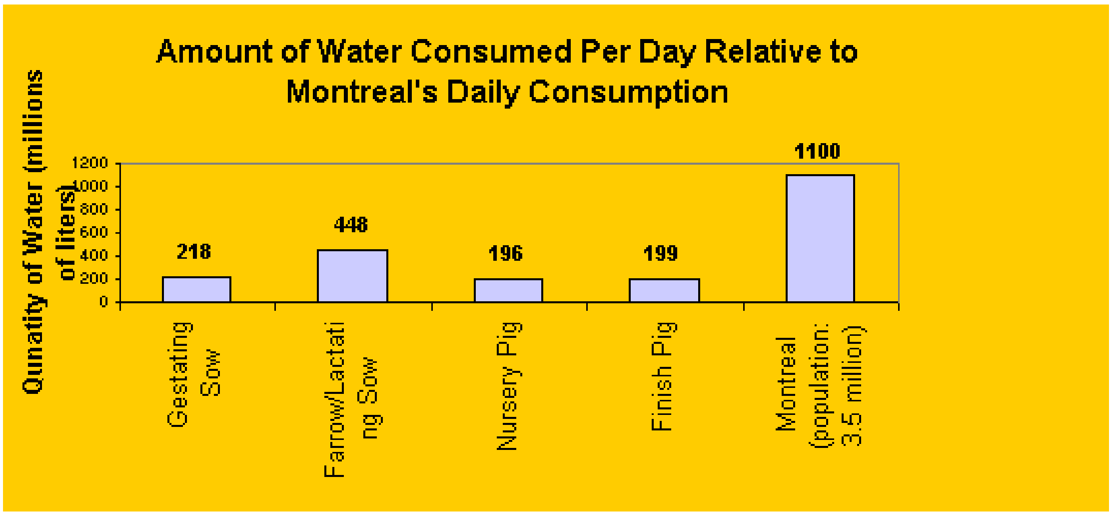
The industrial production of hogs requires a large amount of water for drinking, cleaning facilities, sanitizing equipment, and diluting manure (Kienholz et al., 2000). For the purposes of this assessment, these have been categorized into two main uses: drinking water and flushing water. Drinking and flushing water are considered ‘withdrawal uses’ and are measured as the amount withdrawn from the source for a particular activity over a specific period of time (Environment Canada, 1996). This analysis assumes that minimal quantities of water are reused in hog production facilities. Therefore, all references to quantities of water used pertain to ‘gross water use’ (Environment Canada, 1996). However, the quantity of water consumed by each animals depends largely on physiological and environmental conditions such as age, life stage, temperature, humidity, activity level and water content of the feed (Kienholz et al., 2000). To account for this variability, this analysis will provide a range of water consumption values and water consumption costs, as opposed to a fixed number.

The amount of water consumed for drinking and flushing purposes is presented for four life stages: a gestating sow, a lactating sow, a nursery pig and a finish pig. The total amount of water consumed by individuals in different life ranged from 66.25 to 151.25 liters per hog per day (Table 1).

Table 1: Water consumed for drinking and flushing purposes in liters/ hog/ day by hogs during four physiological life stages from [1]Weida, 2000 and [2]Kienholz et al, 2000 of Agriculture and Agri-Food Canada.

Physiological Life Stage	Drinking Water [L/H/d]	Flushing Water[1] [L/H/d]	Average Total Water Consumed [L/H/d]
Gestating Sow	18.75[1]	56.25	75
Farrow/Lactating Sow	20[2] - 26.25[1]	131.25	154.38
Nursery Pig	11.25[1]	56.25	67.5
Finish Pig	10[2]- 15[1]	56.25	68.75

In order to calculate yearly water consumption by hogs in each life stage (Table 2), the amount of water used on a daily basis per hog was multiplied by the number of hogs in Quebec, which was then multiplied by the number of days in a year. The average Canadian consumes 386 liters of water per day, and the population of Montreal is currently approximately 3.5 million (Statistics Canada, 2000), an estimated 11 billion liters of water are consumed daily. Therefore, the hog industry in Quebec consumes from 18 to 41% of the daily amount of water consumed by the city of Montreal (Figure 1).



The inventory of hogs in Canada as of January 1st, 1999 was 12.5 million, of which 3.63 million (29%) are raised in Quebec farms (Statistics Canada, 1999).

Table 2: Total quantity of water consumed by hogs per day and year in Quebec. [1]values from Table 1; [2]number of hogs housed in industrial farms in Quebec, assumes that all hogs are in the same physiological life stage.

Physiological Life Stage	Water Consumed (L/H/d)[1]	Number of hogs[2] (10^3)	Total water consumed (10^3 L/d)	Total water consumed (10^3 L/yr)
Gestating Sow	75.00	3 630	272 250	99 371 125
Farrow/Lactating Sow	154.38	3 600	555 768	200 855 320
Nursery Pig	67.50	3 600	243 000	88 695 000
Finish Pig	68.75	3 600	247 500	90 337 500

The total annual water consumption by hogs in Quebec was estimated to range from 88.7 billion liters for nursery pigs to 200.1 billion liters for lactating sows (Table 3). To assign a cost to the quantities of water consumed by the hog industry, we used the average municipal water prices for Canada. While most intensive hog production operations are located in rural areas, rural water prices were unavailable for this assessment. The price of tap water, including the cost of waste treatment, in 1992 Canadian dollars, is $0.82 per 1000 liters (Environment Canada, 1996).

Table 3: Total cost of water consumed by hogs per year in Quebec based on value of Canadian currency in 1992.

Physiological Life Stage	Total water consumed (10^3 L/yr)	Cost of Water (per 10^3 L)	Cost of water ($/yr)
Gestating Sow	99 371 125	0.82	79 496 900
Farrow/Lactating Sow	200 855 320	0.82	160 684 256
Nursery Pig	88 695 000	0.82	70 956 000
Finish Pig	90 337 500	0.82	72 270 000

The annual cost of water consumed for intensive production of hogs in Quebec is estimated to range from 71 to 161 million dollars (Table 3). The estimate is likely conservative because we did not account for fresh water added to manure storage lagoons and the price of water was not corrected for inflation. We were unable to find water prices for rural areas, where the majority of hog industries are located. We were also unable to find water prices for different provinces.

Water Pollution and Treatment

Water Pollution

A trend towards large-scale agricultural and livestock production the last few decades has increased the pressures on environmental resources and has contributed to the contamination of surrounding water supplies throughout Canada (Nolet, 1999). In Quebec, four watersheds dominated by the intensive production of cash crops and by intensive hog production also contain the most polluted rivers in the province (FPCCQ, 1999). The poor water quality found in these regions is partially the result of agricultural practices such as improper manure spreading, the increased use of chemical fertilizers and pesticides, and the lack of soil conservation practices which contribute to diffuse pollution (BAPE, 2000). While the deterioration of water quality is linked to the intensification of both the agricultural and livestock industry, there is no direct causal relationship between the size of hog production facilities and the magnitude of water pollution produced. Nevertheless, the complexity of managing manure surpluses and monoculture fields tends to increase as the size and intensity of industry increases, which may have direct implications for water contamination (Fraser, 1985).

To understand the importance of large-scale hog production on water pollution, we analyzed both direct and indirect sources of pollution. In addition, we investigated the different sources of pollution associated with livestock production, including the production of animal feed, and the relative contribution of large-scale hog production practices to water pollution. Thus, the pollution of water by the hog industry is not restricted to pollution from manure alone, but includes pollution that is emitted through crop production as well. Furthermore, the hog farms are often located in agricultural regions that include other types of livestock production and/or other agricultural industries that complicate attempts to isolate and quantify the pollution.

Direct sources of pollution from the hog industry include manure and nutrient volatilization from waste storage facilities. While the provincial Regulation for the Reduction of Pollution of Agricultural Origin (Bolinder et al., 1998) requires the installation of covered, water-tight manure storage facilities, only 90% of hog producers have adequate storage facilities (Enright, pers. comm., 2000). Even with clay liners, lagoons allow waste to leach into the ground. Since lagoon specifications allow leakage through the clay liners at a rate up to 0.036 inches per day, at the maximum allowable rate, a three acre lagoon could legally leak more than a million gallons a year (Weida, 2000). To a lesser extent, ammonia volatilization, a process by which nitrogen from the open waste lagoons is transformed into gaseous forms and enters the atmosphere, can contribute to water pollution when it is deposited in the landscape (Gangbazo, 1984). However, as most lagoon systems are now covered according to regulation, pollution in agricultural landscapes from nitrogen deposition has decreased.

It is difficult to determine how much water pollution could originate from the hog industry, so we examined characteristics of the hog industry to assess whether the risk of pollution was higher from hog farms than other agricultural operations. First, in order to remain competitive industrial hog producers increase the size of operations by increasing animal confinement and by improving feed quality (Enright, pers. comm., 2000). However, these measures may increase the amount of manure produced per animal and change its composition (Fraser, 1985). The larger volume of animal manure in areas with increased numbers of hogs requires more land for manure storage and disposal (Fraser, 1985). Due to the expense involved in purchasing extra land, hog producers have tended to over apply manure to dispose of excess manure (Enright, pers. comm., 2000). Subsequently, the environmental impact of hog production would be reduced if agricultural production zones were less concentrated but the difficulty involved in getting permits for new facilities outside these zones encourages producers to concentrate (Enright, pers. comm., 2000).

In addition to problems related to intensification, are those related to the inherent characteristics of the hog manure that increase nitrogen and phosphorous contamination. First of all, many hog producers in Quebec use liquid manure handling systems, and the nitrogen in liquid manure is generally more readily available to the plants than the nitrogen in solid manure. As a result, the nitrogen is more likely to be lost to the environment through leaching (Enright, pers. comm., 2000). Furthermore, compared to other livestock manure, hog manure contains one of the lowest nitrogen to phosphorous ratios (Fraser, 1985). Since plants generally require two to three times more nitrogen than phosphorous, soils fertilized by hog manure can become saturated with phosphorous (Donham, 1995). The increased input of phosphorous onto soils, coupled with the limited capacity of some soils to retain phosphorous, increases the risk of phosphorous contamination of surface water. Problems related to phosphorous runoff include eutrophication; overgrowth of algae and aquatic plants; reduced oxygen levels in water; and subsequent changes in the species composition of the aquatic ecosystem (Bolinder et al., 1998). In response to problems associated with phosphorous contamination, the UPA (Union des Producteurs Agricoles) now recommend that wastes be spread according to the amount of phosphorous required by the crops, instead of by the amount the nitrogen (BAPE, 2000).

The limited amount of land available for hog producers to spread manure results in the preferential production of corn for hog feed due to its high nitrogen requirements, which allow for the highest rate of manure application per hectare. The recommendations for crops like wheat, barley, oats and canola range from 40 to 90 kg N/ha, whereas the corn recommendation is 120 to 170 kg N/ha, and most producers put on 150 to 200 kg N/ha to ensure a maximum yield (CPVQ, 1996). Despite the high nitrogen requirement of corn, the crop has poor root systems that prevent it from absorbing all nutrients in the manure (Moore, pers. comm., 2000), resulting in a greater potential for nitrogen losses.

Corn production also contributes to water contamination through the use of herbicides to remove weeds. Corn producers are the primary consumers of herbicides, and spray 94% of the fields under cultivation (FPCCQ, 1999). Accordingly, high pesticide contamination risks are found in Lanaudiere, Monteregie-Est and Monteregie-Ouest, which are regions dominated by corn crop production (Table 4). There are currently incentives being developed to prevent pesticides from reaching the water table due to the presence of significant amounts of pesticides in water (FPCCQ, 1999).

Corn production is also associated with herbicides, and heavy use in the past has resulted in the resistance of the crop to some herbicides (Gingras et al., 2000). Compared with other types of agricultural production, St-Laurent Vision (2000) confirmed that corn production is mainly responsible for herbicides leaching into surface and ground water (Giroux, 1998). At the present time, atrazine and metolachlor are the two corn herbicides that are found most often in rivers. Of the two, atrazine has been measured above regulation levels suitable for aquatic life and drinking water (Gingras et al., 2000) in many regions associated with heavy corn crop production (FPCCQ, 1999).

Further complications associated with intensive corn production relate to fertilizer application. Although the Quebec Regulation for the Reduction of Pollution of Agricultural Origin prohibits the application of manure between October 1st and March 31st (Bolinder et al., 1998), the restrictions do not account for climate and soil variability that may allow for less than ideal conditions at the time of application. Since corn producers are discouraged in applying manure during the summer, their fields are fertilized either before seeding or after harvest when the soil is often too damp and the nutrients are not yet required (BAPE, 2000). Consequently, corn production induces soil and field management problems, leading to soil compaction, soil erosion, and over fertilization (Enright, pers. comm., 2000).

To avoid over fertilisation of any farm, waste surpluses need to be reallocated to avoid adverse effects to the environment. Since this involves transporting the manure to other locations at high costs, this practice is not widely performed. In fact, only 10% of cropping industries in Quebec currently accept manure from other industries which indicates there is a high potential for spreading excess manure on other areas, thus reducing the stress in regions of concentrated agricultural practices (FPCCQ, 1999). The nutrient surplus resulted in the formation of the Plan Agro-Environnementaux du Quebec (PAEF), new legislation that requires the installation of cooperatives to allocate surplus manure (BAPE, 2000). Mandatory for all farms by 2004, the new legislation also restricts farmers in the amount of fertilizer that can be applied, as well as the time of its application. Despite this potential solution, mineral fertilizers are being applied to maximize output in certain areas even though nutrient surpluses are observed throughout the province (FPCCQ, 1999).

Hog manure characteristics and land use in agricultural regions occupied by large numbers of hog producers have contributed to higher nutrient surpluses in hog-dominated regions than regions occupied by any other agricultural activities (FPCCQ, 1999). On average, regions in Quebec containing hog farms have almost four times as much nitrogen (Figure 2) and almost twice as much phosphorous per hectare in comparison to regions without hogs (Figure 3).

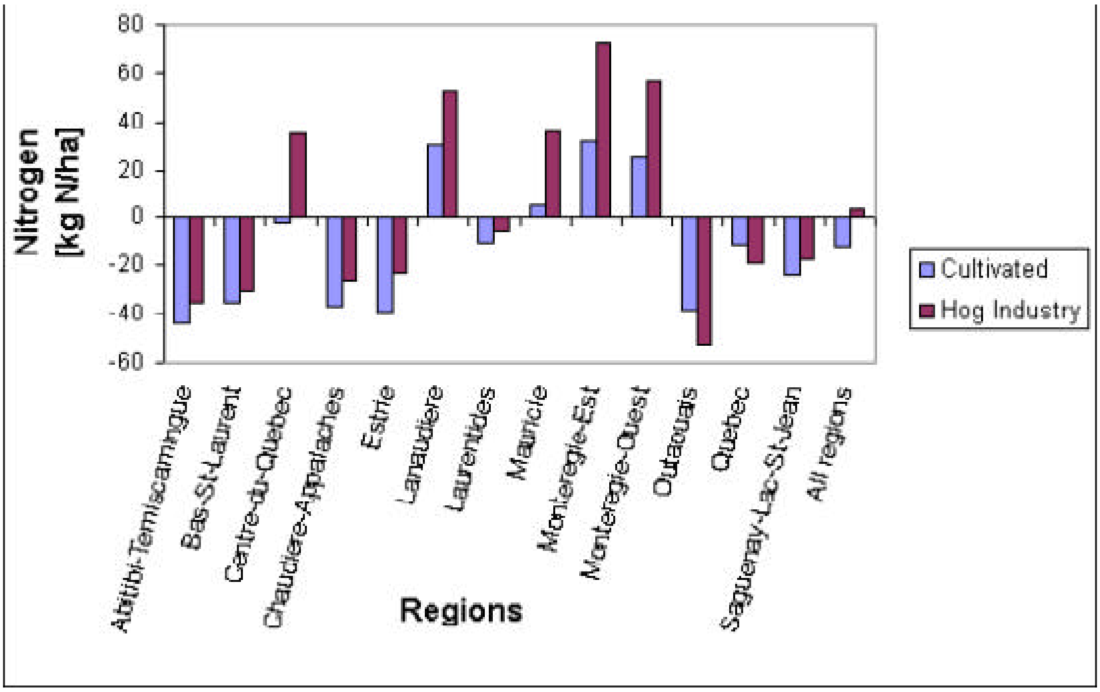


Figure 2: Amount of nitrogen (Kg/ha) on land cultivated by other agricultural industries and on land occupied by the hog industry for thirteen regions in Quebec (FPCCQ, 1999). Note: Region listed as Saguenay Lac St. Jean region includes Cote Nord and Nord du Quebec.

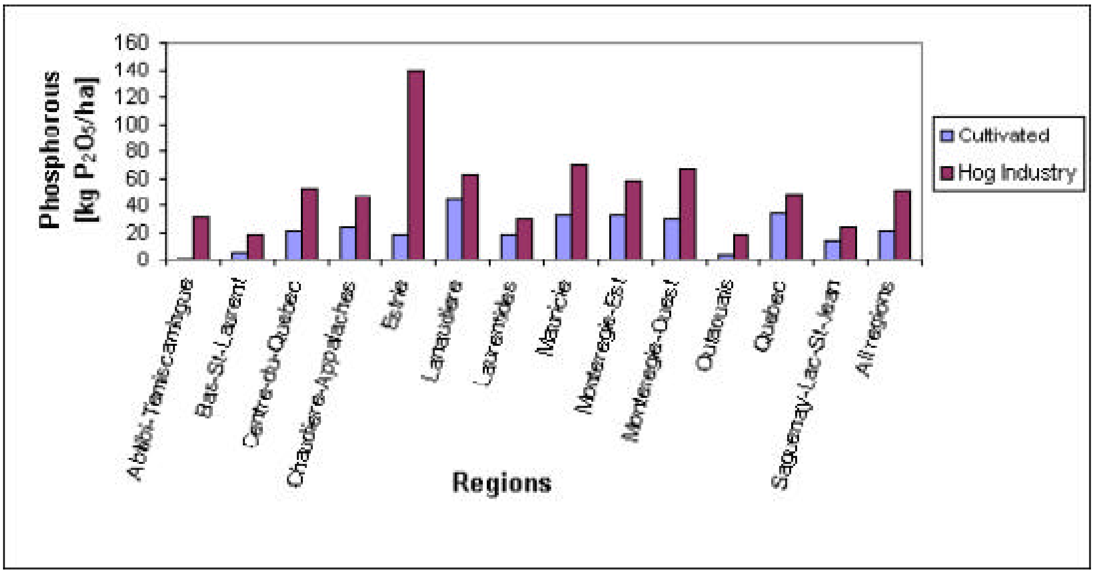


Figure 3: Amount of phosphorous (Kg/ha) on land cultivated by other agricultural industries and on land occupied by the hog industry for thirteen regions in Quebec (FPCCQ, 1999). Note: Region listed as Saguenay Lac St. Jean region includes Cote Nord and Nord du Quebec.

The risk of contamination by nitrogen, phosphorous and pesticide pollution in the agricultural regions of Quebec was assessed (Table 4). Of these thirteen regions, seven had high to very high risks of diffuse phosphorous pollution attributed to over fertilization (FPCCQ, 1999). In addition, three regions were at high risk for diffuse nitrogen pollution, which were assessed from data regarding nitrogen application, volatilization during manure spreading, soil conservation practices, drainage, crop type, and runoff potentials (FPCCQ, 1999).

Table 4: Risks of point source pollution and diffuse pollution for 13 regions in Quebec, including data regarding the presence of cash crop production in the regions. Note: L=low risk; M=moderate risk; H=high risk; VH=very high risk. [1]Saguenay-Lac-St-Jean region includes Cote-Nord and Nord-du-Quebec (FPCCQ, 1999).

Region	Dominant Cash Crop Production	Risk of Point Source Pollution		Risk of Diffuse Pollution		
		N and P	Pesticides	N	P	Pesticides
Abitibi-Temiscamingue	No	H	M	M	M	M
Bas-St-Laurent	No	H	M	M	M	M
Centre-du-	Yes	M	M	M	H	M

Quebec						
Chaudiere-Appalaches	No	H	M	L to M	M	E
Estrie	No	M	M	L	H	M
Lanaudiere	Yes	M	M	H	VH	H
Laurentides	Yes	M	L	M	H	M
Mauricie	Yes	M	M	M	H	M
Monteregie-Est	Yes	H	M	H	H	H
Monteregie-Ouest	Yes	H	M	H	H	H
Outaouais	No	M	L	L	M	M
Quebec	No	M	L	M	M	M
Saguenay-Lac-St-Jean[1]	No	M	M	M	M	M

The six regions with high to very high risk of either nitrogen or phosphorous contamination are also dominated by cash crop agriculture. The risk of water contamination is higher in these regions due to widespread use of conventional rather than conservation tillage practices (FPCCQ, 1999). For example, in the Lanaudiere region, where annual crops account for 70% of cropping area, only 8% of the area practices soil conservation techniques (FPCCQ, 1999). Furthermore, six of these high risk regions including the Centre-du-Quebec, Laurentide, Mauricie, Monteregie Est and Monteregie-Ouest, also contain intensive hog production industries.

In addition to contamination of surface water, studies across Quebec show that around 40% of private wells are contaminated with nitrates, pesticides or microbes emitted by the agricultural industry (MSSSQ, 1996). However, it is difficult to determine what type of industry is responsible for the pollution. This is partly due to the lack of data and hydrogeologic maps of ground water processes such as aquifer vulnerability, recharge, and quality (BAPE, 2000). While independent and fragmented studies do exist for some areas, this information has not been synthesised. Consequently, information regarding well-water quality is derived primarily from well drillers. At present, no policy exists for ground water quality control, but regulations for well water control may be passed by March 2001, and will require new home owners to test water for contamination (Ouellet, pers. comm., 2000).

Water Treatment

Environment Canada (2000) estimates that the limited capacity of our lakes, rivers and ocean to treat the wastes that enter our water is costing us billions and billions of dollars to clean up or to prevent. Practices associated with industrial hog production, including intensive feed crop production, inputs of manure, fertilizer, pesticides and herbicides, contribute to the contamination of water. Water must be treated by municipal water treatment facilities before it is suitable for human consumption. However, it is generally difficult to attribute the cost of water treatment to only one industry because of problems associated with determining the source of pollutants in concentrated production zones (Massicott, pers. comm., 2000).

To quantify the cost of water treatment, we compared treatment costs of two municipalities that use the same technology but take their water supply from either a highly polluted river or a clean river. Differences in the size of treatment facilities, workers employed and amount of water treated make it difficult to compare overall treatment costs (Massicott, pers. comm., 2000). Therefore, we examined the cost difference of products used to treat water in two municipalities, which include coal, ozone, sand, chlorine and the coagulant alum sulphate (Sauvageau, pers. comm., 2000).

The two municipalities chosen are L'Assomption, which treats water from the heavily polluted Assomption River and St. Lambert, which treats a relatively clean section of the St. Lawrence River. The L'Assomption region is an ideal site for this analysis because it is located in a region of concentrated hog farms (Sauvageau, pers. comm., 2000). It is likely that the hog industry contributes to pollution in this watershed because the industry accounts for 52% of the animal production and 31% of the corn production in the area (SLV, 2000). From Table 5, the cost of water treatment products in the L'Assomption region is four times the cost required for St. Lambert water. This comparison provides a general estimate of some of the costs associated with water treatment in agricultural areas concentrated by hog farms.

Table 5: Cost of water treatment products per 1000 m^3 for L'Assomption and St. Lambert regions in Quebec.

Region	River Treated	Level of Pollution	Number of Products Used	Cost of Treatment ($/1000 m^3)
L'Assomption	L'Assomption	High	11	0.062
St. Lambert	St. Lawrence	Low	5	0.015

Human Health

The contamination of water supplies by the livestock industry results in thousands of bacterial infections in Canada each year (Statistics Canada, 1999). Within the last decade, 1100 to 1600 cases of *Verocytotoxigenic E. coli* infection were reported annually in Canada, with the majority of cases attributed to infection by *E. coli* O157:H7. Between 9800 and 14000 cases of *Campylobacter spp*. infection were reported in Canada from 1986 to 1998 (BGOSHU, 2000).

Case Study

The recent outbreak of gastroenteritis in Walkerton, Ontario provides a useful case study of the human health effects of water contamination microbial pathogens originating from animal manure. On May 19th, 2000 the town of Walkerton, experienced the largest outbreak of waterborne, bacterial gastroenteritis by multiple pathogens in Canada to date (BGOSHU, 2000). This incident marks the first time *E. coli* O157:H7 has ever contaminated a treated municipal water supply in Canada (BGOSHU, 2000). Of the 4900 residents of Walkerton, 1346 people (or 30% of the total population) became sick with gastroenteritis, and 2300 people overall (including people from outside the town of Walkerton) became sick with gastroenteritis from consuming the bacterially contaminated water. Gastroenteritis is diagnosed by the presence of diarrhea, or bloody diarrhea. Stool specimens may be infected with *E. coli* or *Campylobacter spp*. and patients can develop hemolytic uremic syndrome (HUS). One hundred and seventy four individuals tested had evidence of *E. coli* in stool samples, and 116 people had *Campylobacter spp*. in stool samples. Sixty-five people were admitted to hospital, 27 individuals developed HUS, and six people with HUS died. A total of 1000 people sought treatment in hospital emergency wards (BGOSHU, 2000).

The health costs resulting from the Walkerton epidemic have not yet been determined. While we cannot quantify the health costs at this time, a citizens group has filed a civil class-action suit claiming a total damage of $300 million dollars. In the aftermath of the outbreak, three separate surveys found that people consuming Walkerton water were nearly 12 times more likely to develop gastroenteritis than people who did not consume Walkerton water (BGOSHU, 2000). By mid-September, it was estimated that the Walkerton tragedy had already cost Ontario taxpayers $20 million and the "big-ticket items have yet to come" (The Edmonton Journal, 2000). Other costs to Ontario taxpayers include 12.2 million dollars to increase the activity in the water-monitoring program (The Edmonton Journal, 2000).

There are many other non-quantifiable damages associated with the outbreak, ranging from psychological damages associated with fear of contamination to the disruptions of regular behavior. The impact of the Walkerton outbreak remains, as the loss of those who died continues to affect the survivors of Walkerton. An environmental simulation model of drainage patterns and rainfall events indicate that the microorganisms contaminating the water supply likely originated from animal manure from a small Walkerton cattle farm (BGOSHU, 2000). The outbreak followed heavy rains that are thought to have played a large role in transporting bacterial contaminants into the water supply (BGOSHU, 2000).

Although the case of water contamination in Walkerton was the result of cattle manure, it is possible that a similar scenario could arise due to contamination of water by hog manure. This is supported by case studies in North Carolina that have linked hog run-off to outbreaks of bacterial gastroenteritis. Furthermore, these studies present the possibility that the existence of large amounts of hog manure stored in lagoons or deposited onto land may possibly be a threat to health in Quebec if drinking (municipal or private) water becomes contaminated. To avoid outbreaks of the same magnitude in the future, and in light of the proposed increase in the size of the hog industry, it is essential that a risk assessment be done to protect all residents of Quebec. In the meantime, it is recommended that all water bodies located near hog farms and all private wells are checked frequently for signs of contamination and more frequently during and after heavy rains. Besides these intervention methods, preventative measures are also recommended to avoid having to investigate health costs and the cost of lives lost when these situations could be avoided.

To date, however, it has been impossible to quantify the degree to which the Quebec population is exposed to environmental contaminants resulting from livestock production (Gingras et al., 2000). This is largely due to the lack of infrastructure available in Quebec to monitor the pollution emitted by the agricultural sector and the links such pollution has to human health (Gingras et al., 2000).

Table 6: Water contamination surveillance system in Quebec.

Item Under Surveillance	Responsible for Surveillance	Contact in Case of Water Contamination
Municipal Water	Municipality	Direction de Sante Public, Ministry of Environment, Hospitals, Police, Media
Well Water	No surveillance	N/A
Water in the Environment	Ministry of Environment	No systematic reporting system
Public Health	Direction de Sante Public	Municipality, Ministry of Environment

Among the class of infections collectively known as "notifiable diseases", which are classified differently at the federal and provincial levels, are those transmitted by hogs to humans including *Salmonella, Campylobacter, E. coli* and *Yersinia entercolitica*. The gastroenteritis infections caused by these microorganisms are generally linked to animal production and animal products, but not restricted to transmission by hogs alone. Professionals working in the field of public health feel that the list of “notifiable diseases” should be expanded to include other vectors, such as the parasite *Cryptosporidium parvum*, to provide a more extensive survey of infection (Millard, pers. comm., 2000). This parasite, found in the feces of hog, cattle and other ruminants, causes profuse diarrhea, abdominal pain, nausea, vomiting, fatigue and fevers. It was responsible for a massive outbreak in Milwaukee in 1993 where 400 000 people were infected through their water supply (MacKenzie et al., 1994). Another hog vector that has recently been discovered to produce antibodies in humans is hog strain of hepatitis E (Gingras et al., 2000), which is not yet classified as a notifiable disease.

Nevertheless, if one of the notifiable diseases is found in a patient, reports are made to one of the 18 Direction de la Sante Publique (DSP) offices located in different regions of Quebec. The DSP is responsible for identifying possible sources of infection and implementing measures to protect public health (Gingras et al., 2000). Possible sources of the infection are determined through a questionnaire. If all other possible sources of infection are eliminated, such as food contamination, the case is sent to the Ministry of the Environment to investigate the possibility of water contamination.

Individual cases of notifiable diseases are entered into a central provincial database (Gingras et. al., 2000). However, the database does not contain information pertaining to exposure and risk factors that are often discovered from the DSP questionnaires nor does it distinguish between individual cases and outbreaks (Gingras et. al., 2000). In January, a centralized registry of outbreaks, which includes information pertaining to possible sources and vectors of transmission, was developed to report and monitor outbreaks (Gingras et. al., 2000). This will help to quantify the mortality and morbidity rates due to outbreaks in the future.

Even though approximately 20% of the Quebec population gets their water from private wells (Gingras et al., 2000), there is currently no legislation requiring systematic testing for contamination (Barthe, pers. comm., 2000). In a survey of outbreaks between 1989 and 1995 (Table 7), several cases were related to private well contamination from microbial byproducts that were suspected to originate from animal production operations. Inadequate information in the database makes it impossible to state conclusively that human disease resulted from water contamination by animal production operations (Gingras et. al., 2000).

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Table 7: Gastroenteritis outbreaks suspected of being linked to agricultural pollution by public health professionals in Quebec (1989 to 1995). Source: Bolduc and Chagnon (1996) [emphasis added].

DATE	MUNICIPALITY/ REGION REGION	SYMPTOMS	# OF PEOPLE AFFECTED	SUMMARY OF CASES
Summer 1989	Ile-aux-Grues Chaudiere-Appalaches (Montmagny)	Epidemic diarrhea	93	Residents supplied by **private wells**. More than 50% of wells on island contaminated with microbes. Grouping of cases confirmed by epidemiological inquiry.
April **1990**	Isle-Verte Bas-St.-Laurent (Grand-Portage)	Gastro- enteritis	67	Clients of a sugar bush. Water from a **well** close to a hog pasture. Fecal coliform + in water and food washed in water.
Spring & **Summer** **1990**	Ile-aux-Grues Chaudiere-Appalaches (Montmagny)	Epidemic diarrhea	46	Residents supplied by **private wells**. More than 50% of wells on island contaminated with microbes. Grouping of cases confirmed by epidemiological

				inquiry.
Dec. 1990	St.-Apolline-de-Patton Chaudiere-Appalaches (Montmagny)	Salmonella	6	Clients of a small private water system serving 5 residences. Infiltration of the reserve. Fecal coliforms + in water.
July 1991	Riviere-Ouelle Bas-St.-Laurent (Grand Portage)	Gastro-enteritis	42	Residents of an old age home.Contamination of **well** probably attributable to excessive spreading of manure.
March 1993	Saint-Antoine-de- l'Ile-aux-Grues Chaudiere-Appalaches (Montmagny)	Epidemic diarrhea	60	Residents supplied by **private wells**. Coliforms present in artesian wells. No disinfections of water.

The current system of surveillance is a passive, rather than an active one, which make it impossible to accurately calculate the costs resulting from microbial infections from contaminated water at this time (Barthe, pers. comm., 2000). As a result of this passivity and the general lack of funding required for further investigation, there is only a limited amount of documentation. Moreover, people may not seek medical attention if symptoms are relatively mild, and the appropriate tests required to identify the potential of microbial contamination may not always be performed (Alors, pers. comm., 2000). Furthermore, the DSP's system of inquiry, namely the questionnaire, is not designed to make the links between agriculture, water and human health (Kasantsky, pers. comm., 2000). This could be addressed by making changes to the questionnaire after consulting with health care professionals to ask appropriate questions (Kasantsky, pers. comm., 2000).

In North Carolina, a public opinion survey was used in one study to determine the degree to which people's health is affected by living near to a hog farm (Wing and Wolf, 1999). A survey of 155 people found that the residents living in close proximity to hog farms reported increased occurrence of headaches, runny nose, sore throat, excessive coughing, diarrhea, and burning eyes than people in the community who resided farther away from livestock operations (Wing and Wolf, 1999). Surveys could be used to quantify the effects of the hog industry on human health to document effects that are not reported to doctors or other health care professionals. Similar surveys have not been conducted in Quebec and should be considered as a method for further research into the effects of the hog industry on human health.

Provincial regulations for the surveillance of drinking water are only applicable to systems serving more than 50 people (Gingras et al., 2000). However, water systems serving less than 5000 people are vulnerable to contamination due to an absence or inappropriate level of water treatment, the lack of mandatory training of managers of water systems, and the limited testing of water supplies (Gingras et al., 2000).

We investigated the cost of water-boiling notifications due to water contamination, which may or may not be linked to animal production. Quebec has the highest number of water-boiling notifications in Canada with approximately 600 notices per year (Hawaleshka, 2000). In Montreal, the cost of one notification is approximately $5000 (Gagne, pers. comm., 2000). Since Montreal is the largest city in Quebec, the cost of a notification of this sort would probably be less in smaller municipalities, so this number will only be used as a rough estimate. Accordingly, six hundred water-boiling notifications in Quebec cost approximately $3 000 000 each year.

An example of human health problems that may result from chemical byproducts of the hog industry is disease caused by consuming water with elevated nitrate concentrations. However, there have been no recent reported cases in Canada of methemoglobinemia (blue baby syndrome), a disease that can be fatal to infants who consume water containing more than 10 ng of nitrate per liter (Gingras et al., 2000). It is impossible to quantify the degree to which the population is affected by low level exposure to nitrates since low-level effects are hard to diagnose. Although nitrate consumption in adults has been linked to spontaneous abortions, non-Hodgkin's lymphoma and stomach cancer, the problem of causality and the lack of research in this area make it impossible to quantify the degree to which the population is affected (Gingras et al., 2000).

Conclusions

Limitations of a Cost-Benefit Analysis

Throughout our report we attempted to quantify and estimate costs for several specific impacts of the hog industry on environmental and human health. In doing so, we explored the possibilities and limitations of a cost-benefit analysis. There are many controversial aspects involved in accurately placing dollar values on factors such as water quality or hog well-being. We will examine several economic techniques that can be used to estimate the human health costs from water. However, in light of our research findings, which revealed many limitations in the knowledge needed to perform an accurate cost-benefit analysis, we will also discuss the feasibility of a risk assessment involving the precautionary principle as an alternative approach.

According to Field (1995), one way to quantify the environmental and health costs is to construct an emissions damage function using the following steps:

1) measure emissions

2) determine the resulting ambient quality

3) estimate human exposure

4) measure impacts (health, aesthetic, recreation etc.)

5) estimate the values of these impacts

A dose-response function is often used to human exposure to a single or various pollutants and involves estimating the response in terms of human mortality or morbidity resulting from different levels of exposure. However, accurately measuring health damages caused by environmental pollution is very difficult. Human health is affected by many factors beside ambient pollution such as lifestyle, diet, genetic factors, and age. To implicate a pollutant suspected of causing disease, large amounts of accurate data on health effects of the pollutant and other possible causal factors are. Even when published studies on the effects of pollution on human health exist, it may not be appropriate to broadly apply the findings of a study group to the general. If accurate dose-response relationships can be established for a particular pollutant, then the standard procedure to estimate health damages from the pollutant involves measuring the increase in monetary expenditures on health care (hospitals, doctors, rehabilitation, etc.) and lost worker productivity (estimation of the cumulative worker production had an individual lived or not been sick).

There are many other costs that are associated with water pollution and human health that do not have an identifiable market value. To address this problem, economists often try to quantify an individuals 'willingness to pay' for abatement of effects or 'willingness to accept' the effects. There are three main ways in which 'willingness to pay' can be calculated (Field, 1995):

1) Determine the value people place on changes in the ambient environment byfinding cases where market goods are purchased to change a consumer's exposure to the ambient environment. An example is the purchase of an air filtration system to minimize odour from a nearby hog farm.

2) Determine people's willingness to pay for a certain environmental or healthcharacteristic through the price variations of goods or services associated with this characteristic. An example is the difference in property value of similar houses, one located near a hog farm and one far away.

3) Contingent valuation through a direct survey. This involves asking individualshow they would act if they were placed in certain circumstances, and what their choices would be if they were faced with a market for those characteristics.

There are many logistical and bias problems that prevent the practical implementation of a cost-benefit analysis. One problem is that people often fail to account for the future value of resources, such as, which cause their present valuation of resources to be underestimated. Another problem is the difficulty involved in estimating non-use values (values for resources that people don't use or benefit from directly) such as existence values (i.e., what is the value of a species?) or option values (i.e., what is the value of a resource you do not use now, but might use in the future?). A cost-benefit analysis that attempts to include non-market and non-use values would be criticized for inaccuracy and illegitimacy, and would remain controversial at best. Due to the great amount of time and money required to begin to quantify all the costs associated with water use, water pollution and human health that are related to the hog industry, we recommend a risk assessment and precautionary approach as an alternative method.

Risk Analysis

A risk analysis considers quantitative costs and benefits as well as qualitative costs, risks and benefits. An advantage of the risk analysis method is that quantitative information is not required for all resources considered to have value. Risk analysis is composed of the following (AFRA):

1) **Risk assessment** involves identifying hazards or risks characterized inquantitative and qualitative terms. This includes the probability of the negative events occurring because of identified hazards, the magnitude of the impact of the negative event, consideration of the uncertainty of the data used to assess the problem and the impact components of the risk.

2) **Risk management** involves identifying, evaluating, selecting andimplementing alternatives for mitigating risk.

3) **Risk communication** is a process for open exchange of information and opinion leading to better understanding of risks and risk related decisions.

However, a risk analysis still requires comprehensive knowledge and large amounts of data. If complete knowledge is not available, decisions and policies to prevent the risk are not made. In the case of environmental pollution and human health effects, there remains great uncertainty. As a result, a growing movement of scientists, citizens and policy makers are advocating a precautionary approach to complement risk analyses in decision-making.

Precautionary Principle

The Precautionary Principle states that when an activity raises threats of harm to human health or the environment, precautionary measures should be taken even if some cause and effect relationships are not fully established scientifically. The Wingspread Statement (1998) came ou t of a conference that brought forty-two international academics, scientists and activists together. It outlines four components of the Precautionary Principle (Raffenspringer, 1999):

1) preventative action should be taken in advance of scientific proof of causality,

2) the proponent of an activity, rather than the public, should bear the burden of proof of safety,

3) a reasonable range of alternatives, including a no action alternative (for new activities) should be considered when there may be evidence of harm caused by an activity, and

4) for decision making to be precautionary it must be open, informed and democratic and must include potentially affected parties.

Although a cost-benefit analysis is an efficient way to inform policy makers and the general public, it is not always the most appropriate or the most effective approach. The cost-benefit framework relies on large amounts of accurate, convincing data and a comprehensive, exhaustive methodology. However, environmental and human health issues inevitably involve externalities, uncertainty and limitations to knowledge, risks, and differing valuations. Consequently, a framework for assessing environmental and health issues needs to consider the quantifiable aspects as well as the qualitative costs, benefits and risks.

There is increasing public awareness and pressure on policy makers to involve precautionary approaches in their decisions. A public perception poll reported by Le Devoir (Francoeur, 1997) found that 97.7% of the population is in favour or strongly in favour of the government taking measures to reinforce protection of the environment. About half the population is of the opinion that the pollution of the rivers and lakes have increased in the last ten years and 75.6% believe that water pollution in Quebec is largely due to the raising of animals and the way that fertilizer is used for agricultural production (Gingras et al., 2000). There are also numerous citizens' groups organizing in opposition to hog farming practices.

Governmental response will occur when there is enough citizen pressure and moral authority. There is already increasing governmental acknowledgment of the desire for precautionary approaches.This can be found in the government report entitled, "Risks Associated with Animal Production Activities in Quebec," (Gingras et al., 2000) which follows three basic principles: prevention, precaution and equality.

Risk analysis and the precautionary principle are recognized internationally in trade agreements and conventions. The General Agreement of Tariffs and Trade (GATT) and the North American Free Trade Agreement (NAFTA), formally recognize risk analysis and risk assessment as methods appropriate for identifying unacceptable risks to human, animal or plant health that may occur from trade in agriculture (AFRA). Also, international treaties, such as the U.N. Rio Declaration, bind many countries such as Canada, the US and the European Union to recognize the precautionary principle for environmental health protection.

Environmental and human health costs are by nature difficult to quantify economically, and this is one of the reasons why they are not included explicitly in current pricing systems. It seems inevitable that a cost-benefit analysis of the hog industry will encounter problems with assigning dollar values to human health and the environment. Alternatively, a precautionary risk analysis would allow us to make transparent, informed decisions involving all affected parties, in particular the citizens of a region, the industry involved and the government, to mitigate risks to our environment and health. In these decisions, we should take the advice of Fredrick Kirschenmann, "to avoid risk, rather than externalizing risk or weighing risk against the benefits" (1999)

Recommendations

To more accurately place a dollar value on water pollution and health costs, it is necessary to:

1) Undertake a survey using contingent valuation to assess people's true valuation of water.

2) Evaluate the pollution of the agricultural industry as a whole. A large proportion of the pollution is diffuse or non-point source pollution which makes it very hard to distinguish between industries or farms.

3) Survey residents in communities near hog farming operations following the methodology used in North Carolina (Wing and Wolf, 1999). Survey data would complement information gathered by health agencies.

4) Conduct more epidemiological research of populations consuming water with nitrate levels between 5 and 10 ng per liter. Anything greater than 2 ng per liter is considered to be due to anthropogenic sources and the maximum acceptable level for human consumption in Canada is 19 ng per liter (Gingras et al., 2000).

5) Expand and revise the list of notifiable to include all diseases that are transferable to humans from animals through the environment. One such parasite that is not included presently is *Criptosporidium parvum*.

6) Develop a province-wide database of water boiling that includes information on the microorganisms present in the water and the suspected source of the microorganisms.

Precautionary or Preventative

1) Soil conservation practices are not widely adopted by producers in some regions Programs and incentives to promote soil conservation practices would significantly reduce water contamination from nitrogen and phosphorous.

2) Regulations aimed at reducing non-point source pollution are ineffective because polluters who do not follow regulations for manure spreading continue to receive government subsidies. If environmental protection is considered a priority then subsidies should only be given to those industries that comply with regulations.

3) Economic, risk and impact assessment comparisons should be undertaken between vertical (specialized) production systems and integrated farming practices.

4) The self-regulation of manure and fertilizer applications in the PAEF legislation may not be successful unless properly regulated and enforced by the government, including fines and/or penalties for those who do not comply. In addition, the government should invest in education programs and farm cooperatives so that producers can monitor themselves and each other.

5) There are currently incentives being developed to prevent pesticides from reaching the water table but the significant amount of pesticides in water indicate that this is not enough. Due to the potential threat to human health and as a precaution for those that may exist, we would suggest an education program that focuses on alternative methods of controlling pest populations, such as the integrated pest management (IPM) model, where you spray only when you need to, or adjust the spraying rates across fields to match the severity of infestation.

6) Results of water surveillance should be communicated to municipalities so they are forewarned of declining water quality and alert to the possibility of implementing additional treatment.

7) Public health problems resulting from agriculture need to be addressed from the perspective of prevention.