Hydro Québec

Effects of Electric and Magnetic Fields on Livestock Health and Productivity

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In the interests of the environment and sustainable development, Hydro-Québec uses renewable energy sources, such as hydropower, to meet customer demand whenever possible. To exploit the hydroelectric potential of northern and northeastern Québec, a network of power transmission lines is needed to bring energy to the areas where it is consumed in the southern part of the province. Inevitably, this network crosses the St. Lawrence lowlands, where most of Québec's farms are located. Although it is impossible to completely avoid building lines in rural areas, Hydro-Québec takes the special features of the farming environment into account when it decides where to locate its electrical equipment.

Power lines cross thousands of kilometres of grazing land throughout the world. Since the dairy industry is the leading form of farm production in Québec and present throughout the province, it is inevitable that there will be high-voltage power lines located near some pastures.

Electricity is recognized as an important component in our quality of life. But for some time now, there have been people who wonder about the potential effects of its constant presence in our environment.

Electric and magnetic fields (EMFs) exist wherever electricity is used, including electric appliances and high-voltage power lines, and interact with whatever is in their immediate environment.

The international scientific community has been conducting research for more than twenty years to get a better idea of the possible effects of EMFs, especially on human, animal and plant health. Many researchers have verified whether phenomena associated with the presence of power lines can affect livestock.

This brochure presents a detailed discussion of the issue of electric and magnetic fields and their effects on the health and productivity of livestock, including dairy cows. The following pages present a summary of the main studies conducted to date, here and throughout the world.

Section 1

Fields Are Everywhere in Nature

Electric and magnetic fields (EMFs) are present everywhere in nature, in every one of the atoms that constitute matter. There is a natural electric field on the surface of the Earth, created by the presence of electrical charges in the upper atmosphere. Moreover, an intense electric field is necessary to sustain life in the cells of living organisms.

At the same time, our planet, the Earth, is surrounded by a permanent magnetic field, which can be detected with a compass. This magnetic field is generated by the mass movements of melted rock in the Earth's core. It should be pointed out that the phenomena just described are of nearly constant intensity (direct current).

On the other hand, the electric energy generated by Hydro-Québec's power stations and required to make our household appliances work is quite different. The electrons that move to create electric current continuously change their direction, at a frequency of 60 cycles per second (60 Hertz). This is called alternating current. The EMFs that result are also alternating.

Section 2

What is an Electric or Magnetic Field?

Electric and magnetic fields are generated by the presence of electricity. The intensity of the fields is high close to the source and usually decreases quickly with distance.

The «field» concept applies to other physical phenomena in our everyday environment. For example, you can say there is a «field» around a campfire. The temperature you measure with a thermometer will be very high close to the fire and will drop as you move away from the source. Even with a large fire, when you get far enough away, you no longer feel the heat it gives off.

Electric field

The electric field (EF) is associated with voltage. It is generated by the presence of electrical charges (electrons) and is measured in **volts per metre (V/m)**. Near high-voltage lines, it is generally measured in kilovolts per metre (kV/m). The higher the voltage supplying the equipment, the stronger the electric field. A cable connected to a device that is plugged in generates an electric field even if the device is not turned on. The intensity of an electric field can be substantially reduced by the presence of objects acting as a shield: trees, fences, buildings, etc.

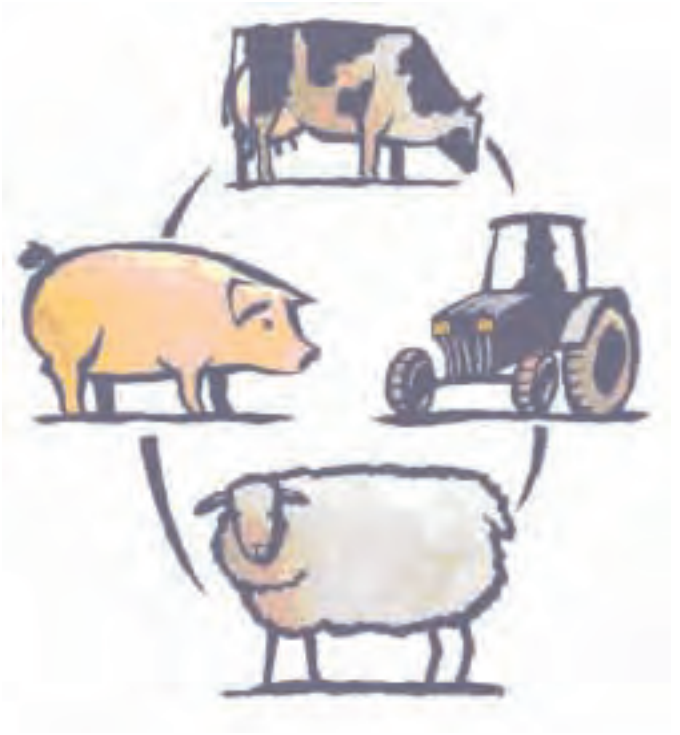
Magnetic field

The magnetic field (MF) is generated by electric current (measured in amperes), i.e. by the **movement** of the electrons. As a result, when a device is on, it creates a magnetic field. When it is turned off, it has no magnetic field. Unlike the electric field, there is no effective and inexpensive screen that can act as a shield against a magnetic field, which can easily cross through matter. The intensity of a magnetic field is expressed in teslas. However, we usually measure it in fractions of teslas, i.e. **microteslas (μT)**. *

* 1 μT = 1 millionth of a tesla

Who is Exposed to EMFs?

All electrical equipment and power lines generate electric and magnetic fields. As a result, ***everyone*** *is exposed to EMFs, whether at home, on the farm, in the office, at school, in the factory, on the sidewalk or in the street. Likewise, people and animals living near Hydro-Québec equipment are exposed to them. The* ***type of equipment****, the* ***distance*** *between the equipment and you or your livestock, and the* ***time*** *spent near it are three important factors for evaluating EMF exposure.*



Electrical equipment on farms

Magnetic fields measured between 30 and 60 cm from source

Milking operations

- milk coolers and sterilizers: 0.1 to 1.0 μT
- compressors for milking machines: 0.4 to 62 μT
- individual milking machines: 0.04 to 0.06 μT
- milk tank: 0.1 μT

Feeding operations

- automatic feed distributor: 0.02 μT
- silo unloader: 0.6 μT
- grain roller: 0.1 to 0.2 μT

Stable hygiene

- manure conveyor: 0.05 to 0.30 μT
- ventilation system: 0.02 to 0.06 μT

Stray Voltage: A Horse of a Different Color

EMFs must not be confused with stray voltage.

EMFs can induce very low currents in anything capable of conducting electricity, including human beings and animals. However, these currents are too weak to be perceptible.

Stray voltage, on the other hand, is caused by electrical problems. It takes the form of an undesirable difference in electrical potential between two objects. For example, if a cow touches a trough with her nose and the damp floor with her hind legs, and if the trough and the floor have different electrical potentials, a weak current will circulate in the cow's body. This current, when it is strong enough for the animal to perceive it, may cause some discomfort.

On a farm, stray voltage problems usually arise from two possible sources: the farm's electrical system or the power grid located nearby. They most often result from faulty grounding of farm equipment or current leaking from defective machinery. Sometimes, the power grid supplying the farm is the cause of the problem.

Before concluding that stray voltage is the cause of animal discomfort, all aspects of the animal's environment must be carefully considered: water, air and feed quality, sanitary conditions on the farm, herd management, etc.

A number of factors can account for apparently abnormal behavior in an animal. For this reason, you should first consult a veterinarian and a master electrician. If you think your livestock is exposed to stray voltage, contact your regional office of the Ministère de l'Agriculture, des Pêcheries et de l'Alimentation *(MAPAQ)(Québec department of agriculture, fisheries and food).*

Section 3

Biological Effects of Electric and Magnetic Fields on Livestock

A number of studies have been conducted to determine whether the EMFs generated by high-voltage lines have effects on the health, productivity, fertility, reproduction and behavior of livestock. Three countries have been particularly active in such research: the United States, Sweden and Canada. However, the studies are not always of the same quality.

Types of Research

The studies described below are not laboratory tests but field studies, i.e. the animals are studied in their usual living environment. The studies conducted to date – on both direct and alternating current lines – can be divided into three main groups represented by pictograms:

Surveys

These take the form of interviews or questionnaires given to farmers. This type of study is based more on observations than on quantifiable data.

Database studies

These consist in analyzing measurable statistical data covering several years. Such studies quantify parameters such as milk output and quality, fertility rates and frequency of abortions.

Worst-case studies

These are conducted under extreme conditions of EMF exposure. In these studies, researchers know exactly what the EMF exposure of the livestock has been. This method uses higher levels and longer periods of EMF exposure than encountered under normal conditions. The parameters studied are carefully controlled. Some studies are conducted in natural settings (pens directly below a power line) while others take place in controlled environments (exposure room where farm conditions are reproduced).

Research on High-Voltage Alternating Current Lines

Livestock Surveys

The first studies were conducted in the 1970s. A study conducted in 1974 for the American Electric Power Service Corporation, coordinated by B.J. Ware, determined which areas under its 765-kilovolt (kV) high-voltage lines were most likely to be used for animal grazing. The method consisted in interviewing the owners of 125 farms in Indiana. Although two of the 125 farmers reported specific observations, the study did not conclude that there were any particular effects.

Likewise in 1974, the Agricultural Resources Commission of New York asked K. Busby to conduct a study on the dairy production and behavior of grazing herds. Eighteen farms located near a 765-kV high-voltage line in Ohio were included in this study. Generally, the farmers whose livestock grazed near the power line did not observe any difference in behavior. Two of the four dairy producers even reported increased milk production compared with the three years prior to the commissioning of the power line. The other two farmers had not observed any difference in production. The authors of this study acknowledged that it was based on observations and was not scientific enough to allow the identification of subtle, difficult-to-observe effects.

From 1977 to 1979, Americans H.E. Amstutz and D.B. Miller conducted a two-year clinical study of the health of beef cattle, dairy cows, sheep, pigs and horses. They compared the results obtained on 11 farms located near a 765-kV high-voltage line (EF: 2.5 to 12 kV/m) with the results for all farms in Indiana. Based on their analysis, the researchers concluded that the power line had no effect on the health, behavior or productivity of the livestock. They did mention, however, that one farmer reported that his horses seemed to avoid certain zones under the line, while another mentioned that his herd of cows seemed to prefer to graze near the line.

Studies of Cows

In a study published in 1979, J.H. Williams and E.J. Beiler analyzed the breeding, health and milk production of 2,765 dairy cows over a six-year period. The animals were located on 55 different farms located near a 765-kV high-voltage line in Ohio. The method used in this survey was different from the previous studies in that the researchers were able to analyze databases comparing results obtained before and after the power line was commissioned. The researchers reported no effects attributable to the new line. This conclusion seemed to be corroborated by the farmers conducting operations near the line, who did not observe any significant changes in their herds.

A Swedish study conducted in 1982 under the supervision of K. Hennichs looked at the effects of the electric field from a 400-kV high-voltage line (EF: 2 to 5 kV/m) on the fertility of dairy cows. The study was conducted on 106 farmers. The researchers concluded that the herds showed no reduction in fertility.

This conclusion was confirmed in 1986 by Swedes B. Algers and I. Hultgren. They conducted an experimental study in which 58 heifers were kept for 120 days in pens located directly beneath a 400-kV high-voltage line (EF: 4 kV/m; MF: 2 μT). A control group of 58 heifers was kept in pens located some distance from the line.

In an American study published in 1982, L.E. Rogers sought to reproduce the actual conditions in which beef cattle grazed in a large enclosure under a power line. During the summers between 1977 and 1981, steer were placed in the electric field of a prototype 1,100-kV high-voltage line (EF: 12 kV/m). This line belonged to the Bonneville Power Administration, an Oregon public utility associated with the U.S. Department of Energy.

The research method consisted in making observations and comparing the results obtained when the line was live with those obtained when it was not. The general conclusions of the study showed that the animals had no systematic preference for grazing either near to or far from the power line. However, the 1980-1981 data indicated that the herd spent more time under the line when it was not live. The authors attributed this effect to the audible noise, the electric field or a combination of both.

Studies of Pigs

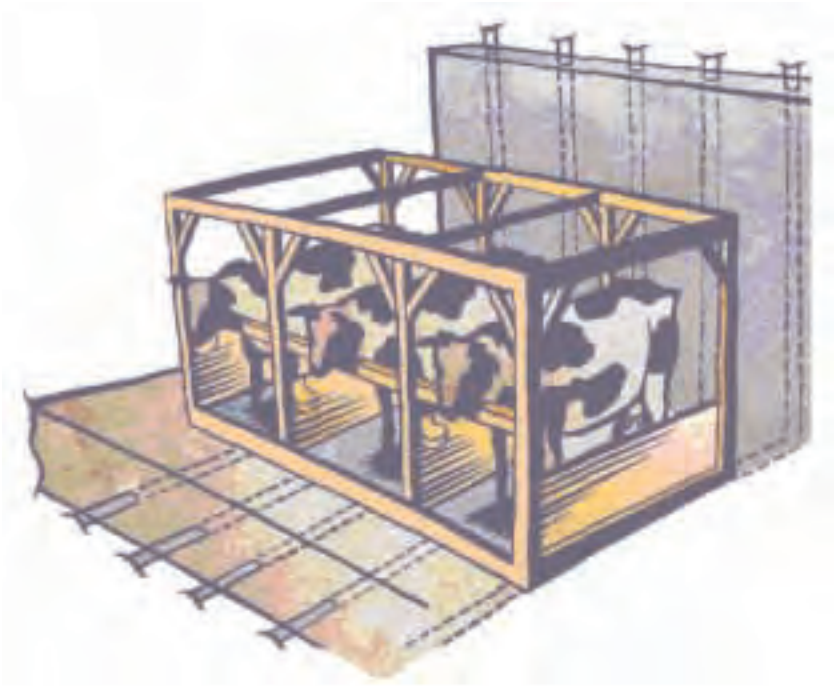
A.A. Mahmoud and D.R. Zimmerman, in collaboration with some American utilities, created an experimentation centre called the Iowa Test and Evaluation Facility. In 1982, they observed the growth and reproduction of a group of 30 pigs exposed to a 345-kV high-voltage line (EF: 4 kV/m). The unexposed control group was located 800 m from the line. No significant difference was observed between the two groups of pigs with respect to weight, food intake, fertility and pregnancy, number of live births, behavior or growth.

Studies of Sheep

Some studies of laboratory animals exposed to EMFs had found a change in their production of the hormone melatonin. Melatonin is produced by the pineal gland, located in the brain. This hormone is especially important for animals that breed at a specific time of year, such as sheep. Its secretion, which acts as a signal for the mating season, is inhibited by exposure to light. In summer and fall, when the days get shorter, secretion of melatonin increases and sexual activity in sheep reaches its peak.

In order to determine if farm animals exposed to EMFs would experience a reduction in melatonin secretion, two experiments were conducted by Oregon State University, coordinated by F. Stormshak. The research was sponsored by Bonneville Power Administration, Hydro-Québec and four other American utilities. Researchers were interested in the breeding cycle of the ewe (the female sheep). The experiments were intended to see if EMFs from a 500-kV AC high-voltage line (EF: 4 to 8 kV/m; MF: 7 μT) could delay puberty in ewes and affect melatonin secretion.

As part of the first study, a group of ten ewes living in a pen directly below a high-voltage line was compared with another group of ten ewes living about 230 m away from the line. The animals were exposed for nearly ten months, from April 1990 to January 1991. The main parameters studied were the hormones melatonin, progesterone (which determines the start of the heat periods) and hydrocortisone (a stress-indicating hormone). The behavior of the ewes and the growth of their wool were also analyzed.



The study showed no effects linked to the ewes' exposure to EMFs; specifically, researchers did not observe any change in the secretion of melatonin or progesterone. There was no delay in the start of the breeding cycle, that is, in the onset of puberty. Analysis of the animals' behavior and growth of wool did not reveal any effect attributable to the presence of the power line.

The second study repeated the same experiment but increased the number of ewes. Exposure took place from April 1991 to February 1992, with the same result: no effect was detected.

Québec Study of Dairy Cows

In 1996, a team under E. Block published a study on EMF exposure and dairy production. The study was conducted at the Macdonald Campus of McGill University. The choice of study type (controlled environment) was made jointly by Hydro-Québec, McGill University, MAPAQ and the *Comité des bovins laitiers du Québec* (Québec Dairy Committee).

The cow exposure chamber was set up in the main building at the Macdonald Campus farm. A number of parameters were monitored on a daily basis: exposure to EMFs, dairy production, food intake and digestion.

Nine Holstein heifers and 40 Holstein dairy cows were exposed to extreme EMF conditions similar to those found directly below a 735-kV high-voltage line (EF: 10 kV/m; MF: 30 μT) during the coldest days of the year when electricity demand is at its highest. The experiments investigated the quantity and quality of milk produced by the cows, hormonal profiles during pregnancy, the estrous cycle (related to ovulation), and functioning of the pineal gland and the nervous system.

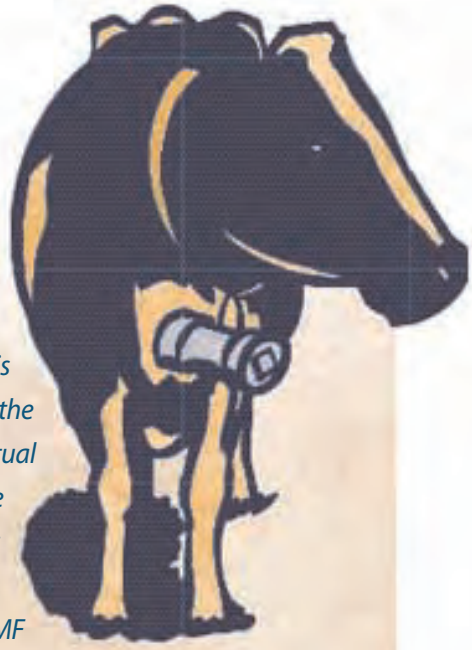
Most of the variables related to hormonal profile and dairy production did not show any change after EMF exposure. These variables were the concentration of hydrocortisone in the blood (stress indicator), concentration of bicarbonate, pH, partial pressures of CO_2 and oxygen in the blood, milk composition (except fat), and uncorrected milk yield.

However, the study did reveal that EMF exposure affected:

- the quantity of feed consumed (rose from 18 to 19 kg/day, an increase of 5.5%, during EMF exposure periods)
- the fat content of milk (rose from 4.06 to 4.43%, an increase of 9.1%)
- the progesterone content of blood plasma during gestation (rose from 5.6 to 6.2 ng/ml, an increase of 11%)
- the 4% fat corrected milk yield (rose from 18.7 to 20.4 kg/day, an increase of 9.1%)
- the length of the estrous cycle (went from 22.0 to 25.3 days, an increase of 15%).

According to the researchers, the values remain within the variations normally observed in Holstein cows. For example, the percentage of fat in the milk of Holstein cows raised in Québec normally varies from 3.2 to 4.5%, depending on the stage of productivity. Thus, although there was a statistical effect, the result obtained when the cows were exposed to EMFs is not abnormal, as it did not exceed 4.5%. The same applies to the other variables.

What Is the Real Level of EMF Exposure?



It should be noted that the EMF levels used in this study were extremely high, in order to increase the possibility of seeing an effect. However, the actual exposure of dairy cows to EMFs in Québec is quite different. Cows usually graze outdoors for about five months a year, from May to October, when the demand for electricity is lowest. So the EMF levels to which they are actually exposed are probably much lower than those used in the E. Block study, given the exposure time (cows are not confined under high-voltage lines and spend only five months outdoors) and the less intense EMFs produced in summer by a lower current.

A Hydro-Québec study conducted in 1996 and directed by S. Maruvada determined the actual EMF exposure of livestock on dairy farms near high-voltage lines operating at 735 kV, the highest voltage used in Québec. In order to measure exposure as precisely as possible, the cows wore dosimeters that recorded their EMF exposure wherever they went. The study concluded that the maximum values actually measured on working farms were much lower than those used in the Macdonald Campus study. In fact, the maximum values recorded in pastures directly below 735-kV high-voltage lines indicated an electric field half as strong (5.3 kV/m) and a magnetic field only one-fifth as strong (6.4 μT) as the fields applied at the Macdonald Campus test site.

Research on High-Voltage Direct Current Lines

Most of the world's transmission lines carry alternating current. The Hydro-Québec power system has only one direct current (DC) line: the Radisson-Nicolet-Des Cantons line linking James Bay to New England.

In view of the rarity of such lines throughout the world, few studies have assessed their impact on animal health. However, the few studies conducted on exposure to EMFs from DC lines are conclusive.

The Minnesota Environmental Quality Board entrusted a team from the University of Minnesota, under F.B. Martin, with the task of examining data collected by dairy cow producers between 1976 and 1982. Statistics on about 24,000 dairy cows were obtained from the database of the Dairy Herd Improvement Association. They had been collected three years before and three years after the commissioning of a 400-kV DC high-voltage line. Analysis showed no significant effect on the production or quality of milk or on the rate of cow abortion.

The Bonneville Power Administration had a team of researchers from Oregon State University conduct a study on beef cattle to evaluate the health risks of exposure to electric fields generated by a 500-kV DC high-voltage line (EF: 5.6 kV/m). This study, led by R.J. Raleigh, was carried out in partnership with Hydro-Québec and eight U.S. electric utilities. The sample in the study, which lasted for 30 consecutive months, from May 1984 to November 1987, contained 200 cows, 200 calves and 12 bulls. Half the animals were kept in a pen located beneath the line, the other half in a pen about 500 m away from the line. The authors were unable to detect any effects on health, fertility, production or behavior.

An Expert's Opinion

"When a high-voltage line passes near a farm that is already having health problems, it's easy for the owner to suspect, sooner or later, that electric and magnetic fields are the cause. This reaction is amplified by the common belief that not much is known about the biological effects of fields and that they must have harmful effects on health.

"The truth is, however, that the effects of electric and magnetic fields on man and animals have been studied extensively and the existence of harmful effects on health is far from being established. For this reason, a field effect must be considered the least probable cause for problems found in the operation, and the farmer's attention should instead be directed to all the other possible causes (condition of buildings, hygiene, food, prevention and care, etc.)."

Henri Brugère, Doctor in Veterinary Medicine, professor at École Nationale vétérinaire d'Alfort, *France*

At this time, every indication is that no biological disorder can be attributed to the exposure of livestock to EMFs generated by high-voltage lines. Analysis of data collected to date has not made it possible to identify any harmful effect on the health, productivity, fertility, reproduction or behavior of livestock exposed to EMFs.

Research nevertheless continues and Hydro-Québec intends to contribute to it.

To learn more

You can obtain more information on these studies by contacting the Electrium, Hydro-Québec's interpretation centre for electric and magnetic fields. Located in Ste-Julie on Montréal's south shore, the Electrium has a toll-free telephone number: 1-800-267-4558.

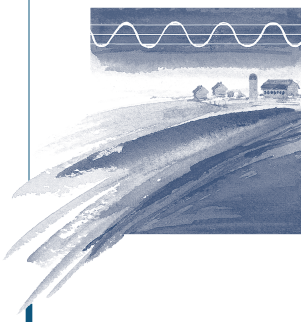
If you would like information on EMFs and human health, call the same number for a copy of the brochure entitled **Electric and Magnetic Fields and Health.**

This document was prepared by:

France Renaud, Agronomist, Expertise et Support technique de transport, TransÉnergie
Daniel Goulet, Ph.D. Biology, Expertise et Support technique de transport, TransÉnergie

in collaboration with:

Richard Bousquet, Stray Voltage Expert, Services à la clientèle, Hydro-Québec



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