CANADIAN HANDBOOK ON HEALTH IMPACT ASSESSMENT

Volume 2
Decision Making in Environmental Health Impact Assessment

DRAFT

DECEMBER 1999

Forests

Canadian outlook

Canada has approximately 418 million hectares of forests, representing 42% of its total area. Of that, 245 million ha can produce merchantable timber. The timber forest is formed of about 63% softwood conifer stands, 15% deciduous forest and 22% composite forest. Provincial governments manage 71% of the country's forests, while the federal and territorial governments manage 23%. The remaining 6% are private forests belonging to more than 425,000 owners.

In 1993, the lumber and paper industry contributed $19.8 billion to Canada's GDP, 40% of which was attributable to the pulp and paper sector. It was the forest sector that generated the most foreign currency revenues, contributing $28 billion to the trade balance. The logging industry provided direct employment for nearly 370,000 people in 1994.

Quebec forests

Quebec can be divided into three major vegetation zones: the tundra north of the 55th parallel; the taiga comprising black spruce stands dispersed over a lichen mat between the 52nd and 55th parallel, and the forest south of the 52nd parallel. This last zone, covering 757,900 km^2, is commercially exploited. It is divided into three more zones: the boreal coniferous forest in the north (belonging almost entirely to the Quebec government); the composite deciduous and coniferous forest in the centre, and the southern deciduous forest located primarily in the St. Lawrence Plain, the Outaouais and Témiscamingue.

Although most of the deciduous forest located in the south of the province belongs to private owners, the boreal forest comprising 73% of the timber forest is so vast that the Quebec government actually owns 85% of the total forest area. Given this fact, the government has assumed the mandate of implementing various measures aimed at protecting the timber forest against fire, destructive insects and competing vegetation, while ensuring its renewal and accessibility for diverse activities.

The forest is a source of intense economic activity, as more than 30 million m^3 of wood material is harvested annually. This volume is equivalent to 460,000 trucks 45 feet long hauling 65 m^3 of average-size non-debarked logs. In 1994, had the logs on about 76 of these trucks been lined up end to end, they would have made a chain about 6,000 kilometres long, comparable to the breadth of Canada (± 7,775 km from St. John's, Newfoundland, to Victoria, British Columbia). That same year, 76,000 people, or 2.4% of the Quebec labour force, were employed in jobs directly related to logging or the lumber and paper industries. The 1994 monetary value of logging industry deliveries (forest harvesting, lumber processing and the pulp and paper industry) was $15.5 billion. In 1994, there were 62 pulp and paper mills and one thousand lumber mills.

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Phytocide utilization for forest clearing and regeneration

In forestry, the term phytocide has the same meaning as the term herbicide in agriculture and the same product may be sold under a different brand name for either use.

Uses of phytocides

Phytocides are usually used after logging to ensure the regeneration of young conifers that grow relatively slowly and face competition from competing or lesser vegetation. The latter group comprises pioneer species that grow rapidly in distressed areas (after logging, destructive forest fires, wind, snow or insect pests). They can hinder the growth of the young, natural or planted trees by blocking light, absorbing water and nutritive elements and taking up a lot of space. While these species are not harmful, they are opportunistic. They include fireweed, wild raspberry, grasses, white birch and hoary alder, which develop quickly.

There is a whole variety of approaches and techniques for limiting the use of mechanical or chemical control of competing vegetation. They are grouped according to their mode of action: biological (grazing organisms in pasture); biomechanical (e.g., mulching to inhibit the growth of competing vegetation); mechanical, and phytocidal (using chemical products to control vegetation growth). As a general rule, clearing is done mechanically using various tools to cut the competing vegetation (motorized or Handbook scythes, bush knives, circular saws, etc.), or chemically with phytocides.

The ultimate goal of these techniques is to protect regeneration in a such way that the young conifers can develop normally under ideal conditions without human intervention.

Competing vegetation is not destroyed mechanically or chemically at all logging sites. This practice is reserved for areas where it is necessary to plant new trees by hand and, in 1996, this represented only 15% of the areas under regeneration. Moreover, 25% of the transplant areas were not treated. Therefore, the 75% of transplanted treated areas corresponded to only 11% of the entire area under regeneration (75% of 15%). The largest areas treated with phytocides are generally in the regions of the lower St. Lawrence (5,715 hectares of mostly public forest, in 1996) and Quebec (2,000 hectares of strictly private forest).

Phytocide application can be carried out using spraying equipment mounted on airplanes or helicopters. It may also be applied at ground level by heavy machinery or by humans using portable motorized or Handbook spraying devices. When motorized ground spraying is carried out, the environmental and worker health impacts of combustion gases must also be considered.

Treated area

From 1984 to 1993, the total Quebec forest area treated with phytocides increased from 3,500 hectares to more than 27,000 (78% public forest and the balance private). However, treated areas have been steadily decreasing since 1993. Predictions for 1997 were 20,935 ha including 14,460 ha of public forest, or 50% of the area treated in 1993. In its 1994 Forest Protection Strategy, the government also announced its intention to abandon the use of phytocides in 2001, and espouse a whole series of preventive techniques to protect and assist regeneration. However, since this is not a ban on forest applications of herbicides, private forest owners may continue to use phytocides beyond this date if they wish.

The nature of glyphosate and how it works

Currently, glyphosate (respectively known as "Roundup" and "Vision" in the agricultural and forest milieus) is about the only phytocide in use. Developed in the 1960s, glyphosate is a non-selective phytocide effective against herbaceous plants, brush and trees. It is an essential aromatic amino acid synthesis inhibitor that alters the plant's metabolism and causes death. As a non-volatile product, it is only temporarily airborne as droplets during spraying. Natural environmental microorganisms break it down rapidly into aminomethylphosphoric acid (AMPA) which then splits into phosphates and CO_2. Its half-life is less than two months and it is undetectable after 12 to 15 months. The active ingredient is applied at a rate of 1.5 kg per hectare. In the days following application, foliage residues average 500 μg/g (wet weight) and the maximum average contamination of fruit such as raspberries is 33 Fg/g (fresh weight).

Effects on humans

In humans, the amount of glyphosate titrated in the urine is directly proportional to exposure. Contamination can occur by any means including ingestion, inhalation, and absorption through the skin. According to the Centre de toxicologie du Québec models, a person living near the site would receive a daily dose of about 0.0004 mg/kg and the dose for people fishing or hunting in a recently-treated area would be 0.0006 mg/kg. But this dose is less than the 0.023 mg/kg that the adult population ingests when consuming cereals and beer. The EPA suggests that the acceptable daily intake is around 0.1 mg/kg. No teratogenic, mutagenic or carcinogenic effects attributable to chronic exposure to glyphosate have been detected.

Environmental effects

All the data and information collated by different organizations indicate that glyphosate has few notable environmental effects. When it is sprayed after the middle of August, it has no effect on the desired coniferous growth because this is the time the conifer buds begin their winter dormancy period and the trees will not metabolize the glyphosate. The metabolism in young deciduous trees, however, is still active, making them vulnerable to glyphosate.

Low concentrations of glyphosate can be found in water and soil after spraying. It is quickly immobilized on soil particles where it is broken down primarily by the existing natural microorganisms. Although deciduous defoliation may alter herbivorous browsing patterns, animals and birds are not affected by glyphosate. Normalcy returns after a few years when the deciduous trees start to grow again. It should be noted that only one spraying is required per sector to enable the conifers to dominate competing vegetation naturally.

Sector: Forest

Activity: Phytocide (glyphosate[11]) Spraying to Promote Forest Regeneration[12]

STRESSOR/ EXPOSURE	Type of Stressor	Environmental Impact	Affected Zone	Control Measures	Standards or Recommendations
Technological disaster					
Gaseous or atmospheric emissions	- glyphosate	- deciduous defoliation - possibility of slight change in nesting bird populations - air pollution	- site and perimeter - site and perimeter - site and perimeter	- limit drift by accommodating wind speed, direction, humidity	- none
	- combustion gases			- none	- CO: 0.3 ppm (1h), 0.13 ppm (8h), Q-2 atmosph. qual. reg. - benzene: 30 mg/m^3 - formaldehyde: 3 mg/m^3 (QC work standards)
Liquid or waterborne emissions	- glyphosate	contamination of captor aquatic environment CL_{50}: 1.3 mg/L (most sensitive species: rainbow trout)	- site and perimeter	- buffer strip: 60 m for aerial spraying, 30 m for ground spraying	- MEF and EC raw water criteria: 0.28mg/L - 0.1 mg/kg/d (EPA)
Solid or soil-borne emissions	- glyphosate	soil contamination: microorganisms are primary means of breakdown	-site (glyphosate immobilized in soil)	- none	-none
Disamenities	- noise (motors) - vibrations - odours (gasoline and phytocide)	- salubrity - salubrity	- site, perimeter and vicinity - site	- motor mufflers - filters	- L_{eq}: 50 dB (day)
Indirect impacts or other exposure	- phytocide spill	- soil and watercourse contamination	- spill site	- preventive measures, training	- Q-2, section IV

[11] Glyphosate is the herbicide used almost exclusively by the ministère des Ressources naturelles du Québec (MRN) and private, government-subsidized producers.

[12] This grid is valid for public and private forest spraying done according to MRN guidelines. It does not apply to Hydro-Québec spraying practices in their rights-of-way or to the agricultural use of glyphosate (Roundup®).

	- social conflict	- economic value	- vicinity	- communication	
	- crash of craft used for spraying	- destruction, contamination	- crash site and immediate perimeter	- recovery of spilled substances	

STRESSOR/ EXPOSURE	**Effects on Health**	**Population at Risk**	**Probability of Occurrence**	**Biol./Environmental Monitoring Indicators**	**Information/ References**
Technological disaster					
Gaseous or atmospheric emissions	- no remarkable effects	- N.A.	- N.A.	- N.A.	BAPE (1997) Couture *et al* (1995) MRN (1995)
	- CO: carboxy-hemoglobinemia - formaldehyde and NO_x: resp. irritations - benzene and PAH: cancers	- workers, mostly those doing ground-level spraying with motorized machines	- unknown - unknown - unknown	- blood CO concentration - symptoms, medical follow-up - epidemiological studies	
Liquid or waterborne emissions	- no remarkable effects at concentrations found in the environment	- N.A.	- N.A.	- conduct fish toxicity tests (determine CL_{50})	- same as above plus Dostie (1991) EXTOXNET (see Internet reference)
Solid or soil-borne emissions	- no effect	- N.A.	- N.A.	- N.A.	same as item on “gaseous emissions”; Legris and Couture (1992)
Disamenities	- quality of life	- mostly workers	- frequent	- complaints	MRN report (see above)
	- quality of life	- workers	- frequent	- complaints	
	- quality of life	- workers and vicinity	- occasional to frequent	- complaints	
Indirect impacts or other exposure	- nausea and vomiting; NOEL: 175 mg/kg/d	- workers	- very rare	- medical follow-up	
	- quality of life/stress	- vicinity, community	- rare to occasional	-complaints/ perception	
	- injuries/death	- pilot	- very rare	- public safety	

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Use of *Bacillus thuringiensis (B.t.)* insecticide

The microbial insecticide *Bacillus thuringiensis* (*B.t.*) is widely used in forests to combat certain destructive insects, notably the spruce budworm[13] and, since 1987, it has been the only product authorized for aerial spraying against the budworm in Quebec. Since the beginning of the 1990s, many Quebec municipalities also use *B.t.* to control a variety of biting insects (mosquitos, blackflies, etc.) that present a real nuisance.

The spruce budworm: Canadian and Quebec outlook

The lepidoptorous spruce budworm causes serious damage in coniferous forests throughout the entire country, from Yukon to Newfoundland. Infestations occur on an average of every 30 years and sweep through Canada from west to east. It attacks mainly balsam fir and white spruce. During the 1940 and 1950 infestations in Quebec, the respective mortality in these trees was 65% and 20%.

[13] In spite of the insect's name, the most vulnerable conifer is the balsam fir.

The budworm is the most destructive parasite in Eastern Canada. As an integral part of the ecosystem for the last 10,000 years, this insect has occasionally helped create new stands by accelerating the decline of old-growth forests. But, when humans began to exploit forests commercially, the situation changed. The first recorded evidence of this insect dates back to 1704. From then until the end of the 19th century, there have been half a dozen infestations lasting up to 10 years each. A major epidemic in Eastern Canada in the 1920s did so much damage in New Brunswick that some companies went bankrupt.

The frequency and duration of infestations increased during the 20th century. By 1975, the last epidemic, starting in Quebec's Outaouais region in 1968, had spread to the entire coniferous forest territory, infesting an area of 35 million hectares. Although the epidemic had ended by 1987, some residual pockets of infestation were found in the Gaspé Peninsula. The losses from this epidemic were estimated at approximately 235 million m^3 of wood.

Biting insects

Biting insects, particularly mosquitos and blackflies, are a nuisance for humans and, to a lesser extent, for domestic and wild animals. Essentially, they make many people's lives so miserable that outdoor activities must be curtailed from the beginning of June until the end of July, during the time when the insects are most active. These insects can thus be economically detrimental to tourism. Unlike those in the tropics and certain regions of the United States, biting insects in Canada are not carriers of diseases such as encephalitis. From the public health perspective, they are considered more of a nuisance than a genuine problem.

Insecticides used in Canada before *B.t.*

The first intensive aerial spraying against the budworm was carried out in New Brunswick and eastern Quebec in the 1950s. Until 1962, the only pesticide used was DDT. When DDT was banned in the early 1970s, organophosphorous fenitrothion, aminocarb and mexacarbate (two carbamates) were used from 1974 to 1976. Mexacarbate was withdrawn in 1977 and *B.t.* was used for the first time in 1978. The scenario was similar in 1982 and 1983 except that the use of *B.t.* increased. In 1987, *Bacillus thuringiensis* became the only insecticide to be used in Quebec forestry for controlling the spruce budworm. After 1990, attempts were also made use *B.t.* to control other destructive forest insects such as the hemlock looper, the jack pine budworm and the Swaine jack pine sawfly.

Basic information on *Bacillus thuringiensis*

B.t. is a rod-shaped aerobic bacteria found everywhere in the world. Although it was discovered in Japan at the turn of the century, it wasn't until the 1920s that its insecticidal property was recognized. There are 34 *B.t.* sub-species (serotypes and varieties) and about 40,000 strains. The strain most commonly used in Canada for aerial forest spraying is *Bacillus thuringiensis* var. *Kurstaki* (*B.t.K.*). The strain used to control biting insects in urban and tourism areas is *B.t. israelensis* (*B.t.i.*). For this use, it is injected into the water to control the mosquito larvae rather than being applied by aerial spraying. There are 17 commercial *B.t.K.* preparations on the Canadian market for controlling lepidoptera. Although this variety is primarily used in Quebec to control the spruce budworm, its use is now spreading into agriculture.

Mode of action

The insecticide preparations contain the endospore of the bacillus and the crystal, a parasporal body. When the latter is dissolved in the alkaline digestive tract of certain insect larvae, it releases a variety of proteins called protoxins or delta- endotoxins. Specific enzymes in the digestive tract transform these d-endotoxins into active toxins that alter the intestinal cellular structure, precipitating epithelial perforation and an osmotic imbalance. Within minutes of ingesting these crystals, larval nutrition ceases and death occurs within a few hours. It must be specified that for the crystal to dissolve, the pH of the medium must be alkaline, i.e., between 9 and 11. Also, the various toxins are quite selective and their action spectrum is limited to certain groups of insects.

Environmental mobility and persistence of *B.t.*

B.t. spore dispersion in the air is obviously a factor of wind direction and speed, the level of humidity and the size of the insecticide particles at the time of spraying. The level of *B.t.* spore concentration in the air decreases rapidly since less than 2% of the total concentration can be detected 2 hours after dusting. Most samples taken in municipalities located close to treated sectors showed bacterial concentrations of less than 1 cfu/m^3 [14]. However, the presence of spores in the ambient air several months after spraying indicates some environmental persistence.

Although not necessarily viable, *B.t.K.* spores can persist on vegetation for up to a year. Viable spores have been found a month after spraying. Protection from ultraviolet solar rays may explain the persistence of viable spores on plants. Spores found in splits and folds of foliage, cones or rough tree bark are not exposed to UV rays and thus have greater longevity.

[14] Cfu, colony-forming unit: in theory, each viable spore and each vegetative bacterial cell placed on a nutrient agar (in a Petri dish) should form a visible colony after a few hours or days. In this context, it signifies one bacterium per cubic metre of air.

Environmental persistence of *B.t.K.* in water follows a pattern similar to that observed in the air. Concentrations decline rapidly within the first hours and medium-term concentrations (several months to a year) are very low (less than 1% of the highest levels recorded in the first few hours). Although the medium-term aquatic persistence of *B.t.* is primarily due to soil leaching by rainwater and snow-melt runoff, most of the *B.t.* is found in sediment after it has been in the water for a few weeks.

B.t.K. is most persistent in the soil where it can remain for up to seven years. One study showed that spore and crystal breakdown is non-existent or minimal after more than 8 weeks in forest and agricultural soils. Another observed that the concentration of microorganisms remained constant a year after spraying. It is noteworthy that the vertical percolation of *B.t.* into the soil is minimal. Since 90 to 99% of the spores remain within the top five centimetres, there is very little chance the *B.t.K.* would reach ground water aquifers. Moreover, studies have shown there is little likelihood of the spores germinating in acid soils and this is the type of soil found beneath the boreal coniferous forest where most of the spraying is done.

Effects of *B.t.* on animals and humans

Experimental oral, respiratory, subcutaneous and ocular exposure of mammals to *B.t.* produced no adverse effects even though *B.t.K.* was observed in all the intestinal flora of the workers and students three months after the spraying period. It appears that the bacillus can be spread from person to person or through indirect contact with clothing or air.

Some mention has been made of the bacillus possibly acting as an opportunistic agent in aggravating disease, or as a co-pathogenic or synergistic agent. There is, however, little information on the subject and the role of *B.t.* in the few documented cases was minor.

B.t. is also known to persist in the blood and digestive systems as well as in a variety of organs including the eyes, nose, lungs, liver, spleen, kidneys and brain. Depending on the organ affected and the initial bacterial concentration, this persistence may last a few hours or several months. The formation of IgM, and later, IgC, antibodies has been observed. These immunological reactions are caused primarily by the presence of vegetative cells rather than the presence of spores or crystals. The antibodies last only a few months and no health problems were detected in the workers or other people who developed them.

Towards the end of the 1980s, an extensive epidemiological study conducted in a region of Oregon with a population of 120,000 (where *B.t.K.* was used to control the Asiatic gypsy moth), brought to light 3 cases in which the role of the bacillus was unclear. The three people in question had immuno-suppressive health problems well before the spraying. In all three cases, however, it was impossible either to attribute infectious problems to*B.t.K.* or to exclude the bacillus's etiological role with any certainty.

In the mid-1990s, some strains of *Bacillus thuringiensis* were found to produce a diarrhoeal enterotoxin capable of causing food poisoning. The authors of the study also identified a strain of *B. thuringiensis* var. *Kurstaki* in several foods of plant origin, the implication being that the micrioorganisms could be ingested. The presence of *B. thuringiensis* was reported in several of the food poisoning victims in an outbreak at a seniors residence, but it was impossible to specify what etiological role the *B.t.* played. Reports from Italy indicated *B. thuringiensis* was also isolated from some severe burn wounds. It is important to specify that, in all these cases, elaborate characterizations were necessary to differentiate *B. thuringiensis* from *B. cereus*, both of which are genetically close. Since *B. cereus* is well known for its role in many infections, and particularly gastroenteritis, the importance of differentiation is understandable. However, the studies were inconclusive as to the exact etiological role of *B. thuringiensis*.

Finally, cutaneous provocation tests brought to light no allergic reactions on unbroken skin and there have been no reports of cases of mutagencity associated with the presence of *B.t.*

It is therefore reasonable to conclude that *B. thuringiensis* represents no risk to the majority of healthy people. Nevertheless, the possibility of opportunistic infection in people with immunodeficiencies or serious infections cannot be ignored. It is also important to remember *B.t.K.* is not the strain used for controlling biting insects; *B.t.i.* is used instead and application in this instance is not by aerial spraying.

Effects of *B.t.* preparation additives

Commercial *B.t.* preparations basically contain the toxin crystals, spores and cellular debris to which various substances are added, the majority of which are the water or oils used to suspend the spores and toxins. Next, additives intended to increase the insecticide's effectiveness are added to the suspension. These additives are diluents (water, oil, powdered clay), emulsifiers, thickeners, humectants, foam inhibitors, substances that encourage the insects to eat the crystals (such as sugar), and stabilizing agents (antioxidants, antibacterials, evaporation suppressants). It must be specified that since the nature and chemical composition of these additives are protected trade secrets, it is impossible to know the exact potential toxicity of commercial *B.t.* preparations.

However, we do have enough information to state that some of these additives have slightly irritating properties, as confirmed by the warnings contained on commercial product data sheets. The organs most sensitive to additives are the respiratory system and the eyes. Eye irritations and conjunctival congestion observed in rabbits are caused by the abrasive properties of the additives. A case of corneal ulceration, diagnosed in a man who splashed insecticide into his eye, was also caused by the additives. Finally, the higher frequency of eye, nose and throat irritation, chapped lips and dry skin in workers exposed to *B.t.K.*, as compared to a control group, could be a response to the presence of products other than the bacteria. In addition, the symptoms of irritation were observed more in workers with a prior history of allergies (asthma, eczema, seasonal allergies).

Sector: Forest

Activity: *B.t.* (*Bacillus thuringiensis*) spraying to control certain destructive forest insects and urban biting insects

STRESSOR/ EXPOSURE	Type of Stressor	Environmental Impact	Affected Zone	Control Measures	Standards or Recommendations
Technological disaster					
Gaseous or atmospheric emissions	- B.t. spores and crystals	- residue on plants; no known toxic effect	- site, perimeter and vicinity	- limit drifting	- no standards
	- various additives	- air pollution	- site, perimeter and vicinity	during spraying - limit drifting during spraying	- commercial B.t. preparations subject to federal pesticide registration process
Liquid or waterborne emissions	- B.t. spores and crystals	- presence and persistence in surface water	- site, perimeter and vicinity	- avoid passing over water-courses and expanses	- stop spraying near shorelines (cut edges), no other standard
	- various additives	- unknown	- unknown	- idem	
Solid or soil-borne emissions	- B.t. spores and crystals	- presence and persistence in soil	- site and perimeter	- none practical	- none
	- various additives	- unknown	- unknown	- none practical	- none
Disamenities					
Indirect impacts or other exposure	- concentrated insecticide solution spill	- soil and watercourse contamination	- spill site	- preventive measures, worker training	
	- crash of the spraying aircraft	- destruction, contamination	- crash site and immediate vicinity	- recovery of spilled substances	
	- social conflict	- economic value	- vicinity	- communication	

STRESSOR/ EXPOSURE	Effects on Health	Population at Risk	Probability of Occurrence	Biol./Environmental Monitoring Indicators	Information/ References
Technological disaster					
Gaseous or atmospheric emissions	- probably none, opportunistic infections in the immunodeficient	- immunodeficient(?)	- unknown or very rare	- viable spore counts (cfu)[15]; epidemiological studies	Lessard and Bolduc (1996) Damgaard *et al* (1995 1996, 1997) Green *et al* (1990)
	- possible eye, skin and respiratory tract irritations	- exposed workers	- rare	- unknown (additives protected trade secrets)	
Liquid or waterborne emissions	- probably none, opportunistic infections in the immunodeficient	- immunodeficient(?)	- unknown or very rare	- viable spore counts (cfu) in surface and drinking water	Lessard and Bolduc (1996) Damgaard *et al* (1995 1996, 1997)
	- unknown	- unknown	- unknown		
Solid or soil-borne emissions	- unknown	- unknown	- unknown	- N.A.	Lessard and Bolduc (1996)
	- none	- N.A.	- N.A.	- N.A.	
Disamenities					
Indirect impacts or other exposure	- irritations caused by additives	- workers	- rare	- unknown (additives are protected trade secrets)	Lessard and Bolduc (1996) Q-2, section IV, impact study on spraying > 600 ha of forest
	- injuries/death	- plane/helicopter pilot	- very rare	- public safety, Transport Canada	
	- stress, worry	- vicinity, community	- rare to occasional	- complaints/ perception studies	

[15] It is important to differentiate *B. thuringiensis* from *B. cereus*. The latter is known to cause many types of infections.

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