CANADIAN HANDBOOK ON HEALTH IMPACT ASSESSMENT

Volume 2
Decision Making in Environmental Health Impact Assessment

DRAFT

DECEMBER 1999

Manufacturing industries

Canadian perspective

Manufacturing is a significant component of Canada's economy. In 1993, some 39,000 manufacturing establishments generated 18% of the country's GDP (approximately $100 billion). However, since 1961, the manufacturing sector's share of Canada's GDP has been declining steadily, when it accounted for approximately 25% of the GDP. The same trend has been observed in the primary industries (metallurgy, pulp and paper, mining), whose share of the GDP dropped from 10% to 7% between 1961 and 1989. The manufacturing sector employs 1.8 million people, or 13% of the Canadian labour force. Its two largest components are transport equipment (15% of activities) and food processing (13%). Most of Canada's manufacturing activity, i.e., 70%, is concentrated in the Windsor-Quebec City corridor.

Reference

Canada (1996). The State of Canada's Environment - 1996. Government of Canada.

Aluminum production

Socio-economic profile

Aluminum production is a major industry in Quebec, with 90% of Canadian production centred in the province. Quebec is the world's third largest producer, behind only the U.S. and the former Soviet Union, with an annual production capacity of around 2.5 million tonnes. In 1993, the value of Quebec shipments totalled roughly $3.5 billion, providing direct jobs to 12,500 people. Quebec has several large smelters producing primary aluminum (obtained from bauxite; see below). Alcan is the largest of the Quebec firms, with four smelters in the Saguenay - Lac-St-Jean region (and a fifth in the works) and one in Shawinigan. Other major producers include Reynolds (Baie-Comeau), ABI (Bécancour), Lauralco (Deschambault) and Alouette (Sept-Iles). The aluminum sector industry is currently expanding, with several firms planning to modernize their facilities or construct new plants.

Description of aluminum production process

Primary aluminum is obtained from a raw material, bauxite (Bayer process), rather than from recycled aluminium (secondary aluminum). Since there are no bauxite deposits in Quebec, the raw material is obtained from places like Australia, Guinea, Jamaica and Brazil. Bauxite is composed mainly of aluminum hydroxides ($Al_2.H_2O$) and iron oxides, the latter giving it its characteristic reddish tint. Alumina (Al_2O_3) is obtained by dissolving bauxite in a concentrated, hot (250^oC) basic solution (NaOH) under high pressure (autoclave principle). The production of 1.9 tonnes of alumina (which will ultimately yield one tonne of aluminum) requires 4 to 5 tonnes of bauxite. The residue, called red mud, is a fairly inert solid waste that is not considered hazardous. However, fugitive dust may escape from storage sites and be deposited on neighbouring communities. In Quebec, the only smelter that extracts alumina from bauxite is Alcan's Vaudreuil plant in Jonquière, which supplies alumina to Alcan's other facilities. The other Quebec firms import processed alumina from abroad, although some purchase their alumina from Alcan. In Jonquière, roughly 600,000 t of red mud is generated annually, which is thickened and piled, with a covering layer of gypsum, in various storage areas.

The alumina is transformed into aluminum using an electrolytic process, which occurs in the smelter's potroom. This process requires a large amount of electricity, each tonne of aluminum produced requiring between 13 and 17 million watts/hour of electricity (and a current between 60,000 and 300,000 amperes), which is why so many aluminum firms have established smelters in Quebec.

In the potroom, the alumina is placed in steel cells, or pots, along with various additives like cryolite (Na_2AlF_3) and aluminum fluoride (AlF_3) which reduce the fusion point to 950^oC (instead of 2400^oC). The electrical current passes from a carbon anode, a rod located in the centre of the cell, to the cathode, the carbon lining of the cell. At regular intervals, the melted aluminum produced is siphoned off and transferred to casting facilities.

Atmospheric pollutants

The transformation of alumina to aluminum is the most polluting stage of this process. It gives off numerous gases (called pot gases) and produces hazardous waste. If no additives were used and the reaction was complete, only CO_2, a greenhouse gas, would be produced. In practice, however, carbon monoxide and polycyclic aromatic hydrocarbons (PAHs) are generated, the latter coming mainly from the spent carbon anodes and pot linings. Old smelters using obsolete electrolytic processes (for example, the horizontal stud Soderberg process) produce significant quantities of PAHs, including carcinogens, such as benzo[a]pyrene (B[a]P). Studies show that the presence of PAHs in the ambient air may be associated with certain cases of bladder cancer in workers. Installing filters and making it mandatory for employees handling the pot covers to wear special safety equipment considerably reduces the risk of exposure.

The electrolytic process also produces dust, suspended particulates and sulphur dioxide (SO_2), which is present in the coke used to prepare the anodes. SO_2 is a major atmospheric pollutant contributing to the formation of acid rain and acid smog. This gas, which is almost completely absorbed between the nose and the pharynx, irritates the respiratory tract. Sulphur dioxide is also fairly damaging to plants, with concentrations around 0.03 ppm causing acute lesions on foliage.

Finally, we must mention the emission of gaseous fluorides resulting from fluorine additives used in the pots. Fluorine is an extremely toxic, very reactive gas that causes disintegration in almost all other elements except for oxygen and nitrogen. Aluminum smelters are the main source of atmospheric fluorides in Quebec. Plants are very sensitive to atmospheric fluorides and often are used as bioindicators. In mammals, absorbed fluorine is retained in dental and bone tissues, and may cause bone atrophy and dental fluorosis, the main symptom of the latter being an orange-brown pigmentation in the teeth. In the 1940s, some farm animals that grazed regularly in pastures around smelters were found to have these ailments.

Hazardous wastes

As previously mentioned, the internal lining of the cells is made of brick, composed mainly of anthracite and other refractory materials called pot wash, which constitutes the cathode. This lining ages over time and must be removed. Although the lining consists mainly of carbon, it is impregnated with cryolite and aluminum fluoride, as well as cyanide, which is a byproduct of electrolysis. The old pot linings are considered hazardous waste, not only because they contain toxic substances but also because, with contact with water, acids or alkalis, or at high temperatures, they may produce toxic or even explosive gases, such as hydrogen fluoride or hydrogen cyanide. Old pot linings are usually stored in a secure place until a way to reuse or decontaminate them can be found.

Water pollution

Many of these pollutants released into the atmosphere are also present in water, particularly fluorides and PAHs. Smelter effluent can also contain total suspended solids and oils and greases from machinery. This is more common in old smelters, with the more modern ones being models in terms of liquid effluent treatment. Changes in production processes and the presence

of treatment systems have resulted in effluents that are much reduced and relatively non-polluting. Some smelters even have zero effluent discharges, except for sanitary wastewater.

Some smelters have a sector called the carbon plant where the anodes suspended in the electrolytic cells are produced. Since these anodes become spent after time, they must be periodically replaced, usually every 20-30 days. Formerly, anodes were cooked in the pot, with the coke and pitch binder being transformed into graphite. Modern smelters produce prebaked anodes in their carbon plant. This production usually generates pollutants such as PAHs, which result from the heating of carbon compounds.

In conclusion, it must also be mentioned that secondary aluminum, made from recycled scrap, saves up to 95% of the energy used in making primary aluminum, and greatly reduces pollutants since electrolysis (the transformation of alumina into aluminum) is not needed.

Sector: Industrial Activity: Aluminum production[29]

STRESSOR/ EXPOSURE	Nature of stressor	Impact on environment	Zone of influence	Control measures	Standards or recommendations
Technological disasters	fires, explosions, spills, floods	toxic gases and liquids; destruction	site, surroundings and neighbourhood	Recovery, containment, interception	CSA Z731-95 Emergency Planning for Industry
Gas or atmospheric emissions	- fluorides	- dieback in plants and decalcification in mammals	- site, surroundings, neighbourhood	-scrubbers, new technologies, buffer zones	-2.5 Fg/m^3 (24h), (workplace)
	- SO_2	- acute chronic lesions in plants	- regional (up to 100 km)	- scrubbers, non-sulphur fuel	- 0.5 ppm (1h) and 11 ppm (24h) (Q-2 Reg. atmos. quality)
	- CO_2	- greenhouse effect	- global	- reduce fossil fuel use	- none
	- PAH (anodes)	- none	- site and neighbourhood	- capture	- 0.2 Fg/m^3 (8h) total PAHs (MUC[30])
Liquid effluent or in water	- aluminium	- toxic for fish and aquatic insects	For all pollutants: receptor watercourse	For all pollutants in water: abstraction and treatment	- 0.2 mg/L (MEF criteria untreated water intake -1.0 mg/kg/j (WHO)
	- fluorides	- bioaccumulation in aquatic organisms			- 1.5 mg/L (Reg. Potable water, MEF) 60Fg/kg/d (EPA)
	- suspended and dissolved solids	- unhealthiness, reduced visibility			- 0.5 g/L (Environ. Canada criteria, untreated water)
	- oils and greases	- unhealthiness			- no criteria
	- PAH (from atmosphere)	- neoplastic and genotoxic effects			- 2.8 x 10^{-6} mg/L (MEF untreated water) 1/7.3 mg/kg/d (estimated risk, B[a]P, EPA)
Solid emissions or in soil	- used pot linings	- very toxic	- site	- safe confinement	- Q-2, Hazardous Waste Reg. - Q-2, Reg. solid waste
	- dross, grit	- unhealthiness	- site	- recovery, recycling	
	- domestic waste	- unhealthiness	- site	- disposal, recycling	
Nuisance	Noise (fixed and mobile sources)		site and surroundings	- noise abatement bank -buffer zone	L_{eq} 45dB (night)
Indirect impacts or other exposure					

[29] Impacts evaluated in the current content, excluding old polluting technolgies (Soderberg process). The analysis includes the carbon plant, a sector not found in all smelters, but excludes the production of alumina from bauxite, which is usually done outside Quebec.

[30] Montreal Urban community air quality standard

STRESSOR/ EXPOSURE	Health effects	Population at risk	Probability of occurrence	Indicators, monitoring	Information/ references
Technological disasters	resp. irritation, asphyxia, injury, death	workers and immediate neighbours	very rare	morbidity/ mortality ratio MEF DATA BANKS???	
Gas or atmospheric emissions	- eye, skin irritations, dental fluorosis, osteoarthritis	- workers	-rare - very rare - N.A. - frequent - very rare	- fluorides in ambient air	- BAPE (1997) - ECB (1986) BAPE (1997) Reg. air quality (QC) - Jacques (1992) - Environment Canada (1994)
	- irritations of mucous membranes in respiratory tract	- none at concen-trations emitted		- SO_2 in ambient air	
	- climate change	- global		- concentration of atmospheric CO_2	
	- cancer (mainly lung, bladder)	- workers and Neighbours		- concentration of B[a]P and other PAHs in ambient air	
Liquid effluent or in water	- neurological problems	- those consuming water from receptor watercourse	- unknown	- concentration of Al in water	BAPE (1997) Lalonde (1991) Env. Canada; Canadian Water Quality Guidelines and MEF; Water quality criteria - Environment Canada (1994)
	- probably none at concentrations found	- N.A.	- N.A.	- concentration of fluorides in water	
	- unhealthiness	- none	- N.A.	- visual or quantities of SS in water	
	- unhealthiness	- none	- N.A.	- visual or quantities of SS in water; quantities of oils/greases in water	
	- cancer	- those consuming water or aquatic organisms	- unknown	- concentration of PAHs in water and fauna	
Solid emissions or in soil	- extreme toxicity,	- workers	- rare to occasional	- accident reports from incidents	Alcan data sheet on used pot liners (# A0026)
	irritation of skin and respiratory tract	- workers	-???	-	
	-??? - unhealthiness	-	-	-	
Nuisance	sleep disturbances stress	neighbourhood	occasional	complaints/ perceptions	

Indirect impacts or other exposure					

References

Alcan (1994) Alcan brochure. Alcan Smelters and Chemicals Ltd., Montreal, 20 p.

AIAQ (1993) *L'industrie de l'aluminium*. The Aluminum Industry Association (of Quebec), Montreal, 12 p.

BAPE (1997) *Projet de construction d'une usine d'électrolyse à Alma, par Alcan Aluminium ltée*. Bureau d'audiences publiques sur l'environnement (Government of Quebec), Report No.120, 180 p.

Capano, M (1996) *Rapport environnement.* Alcan Smelters and Chemicals Ltd. Montreal, 15 p.

Chevalier, P. (1995) *Gestion de l'environnement en milieux urbain et industriel*. Presses de l'Université du Québec, 577 p.

Fabri-Forget, M (1993) *PAH Emissions into the Canadian Environment, Supporting Document No. 1 for the National Evaluation Report on PAHs*, Environment Canada, various pagings.

Jaques, A.P. (1992) *Canada's Greenhouse Gas Emissions: Estimates for 1990.* Department of the Environment, Government of Canada, 80 p.

Lalonde (1991) *L'aluminerie Laterrière et la protection du milieu aquatique: vers une intégration harmonieuse*. Sciences et techniques de l'eau, mai: 145-150.

MEF (1993) *Bilan de l'environnement au Québec.* Quebec Department of the Environment and Wildlife, Government of Quebec, Éditions Guérin (Montréal), 560 p.

Sala, J,-M. (1992) *Sécal; dix ans de progrès sur la voie du développement durable. Quatrième colloque de formation en santé environnementale*, October 1992 (Quebec), 8 p. + appendices (document updated in 1993)

UNEP (1986) Guidelines for environmental management of aluminium smelters. UNEP-Industry & Environment Guidelines Series, United Nations Environment Programme, 42 p.

Other sources

Fact sheets produced by Aluminum Industry Association of Quebec on aluminum in Quebec, aluminum 100 years later, production and processing of aluminum and recycling aluminum

Fact sheets and documents produced by Alcan on aluminum metallurgy, Alcan in Quebec, paper presented to the Ninth World Clean Air Congress (1991) and the Bayer process.

Website on aluminum production process and world production (in French): www.sfc.fr/Vignes/Vig3_al.htm#Alumine

Pulp and paper production

Canadian perspective

In 1994, there were 668 mills producing pulp, paper or related products in Canada. This industry makes a major contribution to Canada's trade balance, with newsprint exports of $5.5 billion (53% of world newsprint sales) and pulp sales of $6.7 billion (34% of world sales) in the same year.

Quebec production

Pulp and paper production is a key component of Quebec's economy. In 1995, the value of industry shipments (from just over 60 mills) represented 11.6% of all manufacturing activity in the province[31]. Pulp and paper mills provided 21,200 direct jobs and an additional 10,600 jobs in related sectors.

Technology

As explained further on, there are two main technologies for making paper pulp. In Quebec, most pulp produced is mechanical pulp (66% in 1995, or 4.8 million tonnes), with the rest being chemical pulp. Most of the mechanical pulp produced is used to make newsprint. In 1995, Quebec accounted for 11.8% of world newsprint production and 42.5% of total Canadian production. Elsewhere in Canada, as in the United States, chemical pulp accounts for two-thirds of total pulp production, the opposite of the situation in Quebec. This is significant from an environmental and public health standpoint, since chemical pulp production results in more toxic substances and greater nuisance.

---

[31] Manufacturing activity should not be confused with gross domestic product (GDP), which is used in the descriptions of other types of activities.

Paper, which was first made in its present form in China 2000 years ago, is basically a sheet of entangled fibres. Paper can be made with various raw materials such as cotton, but wood is used in almost all modern mills. The cellulose molecules in wood pulp provide the fibre to make the paper. The various different papermaking technologies all have the same purpose, i.e., to separate the desirable cellulose (or other) fibres from the undesirable components, such as lignin.

There are two main pulping technologies, the mechanical and chemical processes. The mechanical process (using a grindstone) is the oldest; it provides high yields and generates little waste, but weakens the fibre in the process of separating it from the lignin. To obtain a stronger fibre, variations to this basic process have been devised, including thermomechanical and chemithermomechanical methods. There are two main chemical processes: the bisulphite (or acid) process and the sulphate or Kraft (alkaline) process. In the bisulphite process, the wood fibres are treated by sulfonation using a sulphur dioxide and alkaline oxide solution; the Kraft process relies on a caustic solution of sodium hydroxide and sodium sulphide.

Pollutants inherent in chemical pulping processes

It is important to fully grasp the environmental consequences of chemical pulping processes. First, the use of sulphur-based reactants results in the emission of foul-smelling sulphur compounds. The foulest odours produced by the pulp and paper industry are usually from Kraft pulp mills. Secondly, both chemical processes produce a fairly dark pulp that has to be bleached. The bleach generally used in both processes is chlorine-based (chlorine gas, chlorine dioxide or hypochlorite), which reacts with the organic matter in the pulp to produce dioxins, chlorophenols and chlorinated resin acids, known collectively as adsorbable organic halides (AOX). In the mechanical process, a less aggressive product, such as hydrogen peroxide, is generally used.

Atmospheric pollutants

The main air pollution problems caused by the pulp and paper industry result from its use of mechanical processes, and the combustion equipment required to heat the fibre and pulp. The use of combustion equipment is common to both mechanical and chemical processes. Therefore, the industry is responsible for emissions of suspended particulates and pollutants specifically related to fossil fuel combustion: carbon monoxide (CO), carbon dioxide (CO_2), sulphur dioxide (SO_2) and nitrogen oxides (NO_x). Pulp mill emissions contain very high levels of NO_x, which is responsible for the formation of acid rain and photochemical smog (an ozone-depleting gas). Pulp mills also emit large quantities of CO_2, a greenhouse gas. Mills using chemical pulping technology produce various sulphur oxides (SO_x), including SO_2, and a number of foul-smelling compounds, such as hydrogen sulphide (H_2S) and thiols. As we have seen, sulphur dioxide (SO_2) is a major atmospheric pollutant that contributes to the formation of acid rain precipitation and acid smog. This gas, which is almost completely absorbed between the nose and pharynx, is irritating to the respiratory tract. Sulphur dioxide is also fairly damaging to plants, with concentrations around 0.03 ppm causing acute lesions on foliage.

Pollutants in aquatic habitats

The nature of mill effluent depends on the type of process used, but most mills probably release the following pollutants:

- suspended solids (SS) such as fibre and bark;
- organic matter, which increases the biological oxygen demand (BOD);
- various inorganic compounds (mainly aluminium, manganese and zinc);
- hydrocarbons from machine lubricants;
- resin and fatty acids and phenolic compounds.

Mechanical pulping mills generate mainly resin acids, cellulose fibres and pulp screening residues, which are discharged with the effluent. The actual paper manufacturing process (from pulp) may result in the release of fungicides and additives used to make the various types of paper, particularly coatings (kaolin, wax, solvents, latex, resins) and adhesives (flour adhesive, fish glue, starch adhesive, etc.). If the pulp mill also uses recycled paper, the effluent will contain coatings and adhesives along with printing inks for newspapers, Xerox toners, and offset, typographic, flexographic and rotogravure inks. Coatings are used to improve the texture of the paper by giving it a more uniform, smoother, more glossy or glazed finish. The most commonly used products include kaolin (a type of clay), wax, solvents, latex and various resins. Some are natural products (kaolin), while others are completely synthetic. All coated papers are not recyclable; kaolin-treated paper is, while papers treated with plastic are not. Adhesives may be of animal (fish glue, casein) or plant origin (flour, starch) or be made from synthetic resin (such as polyvinyl acetate). Synthetic adhesives are difficult to remove because they are often insoluble in water and form spots on recycled paper. Ink for newsprint has a mineral oil base, while offset inks are made from varnish solubilized in vegetable oil (linseed or soy). Flexographic inks are usually made from fine particles of carbon encapsulated in a water-soluble polymer. The particles, which are very tiny, are difficult to eliminate during de-inking, resulting in a significant reduction in the whiteness of the pulp. Finally, toners for photocopy machines are almost impossible to eliminate.

Resin acids

These acids (mainly pimaric and dehydroabietic acids) along with fatty acids (mainly oleic, linoleic and linolenic) are present naturally in wood. Various studies have shown that concentrations of these acids in effluent frequently exceed the limit above which mortality occurs in aquatic organisms. Quebec paper mills have been shown to have average concentrations of 6.9 mg/L of resin acids in their effluent. This figure should be no greater than 0.25 mg/L (at a pH of 7.0), the limit set by the Quebec Department of the Environment and Wildlife. However, it must be determined whether the concentration applies to raw effluent; dilution in water results in a considerable reduction of concentrations. Nonetheless, acids can accumulate in sublethal concentrations in the tissues of fish, molluscs and crustaceans. Since some of the acids have been shown to be mutagenic, their presence is of additional concern. Finally, it should be noted that effluent from mechanical pulp mills generally contains more resin and fatty acids.

Phenolic compounds

Effluent released in aquatic environments also contains phenolic compounds, such as cresol, catechol, guaiacol and others. These compounds occur in higher concentrations in softwood (fir, spruce, pine). Although these substances have a certain degree of toxicity in themselves, the chlorinated forms are the main cause for concern; these forms are only present in effluent from mills that use a chlorine bleaching process.

Solid waste

Most of the solid waste from the pulp and paper industry consists of “mill residue”, which comprises bark, wood residues, refuse (pulp, paper and cardboard), ash from combustion facilities and sludge from the treatment of process water and de-inking. In the late 1980s, the 60 or so Quebec pulp and paper mills generated over 1.6 million tonnes of waste, most of which was sludge from the treatment of effluent (39%), bark (31%) and wood residues called splints (8%). Furthermore, 50% of the solids in de-inking sludge consist of kaolin, a substance used for coating paper (see above). This inert substance does not prevent the sludge from being reused, but it would be better to recover the kaolin for reuse. The presence of resins and inks may lead to a certain degree of toxicity in the sludge.

Interest has focussed on the reuse of sludge from treatment systems. The sludge resulting from the primary treatment of mill process water (in settling tanks) contains mainly macroscopic substances and particles. The sludge resulting from secondary (biological) treatment usually contains a number of toxic substances such as heavy metals, phenols, and resin acids that were not digested by the microorganisms used. It is well known that most heavy metals are fairly toxic, including mercury, chromium, lead, and zinc. Cadmium, arsenic, nickel and hexavalent chromium are carcinogenic. De-inking sludge may also contain toxic substances, particularly glues, plastics and inks.

Most of the sludge is buried at special sites. In the early 1990s, there were roughly 30 sanitary landfills for pulp and paper mill effluent. A small percentage of the sludge (less than 20%) is used in mill boilers fuelled by wood residues and bark. There have been experiments in using sludge in agriculture and forestry; the sludge contains some plant nutrients and can also be used as an organic soil amendment. In agriculture, however, these advantages may be offset by the presence of heavy metals that may be absorbed by growing plants.

In conclusion, the use of filters, cleaners and effluent treatment systems and the development of processes for reusing the solid waste as biosolids will allow the pulp and paper industry to become much less polluting.

Sector: Industrial Activity: Thermomechanical pulp production[32]

STRESSOR/ EXPOSURE	Nature of stressors	Impact on environment	Zone of influence	Control measures	Standards or recommendations
Technological disasters	fire, explosion chemical spill	smoke destruction contamination	site and surroundings	interception, confinement, recovery	CSA Z731-95 Emergency Planning for Industry
Gas or atmospheric emissions	- Vapour plume	- reduced visibility	- site	- keep at distance from traffic	- none
	- CO_2	- greenhouse effect	- global	- reduce fossil fuel use	- none
	- No_x	- accompanies formation of ground-level ozone and photochemical smog	- local and regional	- interception and treatment, energy efficiency	- NO_2: 0.2 ppm (1 h) and 0.1 ppm (24 h) (Q-2, Reg. air quality)
	- particulates	- unhealthiness	- site and neighbourhood	- dust collector	- 150 Fg/m^3 (24 h) Q-2, Reg. air qual.
Liquid effluent or in water	- suspended and dissolved solids	- unhealthiness, reduced visibility	For all pollutants: receiving waters	- settling, primary treatment	- 0.5 mg/L Env. Canada criteria, untreated water)
	- phenols	- toxicity (mainly salmonids)		- secondary treatment	- 2 Fg/L (Q-2 Reg. potable water) 0.6 mg/kg/j (EPA)
	- resin acids	- very toxic		- secondary treatment	- none
	- organic materials	-reduction in dissolved oxygen in water		- secondary treatment	- 3-7 mg/L (MEF criteria, untreated water to be chlorinated)
Solid emissions or in soil	- bark, mill residue	- unhealthiness (floating debris, scum)	- site and surroundings	- recovery, reuse for energy production	Q-2, Reg.on pulp and paper section VI
	- organic and inorganic materials from sludge from primary treatment	- unhealthiness, soil pollution	- site or landfill offsite	- sanitary landfill	
Nuisance	Odours	unhealthiness	site, surroundings and neighbourhood	buffer zone interception and treatment	Q-2, section X
Indirect impacts or other exposure	drop in value	economic value	surroundings and neighbourhood	compensation communication	Q-2, section IV

[32] The process selected was thermomechanical pulping using sodium hydrosulphite bleaching, which is common in Quebec.

STRESSOR/ EXPOSURE	Health effects	Population at risk	Probability of occurrence	Biological and environmental indicators (monitoring)	Information/ references
Technological disasters	resp. irritation, injury, death	workers and neighbours	very rare	morbidity/mortality ratios	
Gas or atmospheric emissions	- none	- none	- N.A.	- N.A.	MEF (1993)
	- climate change	- global	- frequent	- atmospheric CO_2 concentrations	
	- altered respiratory function	- residents of urban and near-urban areas	- rare to occasional (mainly in summer)	- atmospheric NOx, concentrations, epidemiological surveys of pneumonopathy	
	- irritation to resp. tract	- neighbours (asthmatics)	- rare	- epidemiological monitoring, quantification	
Liquid effluent or in water	- unhealthiness	- users of water (swimming, canoeing, fishing)	- occasional to frequent	- visual appearance of watercourse and SS measurements	- MEF (1993) - Lavallée, Rouisse and Paradis (1992) - Envirobec (1992)
	- bad tasting water or aquatic organisms	- consumers of water from polluted watercourse	- unknown	- phenol measurements in drinking water	
	- unknown	- unknown	- unknown	- quantification of resin acids	
	- unhealthiness and possible formation of trihalomethanes in presence of chlorinated water	- consumers of chlorinated water from polluted area	- rare to occasional	- BOD + quantities of trihalomethanes in drinking water	
Solid emissions or in soil	- unhealthiness (debris on ground), risk of injuries	- workers and neighbours	- unknown	- complaints, visual appearance	Q-2, Reg. on pulp and paper (r.12 and r.12.1)
	- unhealthiness (presence of vermin, insects, birds)	-workers and neighbours of sanitary landfills	- unknown	- complaints, visual appearance, inspection of landfill sites	
Nuisance	quality of life	neighbours and communities down wind	rare to frequent	complaints, studies of perceptions	

Indirect impacts or other exposure	assessment role	neighbours and community	rare to occasional	assessment role, studies of perceptions	

References

AIFQ (1993) *L'industrie des pâtes et papiers du Québec*. Association des Industries Forestières du Québec, 12 p.

AIFQ *(1996) L'industrie des pâtes et papiers, coup d'œil 1995.* Association des Industries Forestières du Québec, pamphlet.

Canada (1996) The State of Canada's Forests, 1995-1996. Canadian Forest Service, Department of Natural Resources, Government of Canada 112 p.

Chevalier, P. (1995) *Gestion de l'environnement en milieux urbain et industriel*. Presses de l'Université du Québec, 577 p.

CPPA (1995) 1995 Annual Review. Canadian Pulp and Paper Association (Montreal), 20 p.

ENVIROBEC (1992) *Étude sur les normes d'effluents basées sur la technologies pour le secteur des pâtes et papiers; fabrication de pâte mécanique de meule*. Document prepared for the Department of the Environment and Wildlife, Government of Quebec, 38 p.

Environment Canada (1991) Effluents from Pulp Mills Using Bleaching. Priority Substances List Assessment Report No. 2, Environment Canada, Government of Canada, 68 p.

Lavallée, H.C., L. Rouisse and R. Paradis (1992) *Caractérisation des effluents des usines de pâtes et papiers du Québec localisées sur le fleuve*. Science et techniques de l'eau (November 1992): 501-510.

McCubbin, N. (1983) *The Basic Technology of the Pulp and Paper Industry and its Environmental Protection Practices*. Training Handbook EPS-6-EP-83-1, Environment Canada (Government of Canada), 224 p.

MEF (1993) *Bilan de l'environnement au Québec.* Quebec Department of the Environment and Wildlife), Government of Quebec, Éditions Guérin (Montreal), 560 p.

Parent, B (1996) *Ressources et industrie forestières; portrait statistique*, 1996 edition. Quebec Department of Natural Resources, 142 p.

Smook, G.A. (1989) *Manuel du technicien et de la technicienne en pâtes et papiers*. Collège de Trois-Rivières (Quebec), 465 p.