CANADIAN HANDBOOK ON HEALTH IMPACT ASSESSMENT

Volume 2
Decision Making in Environmental Health Impact Assessment

DRAFT

DECEMBER 1999

Agriculture

The Canadian outlook

Despite its size, only 11% of Canada's total area has agricultural potential, and less than 5% of this land is really suitable for agriculture. Nevertheless, agriculture and the agri-food business play an important role in the country's economy with a contribution of $23.8 billion to Canada's GDP in 1993. Furthermore, Canada is a net exporter of agricultural products, with the value of these exports totaling $14 billion in 1994. The main producing sectors in the Canadian agricultural industry are meat (beef, porc, veal and lamb), grain, and oilseeds (wheat, durum wheat, barley, flax, rapeseed, soya, and corn).

Canadian agriculture has changed considerably over the past several decades in response to various forces. For example, the number of farm operations has decreased steadily, from over 700,000 in 1941 to less than 300,000 in 1991. At the same time, there has been a steady increase in the size of the operations (from about 50 hectares in 1941 to 250 hectares in 1991). This has resulted in important changes that have launched the industrialization of agriculture, as typified by soilless hog raising facilities housing several thousand animals.

Agriculture in Quebec

Agriculture in Quebec underwent profound changes after the Second World War, when regional specialization occurred in Canada (grain production in the west, and dairy and vegetable production in the east). Furthermore, the agricultural crisis in the 50s brought about a gradual disappearance of traditional agriculture. This process, ongoing for four decades, continues today. The transition toward industrial agriculture, evidenced by regional specialization, mechanization and the increasing use of fertilizers and pesticides, was also accompanied by a significant decrease in the number of farms and by more intensive use of better quality land, while land with serious limitations was abandoned. The final stage of this phase, which began in the mid-80s, is the development of environmental awareness in the agricultural community.

In Quebec, there are 6.4 million hectares of land suitable for farming, but only 2.3 million hectares have good agricultural potential (land classed 1 to 3). This type of land, about 1 million hectares, is mostly concentrated in the St. Lawrence lowlands. This is the region where the environment is most threatened by agricultural practices.

Animal production dominates agriculture in Quebec, involving 70% of the 46,000 producers in Quebec. Thirty percent of farmers specialize in vegetable production. Dairy farming is the most important agricultural activity in Quebec, supporting 33% of all producers. Next in importance are beef and veal calf production, with 21%, grain and protein crop production (soya, rapeseed) with 9.7%, followed by fruits and vegetables (7.5%). Hog farming (6.8%)

ranks just ahead of maple syrup production (6.4%). Other types of agricultural production (horse breeding, poultry, forage crops, etc.) each account for less than 5% of agricultural activity. In 1996, revenues from all animal and vegetable productions totaled $4.6 billion, with vegetable production accounting for 20% and animal production accounting for 66%. Government payments and miscellaneous productions not classified elsewhere account for the remaining percentage.

A different picture is revealed when revenues are considered. Indeed, dairy production dominates the agricultural sector (35% of revenues or $1.4 billion), followed by hog farming with 18% of revenues ($730 million). Poultry farming (11% of revenues or $470 million) and beef production (9% or $360 million) are ranked respectively 3rd and 4th, followed by vegetable production excluding potatoes (6% or $228 million), and by wheat and grain production (6% or $221 million).

In 1995, direct agricultural activity (excluding fishing and food bio-processing) accounted for 1.1% of the Gross Domestic Product in Quebec, with a share of the GDP totaling $1.8 billion. Downstream from agricultural production, food and beverage processing generated a sectorial GDP of $3 billion. Employment in the agricultural sector supports 2.1% of the labour force in Quebec, with some 67,600 workers directly involved in agriculture. When food bio-processing is included, another 47,000 jobs can be added to this sector.

In conclusion, the political importance of agriculture in rural areas should also be mentioned. The agricultural community is represented by various groups, the most important being the Union des producteurs agricoles (UPA). This organization is based on a union model and is dedicated to the defense and promotion of the professional, economic and social interests of its members. It has a membership of 50,000 producers and it is the umbrella organization for 16 regional federations and 21 specialized federations. Each federation consolidates all grassroots and specialized unions in its area. The UPA is also a powerful mechanism for lobbying governments, frequently making representations on behalf of its members.

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Hog farming and health

Socio-economic overview

Hog farming has been condemned as one of the most polluting agricultural activities. With the rise of this industry over the last 20 years, environmental problems have increased to the point where confrontations have occurred in several rural municipalities.

Hog farming experienced tremendous growth at the end of the 70s, as is evident from the figures below. In Quebec in 1961, there were a little over one million hogs (1.114 M), and this number remained relatively stable for 17 years[17]. However, starting in 1977, the number of hogs rose from 1.076 M to 1.792 M in 1978, and 2.760 M in 1979. The number of animals totaled over 3 million in 1980 and peaked in 1983 at 3.104 M. This vigorous growth was the result of favorable economic conditions and strong financial incentives provided by the government for the construction of hog raising facilities.

With the recession of the early 80s and the stabilization of demand, the number of hogs remained stable until 1990 (3.055 M animals). New growth occurred starting in 1991, but it was much weaker than the growth of the 1977-1980 period. In 1995, in Quebec there were close to 3.4 million hogs, the majority of which (3 million) were feeder pigs slaughtered a few months after birth. In 1995, 5 million hogs were produced, 2 million of which were slated for export.

Over the years, several regions in Quebec demonstrated that they were particularly well suited for hog raising. Quebec production is dominated by growers in the valley of the Richelieu River (including the St. Hyacinthe region), with a production of 25%, followed by the Beauce region (20%), the Quebec region, excluding the Beauce region (17%), and the Eastern Townships (16%).

The hog industry contributes considerably to the trade balance in Quebec in the area of agri-food. In 1995, the hog industry generated $730 million, or 18.2% of total agricultural revenues in Quebec. The number of jobs directly related to this industry is estimated at close to 6,000, with the number of indirect jobs totaling 25,800. A considerable portion of production is exported. Pork was the main agricultural export from Quebec in 1996, with a value of $455 million, representing 33% of agri-food exports from the province. Japan, the United States and South-East Asia are the main export markets. However, continued growth of hog meat exports is not assured. For example, the Asian financial crisis of 1997 and 1998 has resulted in decisions by the countries of that region to reduce their imports of hog meat.

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[17] These figures represent the number of live animals at a given date, ordinarily July 1. This number is lower than the actual number of animals slaughtered in one year, because the animals are slaughtered less than one year after birth.

Type of operations

Large scale "soilless" hog raising operations are classified as industrial. This is because they could very easily be located in an industrial park if it were not for the necessity of spreading the pig slurry[18], or if this slurry could be easily processed to benefit from its potential as fertilizer, thus eliminating it more readily. Pigs are given industrially-produced feeds, and in this respect as well, a mega hog raising operation need not be located in a rural environment, if it were not for the requirement of spreading the slurry. Each year, hogs in Quebec generate a little over 7 million cubic metres of droppings. However, hog farms operate with what is called a liquid management system for droppings, in which the manure is mixed with urine and where no litter such as sawdust, straw or peat is added. With such a management system, the total volume of pig slurry that must be processed annually is approximately nine million cubic metres.

Risks to the public

Pollution caused by animal droppings

Animal droppings managed in liquid form represent a potentially greater burden for the environment. Pig slurry contains high concentrations of microorganisms, some of which can cause diseases in humans. This slurry is laden with minerals (nitrogen, phosphorus, potassium, etc.) and also with various organic materials. Nitrogen and phosphorus compounds are nutrients that foster growth of algae and other marine vegetation. As for the organic matter that finds its way into the water system, it uses up a considerable part of the oxygen, generating an overload of substances that cause the proliferation of various organisms. Liquid management of animal droppings is the method with the most negative environmental impacts; in addition, it is most likely to produce very strong odours.

Water pollution

Four watersheds are especially affected by pollution by agricultural operations where manure or slurry is produced in excessive quantities. These are the watersheds of the Yamaska, Chaudière, Etchemin and Assomption rivers. There is a significant concentration of hog farms in those regions. Overall in Quebec, and especially in these four catchment areas, the quantities of nitrogen and phosphorus from animal droppings far exceed the capacity of the soil to absorb these substances. Indeed, for all of Quebec, these two sources, manure and slurry, cover crop requirements in nitrogen and phosphorus respectively at a level of 133% and 167%. In the case of nitrogen requirements, percentage coverage in the Yamaska watershed

[18] Slurry includes all waste with a water content greater than 85 to 90% and is in liquid form. Otherwise, animal droppings are called manure. Manure effluent, not to be confused with slurry, is the liquid flowing from manure.

is 144%, in the Chaudière watershed, 267%, in the Etchemin watershed, 252%, and in the Assomption watershed, 176%. As for phosphorus, the requirements are covered in these watersheds respectively at 285%, 220%, 265% and 280%. In 1996, according to figures provided by the Plant Protection Council of Quebec (CPVQ), the surface areas required to spread the phosphorus and nitrogen from manure in these four watersheds were 2 to 5 times greater than the actual land available.

The Yamaska River is one of the most polluted rivers in Quebec. The river is in this condition because of industrialization, municipal sewage and agriculture. Between 1975 and 1988, nitrate levels in the river's water increased by 100%. As for hog farming, there are over 1,000 slurry pits in this area, demonstrating the extent of these operations. There are currently about 1 million pigs in this catchment area.

Water quality in the Chaudière River has declined considerably since 1960. Already in 1985, this catchment area had to support a number of animals per hectare exceeding by the acceptable limits by 300%. Hundreds of operations have surplus animal droppings, 90% of which is pig slurry. An additional 50,000 hectares would be required to spread the pig slurry and cattle manure. It is estimated that there are 650,000 pigs in this catchment area.

The Etchemin River, which has a low waterflow, is highly polluted from one end to the other by bacteria, organic matter or nutrients. The pig population in this catchment area is estimated at 300,000.

Water quality in the Assomption River is generally good in its upstream area, but it declines rapidly downstream from some tributaries such as the Saint-Esprit and Achigan rivers that flow through agricultural land. Hog farming, with close to 250,000 heads, has been identified as an important source of pollution.

Water pollution is usually caused by leakage from storage pits and by improper spreading (over-fertilization), which pollute surface and ground water. In the case of surface water, there can be a considerable lack of cleanliness if pollution exceeds certain levels. In this respect, the production of drinking water becomes more difficult. High levels of fresh organic matter not only produce trihalomethanes but also prevent water filtration systems from operating properly. In addition, in extreme cases, concentrations of nitrogen in the form of nitrates/nitrites in underground water can cause methemoglobinemia, especially if synthetic fertilizers are used in addition to slurry and manure.

Inorganic pollution

Total nitrogen levels in pig slurry can reach 3,500 mg/L, and phosphorus levels can reach 2,500 mg/L. This high nutrient content is caused in part by the fact that up to 70% of the

nitrogen in animal feeds (meal) can be lost through improper handling or because of incomplete digestion.

Ammoniacal nitrogen (in the form of HN_3 or of NH_4^+) is an important component of manures and slurries. For example, a feeder pig excretes about 24 g of nitrogen per day (in inorganic or organic form) and 7 g of phosphorus, compared to 10 g and 2 g with humans[19]. A clearer picture of such a pollution load can be given by mentioning that the excretions from 6.9 million Quebecers produce daily 6,900 kg of nitrogen, whereas three million pigs generate 7,200 kg.

Organic pollution: mIcrorganisms

Slurry contains high levels of microorganisms, usually between 10 and 100 million per ml. The main hazards to human health from pathogenic microorganisms in pig slurry are bacterial enteritis caused by *Salmonella* sp, *Campylobacter* sp and *Yersinia enterolitica*. Other bacteria, such as *Escherichia coli*, parasites such as *Cryptosporidium* sp, and viruses can also occur. There is evidence also that bacteria of the type *Listeria* occur quite frequently in pig excrement. However, current data allows only a partial assessment of the magnitude of this problem. In the case of diseases whose reporting is mandatory, in Quebec in 1995 there were several cases of infection caused by *Campylobacter*, of salmonellosis, and of gastroenteritis caused by *Yersinia enterolitica*. However, it is believed that the number of cases identified is much lower than the real number of occurrences, and furthermore, the origin of the infection is unknown most of the time.

As for outbreaks of water-borne infectious diseases, data for the Chaudière-Apalache region, one of the most vulnerable to agricultural pollution, indicates that between 1989 and 1995, five outbreaks of gastroenteritis affecting 247 persons were possibly related to agricultural activities. However, these cases were not specifically linked to hog production. The fact that the origin of the contamination remains unknown in over 40% of the epidemics reported in Quebec increases the probability that other outbreaks may be caused by non-point source pollution from agricultural practices.

Organic matter

Organic matter found in surface water processed by filtration plants can be natural in origin or can result from human activities in general. It is recognized however that in rural or semi-rural regions, animal breeding constitutes an important source of water pollution through organic matter.

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[19] This is a mathematical average, and the values can vary for each class of feed pig (20-42 kg, 42-70 kg, etc.)

In Quebec, there are many hog farms in catchment areas that supply water to relatively large municipalities. Such rivers include the Saint-François, the Yamaska, the Richelieu and the Assomption. At 40,000 mg/L, the biochemical oxygen demand of slurry is considerable; in fact, it is 250 times greater than ordinary urban wastewater. Furthermore, it can be reasonably assumed that chlorination byproducts are formed in water treatment plants. These represent a risk for public health.

Formation of chlorination byproducts

When drinking water is disinfected with chlorine, water-borne infectious diseases are reduced considerably. However, when water containing high levels of organic matter is treated with chlorine, toxic byproducts are produced, such as trihalomethanes (THM), halogenated acetic acids (HAA), halogenated acetonitriles (HAN), picrines, aldehydes, and phenols. THMs, especially chloroform, are the main substances that have been studied, and it was long believed that these were the most important in terms of health risks. We know today that this is not always the case and that, for instance, halogenated furanone (MX), even in low concentrations (in the order of 20 or 30 nanograms per litre), accounts for 40 to 60% of the mutagenicity of drinking water. Although it is difficult to establish any causal relationship, a significant link is suspected between the absorption of chlorinated water over many years and cancer of the bladder.

The best way to prevent water pollution caused by slurry is to ensure that it does not leak, and to enforce strict rules for spreading, to prevent run-off of slurry into watercourses. However, even when best practices are applied, they cannot account for over-fertilization which causes over-saturation of the soil with nutrients. In this context, the implementation on farms of an environmental plan for fertilization, as required by the*Regulations Concerning the Reduction of Agricultural Pollution* (1997), should provide a solution to some of the problems associated with over-fertilization.

Odours

There has been a considerable increase in odors from animal production operations over the last 30 years in Quebec, mostly because of the transition from solid to liquid management of manure, especially in hog farming. The result has been a 5.2-fold increase, between 1961 and 1995, in odors from buildings and storage facilities for pig slurry, with a 8.2-fold increase when spreading operations are conducted.

Odours linked to animal production can be released by over 75 different compounds. Droppings are clearly the main source of smelly compounds, which result from bacterial activity in the intestines and from fermentation at a later stage, usually under anaerobic conditions. Theoretically, this type of fermentation produces methane and carbon dioxide (two

greenhouse gases), but very often there is only partial methanization, producing smelly compounds such as volatile fatty acids and sulphur compounds (H_2S, CH_3SH – [methylmercaptan], CH_2SCH_3 [dimethylsulphide]).

Slurry releases few odors when it is stored, but as soon as it is stirred, volatile compounds are released. Therefore, the strongest odors are produced when the slurry is taken from the tank, transported and spread.

Air pollution problems related to hog production originate in animal buildings (the animals themselves and the slurry that is stored), but spreading is also an important source of odour nuisances. Spreaders that avoid dispersal and spraying of the slurry are recommended; with some systems, it is possible to spread the slurry very close to the ground, and even to mix it with the soil. As for the odours released by the animal buildings, it is suggested that the animals' diet be modified, that the air undergo biological filtration before being released, and that deodorizers be used. New breeding techniques such as the use of biocontrolled litter are also suggested. In this system, the animals are raised on a 70 cm thick bed of litter, in which microorganisms are activated to produce composting in the litter itself. This results in less odour production, and destroys pathogenic microorganisms.

Risks for workers

Constant exposure to the air inside a hog house can lead to several acute and chronic respiratory problems for people who work in this environment. Workers often suffer from eye, nose and throat irritations, and from chronic bronchitis and asthma. It is estimated in fact that the air in hog

houses is 1,200 times more laden with microorganisms than ambient air. The bacterial content of air in hog houses has been well documented. It contains large amounts (10^5 to 10^7 ufc per cubic metre of air) of Gram-positive bacteria such as *Staphylococcus* sp., *Micrococcus* sp. and *Bacillus* sp. However, respiratory problems seem more closely connected with Gram-negative bacteria such as *Acinetobacter calcoaceticus, Flavobacterium* sp., *Pseudomonas* sp. and *Serratia marcescens*, mostly because of the effect of their endotoxin. The incidence of chronic bronchitis is very high among pig farm workers - from 15 to 40% according to studies. Occupational asthma also affects many workers and often forces people to seek work elsewhere. These respiratory problems are mostly linked with high levels of dust, gas and microorganisms in the air of the buildings. The presence of mold in the air is also responsible for health problems such as organic dust toxic syndrome, and, to a lesser extent, for extrinsic allergic alveolitis, or farmers' lungs, whose main causal agent is *Saccharospora rectivirgula* (formerly *Micropolispora faeni*).

Finally, hog farm workers can suffer from various zoonotic diseases. Erysepeloid (*Erysipelothrix rhusiopathiae*), a non-malignant skin infection caused by a streptococcus, often affects hog farm workers. It produces a painful sore that swells around the edges. These workers are also exposed to *Yersinia enterolitica,* which can cause intestinal infections and which may be linked with higher rates of appendicitis. Hog farm workers are also exposed to intestinal diseases caused by *Salmonella* sp and *Campylobacter* sp. In rarer cases, *Streptococcus suis* can cause severe systemic illness in the form of meningitis, pneumonia, endocarditis or arthritis. The risk of contracting leptospirosis, tuberculosis or brucellosis is rather low because these animal diseases are generally well controlled.

Hog producers and their employees are also exposed to poisoning by manure gases, which can occur mostly when work is being done in temporary manure storage areas. Most often, the agent responsible is hydrogen sulphide (H_2S). Half of the severe cases of manure gas poisonings are fatal.

Social and human impacts

The development of large hog raising operations and the large scale spreading of pig slurry are currently a problem in Quebec because of the strong odors that affect the quality of life of people living in those areas. Supplemental analyses were conducted recently on data provided by the 1992-1993 Quebec Social and Health Survey, to study mental distress related to high densities of hog raising operations (Pampalon 1997). The results reveal that in spring and summer, as compared to autumn and winter, there is a significant increase in high levels of mental distress (from 20.8% to 34.3%) in municipalities with large numbers of hog raising operations (20,000 pigs or more). Slurry spreading activities might be responsible for such a reaction. However, the authors point out that based on these results, no causal relationship can be established between hog raising activities and mental distress. They do consider that such a link can be seriously hypothesized, and that further analysis of the data should be conducted or, preferably, that a specific study should be undertaken on this issue.

Sector: Agriculture
Activity: Large Scale Hog Farming

STRESSOR/ EXPOSURE	Type of Stressor	Environmental Impact	Area of Influence	Control Measures	Standards or Recommendations
Technological disaster	- fire, explosion	- deposits, fumes	- site and perimeter	- covering, capture	- ?
	- leakage from slurry pit	destruction - soil and water pollution	- site, perimeter, vicinity	- sealing, repairs	- monitoring facility witnesses
Gaseous or air emissions	- methane, N_2O	- greenhouse effect	- world-wide	- capture	- none
	- bacteria and endotoxins *Acinetobacter, Flavobacterium, Pseudomonas Serratia*	- pollution	- site	- farming practices	- none
	- mold and actinomycetes	- contamination of air inside buildings	- site	- ventilation	- none
Liquid emissions or discharge into water	- nutrients (phosphorous)	- eutrophication, algae growth (see below)	- vicinity and community	- leakproof slurry pit, buffer zone observed when spreading	- NO^2+NO^3=10 ml/L (Q-2, Drinking Water Reg.); P: no standard
	- organic compounds	- BOD, oxigen deficiency in aquatic environment	- receiving waters	- same as above + biocontrolled litter	- 3 to 7 mg/L [20] (DEW criteria for raw water intake), 350 Fg/L for THM(Q-2 Drinking Water Reg.[21]
	- suspended matter	- pollution, healthy conditions	- receiving waters	- same as above	- Q-2, same regulations as above
	- microorganisms: Salmonella Campylobacter Yersinia enterolit. Escherichia c. Cryptosporidium	- pollution, healthy conditions	- receiving waters	- same as above + use of biocontrolled litter	- fecal coli: 0 total coliform count: 10/100 mL

[20] Applies mostly in the case of raw water that will be treated with chlorine, which can trigger the formation of cancerogenic trihalomethanes.

[21] Should be lowered to 100 Fg/L in accordance with Health Canada's new Maximum Acceptable Concentration (MAC)

STRESSOR/ EXPOSURE	Type of Stressor	Environmental Impact	Area of Influence	Control Measures	Standards or Recommendations
	- microalgae: *Microcystis*	- pollution, healthy conditions	- water receiving nutrients (N and P)	- activated charcoal and ozonation for drinking water	-microcystine: 1.5 Fg/L (Health Canada)
Solid emissions or discharge into the soil					
Nuisances	odors	healthy conditions	vicinity and community	buffer zone; biofiltration of air inside the building; aeration of slurry; breeding practices	- municipal regulations - guidelines on odors in agricultural areas
Indirect impacts or other exposure	- inhalation of heavy sulphide gases in the temporary manure storage area	- N.A.	- N.A.	- avoid entering temporary manure storage area without adequate breathing equipment	- Regulation respecting entry into confined spaces, CSST? (Applicable to employees only)
	- downgrading, devaluation, and social conflict	- possible decrease in economic value	- vicinity, community, and region	- communications compensation	

STRESSOR/ EXPOSURE	Effect on health	Population at risk	Probability of occurrence	Environment/ biological indicator (monitoring)	Information/ references
Technological disaster	- respiratory irritations, burns, deaths	- workers	- rare	- fire, morbidity, mortality reports	
	- unhealthy conditions	- vicinity	- rare to occasional		
Gaseous or air emissions	- climatic change - various respiratory problems - various zoonotic diseases - allergic alveolitis STEPO	- world-wide - workers - workers - workers	- frequent - frequent - occasional - rare to occasional - rare to occasional - frequent	- air emissions containing CH_4 and N_2O - presence of Gram-bacteria in the air inside hog confinement buildings - presence of mold spores and of actinomycetes	- Jacques (1992) Cormier *et al* (1990) Zejda *et al* (1994) Cormier *et al* (1990)
Liquid emissions or discharge into water	- methemo globinemia if N level is too high	- people (especially newborns) drinking	- very rare	- overt symptoms: respiratory problems, cyanosis ...	Levallois *et al* (1994) Laferrière (1996) Levallois (1997) Laferrière (1996) + Laferrière *et al* (1996) Anonymous (1995) + Internet references (see text)
	- unhealthy conditions + possible formation of cancerogenic trihalomethanes (THM): bladder, colon	polluted ground water	- frequent	- surface water BOD	
	- unhealthy conditions	- people using and drinking polluted water	- unknown	- trihalomethane levels in drinking water	
	- gastroenteritis, mucosal and skin infections	- people using polluted water	- frequent	- suspended matter levels in water	
	- hepatic toxicity, potential tumour-causing effect	- people using and drinking polluted water	- rare to occasional	- identification of indicator/pathogen ic microorganisms	
		- people drinking polluted water	- unknown	- microalgae identification and determination of microcystine levels in water	

STRESSOR/ EXPOSURE	Effect on health	Population at risk	Probability of occurrence	Environment/ biological indicator (monitoring)	Information/ references
Solid emissions or discharge into the soil					
Nuisances	- stress, psychological problems, insomnia and nausea in extreme cases	- vicinity and community	- occasional to very frequent	- volatile fatty acids, sulphur compounds - complaints, perception studies	- Gingras (1996) - Gingras and Gosselin (1997) - DHSS (1996) - Pampalon and Legaré (1997)
Indirect impacts or other exposure	- poisoning, death	- workers	- occasional	- identification of heavy gases in temporary manure storage area - investigation report CSST, public health - assessment role, perception studies	CSE, CDSP, DHSS (1997)
	- quality of life stress	- vicinity, community, region	- very frequent		

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Use of pesticides in apple growing operations

General information on pesticides

Agricultural industrialization has led to a greater use of synthetic pesticides of all kinds. With farms engaging in monoculture over extensive areas (e. g., wheat and corn), it became necessary to use pesticides to protect crops against insects and fungi, and also to control

competing vegetation whose growth rate is usually greater than that of planted crops. The reason for such an extensive use of these compounds on a global scale is that agricultural products are threatened by some 8,000 fungus species, 10,000 insect species and 2,000 weed species.

Hundreds of active ingredients (starting material) can be used as herbicides, insecticides, fungicides and rodenticides. Many commercial formulas are mixtures of several pesticides. During the 19th century and the early 20th century, mostly inorganic substances were used, such as

copper sulphate, arsenic salts and mineral oils, whose toxicity could have a devastating effect both on the organisms targeted and on humans. DDT made its appearance following the Second World War. This was an organochlorine insecticide that was to become famous for its efficiency, as well as its toxicity and persistence in the environment.

The use of pesticides in industrialized nations generally increased steadily between 1945 and the early 90s. Over the past several years, there has been a leveling off and perhaps even a slight decrease in the agricultural use of these substances in a number of developed countries.

In Quebec, for example, active ingredients for pesticides sold in 1995 totaled slightly over 3 million kg, compared to 3.6 million kg in 1992. This represents a 15% decrease over 3 years. However, based on methodological principles, it cannot be claimed that there is a real downward trend; longer term monitoring is necessary to confirm such a trend. Herbicides are the most widely sold pesticide, with 56% of the market, followed by insecticides (16%) and fungicides (11.5%). In terms of chemical groups, carbonates (insecticides and fungicides) are the most widely sold (14% of the market), followed closely by popular herbicides such amides, acetamides and anilines (14%), triazines and triazoles (11.8%), and aryloxyacides (10.9%).

In Quebec, farm operators purchase a little over 78% of all pesticides sold, followed by the household sector (11%). Industrial, logging and landscaping applications represent each less than 5% of the market.

Apple production in Quebec

In Quebec, orchards cover about 8,900 hectares, representing slightly over 0.5% of the total crop surface area. This is greater than the land used for vegetable production (on an individual basis), but less than the land used for major crops, such as corn-grain, with 280,000 hectares, barley with 130,000 hectares, etc. Also, this land is shared by 1,800 producers, so that the average surface area is 5 hectares per producer. Very often, these are family orchards, operated from one generation to the next.

The greatest number of apple trees are semi-dwarf trees (1.3 million), followed by dwarf apple trees (982,000), and standard apple trees (604,000). McIntosh apples represent 76% of total production (56,000 tonnes in 1995), followed by Cortland apples (16.5%), Empire apples (5%), and Spartan apples (5%).

Pesticides and apple production

Apple growing is subject to numerous abiotic and biotic uncertainties. A prolonged thaw in winter followed by a sudden and severe freeze, or for that matter an extensive ice storm, can cause irreparable losses. Indeed, some small orchards have been almost completely wiped out because of such occurrences. In addition, some 15 insect species can attack apple trees. The apple fly is the most important among these. Approximately 10% of all insecticides used in Quebec are in fact targeted against this insect, which burrows into the fruit. Slightly over 7% of all insecticides are used to control plum curculio, which feeds on buds, fresh leaves and baby apples. Another insect

harmful to apple trees, the European red mite, is also the subject of special attention, with 6.5% of all insecticides used in agriculture in Quebec targeted against it.

About 15 insecticides are recommended for orchards in Quebec, but the main products used are azinphos-methyl, dimethoate (organophosphorus products) and mineral oil-insecticide. Other organophosphorus products, such as diazinon and chlorpyrifos, are also used and have been detected in areas near certain orchards. On average, an orchard is treated three to four times a year with insecticides. These substances must not be spread during blossoming, to avoid harming insect pollinators.

Although insect pests greatly affect apple growing, approximately 70% of the pesticides that are spread are fungicides (compared to 30% insecticides). The main target of these fungicides is the scab, a fungus that primarily damages the fruit's appearance, leaving a type of scale on the skin. Long periods of rain, heat and humidity worsen the problem. The extent of the use of fungicides is evidenced by the fact that 7 to 16 treatments with these substances are applied annually in a typical orchard. The main active ingredients used are captan, myclobutanil (a triazole) and mancozeb (a dithiocarbamate).

In addition to the insecticide and fungicide treatments, 2 to 3 acaricide treatments are used. The total amount of pesticides used in apple production is considerable: compared to corn farming where 3 kg of active ingredients are used per hectare, apple farming requires 30 kg of active ingredients per hectare.

Studies carried out in Quebec on the presence of pesticide residues in apple growing areas and their effects on health have focused mainly on organophosphorus insecticides. Although the environmental persistence of these substances is much lower than organochlorines (they have a half-life of several days to several weeks, compared to years in the case of chlorinated substances), their acute toxicity is much higher, ensuring their efficiency. Organophosphorus compounds mostly affect the target insect by contact, because they inhibit cholinesterase, a neurotransmitter that regulates the level of acetylcholine when a neural impulse is produced.

The most widely used fungicide is mancozeb. As for captan and myclobutanil, their acute toxicity for mammals is generally lower than organophosphorus compounds. However, captan is considered a mutagenic and teratogenic agent; it is probably also a carcinogenic substance.

Residues following spreading

Studies conducted in Quebec reveal that high levels of pesticide residues are still present in the air 6 to 12 hours following spraying. In the case of organophosphorus compounds, concentrations exceeding 2 mg/m^3 have been observed. As for residues in the soil, the highest level detected was 1.7 mg/cm^2. The people most likely to be affected are apple growers and their families, and people living close to the orchards, i.e. under 30 metres from its perimeter. In this regard, it should be noted that the increase in outdoor activities in rural areas can lead to an increase in the number of people likely to be exposed to pesticide residues.

Potential toxicity

According to a 1996 study conducted in Quebec, the levels of organophosphorus compounds detected in the environment are insufficient to induce acute or chronic toxicity. The levels of alkyl phosphates (alkyl phosphates are a derivative used to measure the presence of organophosphorus compounds in the human body) identified in urine from people exposed to these substances correspond to body burdens 10 times lower than the NOAEL. It was concluded that the health hazard for directly exposed people and for the surrounding population was minimal. Acute poisoning resulting in neurological and digestive disorders can only occur when there is considerable exposure during handling of the active ingredients, or when the product is sprayed without taking adequate protection measures. The same statement cannot be made in the case of the other types of pesticides used in orchards.

Sector: Agriculture
Activity: Pesticide Spraying in Orchards

STRESSOR/ EXPOSURE	Type of Stressor	Environmental Impact	Area of Influence	Control Measures	Standards or Recommendations
Technological disaster	fire in pesticide storage facility	destruction, contamination	site and perimeter	covering, capture, and confinement, emergency plan	- none
Gaseous or air emissions	- organo-phosphorous insecticides[22]	- air pollution caused by pesti-cide drift, especi-ally with wind	- site and perimeter (up to 30 m from sprayed area	- avoid spraying during nesting and pollinization periods	- 0.2 mg/m^3 for skin contact (NIOSH)
	- fungicides[23]	- air pollution caused by pesticide drift	- site and perimeter	- avoid spraying during nesting and pollinization periods	- none
Liquid emissions or discharges into water	- organo-phosphorous insecticides	- disturbance of aquatic life. Toxicity can be very high (e.g., 3 Fg/L for rainbow trout)	- surface water on site and at perimeter	- avoid spraying during rainy periods, buffer zone	- 0.07 Fg/L for azinphos-methyl (DEW standards for raw water intake) - 0.03 m/kg/d (safe level for occupa-tional exposure (EXTOXNET)
	- fungicides	- high toxicity: 56 Fg/L for trout and salmon	- surface and ground water on the site and at the perimeter	- avoid spraying during rainy periods, buffer zone	- 15 Fg/L for captan (DEW and Env. Canada criteria for raw water) 0.13 mg/kg/j
Solid emissions or discharge into the soil	- organo-phosphorous insecticides	- soil and water table pollution	- site and perimeter (up to 30 m from sprayed area)	- none	- none
	(see note 3) - fungicides (see note 4)	- soil and water table pollution	- site and perimeter	- none	- none
Nuisances	odours	- quality of life, stress	- vicinity	- buffer zone	- none
	noise (spraying operations)	-quality of life, stress	- vicinity	- less noisy sprayers	- none
Indirect impacts or other exposure	accidental spilling of pesticides (concentrated)	- contamination, destruction	- usually on the site itself	- capture, cleanup, decontamination - prevention	

[22] Azinphos-methyl is the typical substance considered for reference purposes
[23] Captan is the typical substance considered

STRESSOR/ EXPOSURE	Effect on health	Population at risk	Probability of occurrence	Environment/ biological indicator (monitoring)	Information/ references
Technological disaster	injuries, poisoning, burns, deaths	workers, firefighters, vicinity	rare	morbidity/mortality reports	
Gaseous or air emissions	- cholinergic effects of varying intensity depending on extent of exposure	- workers, and producers and their families	- rare to occational	- alkylphosphate levels in urine: 5.3 mg/g - creatinine = NOAEL workers 2.2 mg/g creatinine = NOAEL children	Boudreault *et al* (1997) DEW (1997) Keifer (1997)
	- captan: dermatitis, allergies, potentially cancerogenic, teratogenic and mutagenic	- workers and producers and their families	- unknown	- ???	EXTOXNET (Internet reference)
Liquid emissions or discharges into water	- same as above	- people drinking contaminated surface water	- unknown	- same as above	Boudreault *et al* (1997) Giroux (1997) Environment Canada, Canadian Water Quality Guidelines (for captan) Keifer (1997)
	- same as above NOAEL: 12.5 mg/kg/d (rats) for captan	- people drinking contaminated surface water	- unknown	- ???	
Solid emissions or discharge into the soil	- same as above	- people drinking ground water	- unknown	- N.A.	DEW (1997)
	- same as above	- people drinking ground water	- unknown	- N.A.	
Nuisances	- stress, health concerns	- vicinity	- rare to frequent	- complaints, perception studies	Étude exploratoire sur exposition aux organo-phosphorés et risques pour la santé, DSP, Montérégie, 1997
	- quality of life, disturbance	- vicinity	- rare	- complaints	
Indirect impacts or other exposure	acute: blurred vision, stomach pains, nausea, dizziness, nervousness, various central nervous system disorders	handlers of concentrated solutions	- rare	- medical report, public security	Guide “Pesticides et agriculture; bon sens, bonnes pratiques (DEW, DHSS, DAFF, UPA) Keifer (1997

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