

An Assessment of Health Implications Associated with Exposures to Electromagnetic Fields in and next to Hydro Corridors in the City of Toronto

Dr. David McKeown
Medical Officer of Health
Toronto Public Health

June 2008



Reference: Toronto Public Health. An Assessment of Health Implications Associated with Exposures to Electromagnetic Fields in and next to Hydro Corridors in the City of Toronto. Toronto: January 2008.

Authors: Ronald Macfarlane, Monica Bienefeld, Melanie Lalani, Monica Campbell, and Vanita Sahni (formerly with Toronto Public Health)

Acknowledgements: We gratefully acknowledge the expert review and insightful advice by the following individuals: Rosana Pellizzari and Hong Ge formerly of Toronto Public Health and Paul Villeneuve and Lois Green of the University of Toronto, Department of Health Sciences. We also thank Liligrace Cuanang of Toronto Public Health for her clerical support.

Distribution: This report is available at www.toronto.ca/health/

Contact: Environmental Protection Office
Toronto Public Health
277 Victoria Street, 7th Floor
Toronto, Ontario
Canada M5B 1W2
Telephone: 416-392-6788
Fax: 416-392-7418

Summary

The transmission of electricity creates electromagnetic fields (EMF). Background levels of EMF in urban areas are usually less than 1 milligauss (mG). However, overall levels of EMF in and right next to hydro corridors can be higher than those usually found both indoors and outdoors elsewhere in Toronto. In 2005, Toronto Public Health measured the level of magnetic field in selected parks in and away from hydro corridors. Levels in parks in hydro corridors were 4-102 mG, with a median of 37 mG. In the parks away from hydro corridors, the levels were above 2 mG only when measurements were taken directly underneath the local distribution lines (maximum 16 mG). The median of measurements taken in parks outside hydro corridors was 0.4 mG, or equivalent to background.

The potential health impact of electromagnetic fields (EMF) from power lines came to public attention in the late 1970s, when a study found an association between childhood leukemia and living close to transmission lines. In 1993, based on the evidence then available, the former City of Toronto adopted a policy of prudent avoidance, which encouraged limiting exposure to EMF in public spaces where practical and feasible at little or no cost.

In 2002 the International Agency for Research on Cancer (IARC) published the findings of its review of the evidence. It found an association between exposures to extremely-low-frequency (ELF) magnetic fields in the home and a doubling of risk of childhood leukemia at average magnetic field strengths above 3 or 4 mG. Based on these studies, IARC has classified extremely-low frequency magnetic fields as a possible carcinogen. In 2007 the World Health Organization published a review on EMF which concluded that “on balance, [for childhood leukemia] the evidence is not strong enough to be considered causal, but sufficiently strong to remain a concern.” Areas of uncertainty include: understanding how EMF could cause cancer; the type of exposure that might be important (short periods of exposure to high levels or long periods of exposure to low levels); and lack of supporting evidence in experimental animals.

Studies have looked at a wide-range of other potential health effects of EMF, including miscarriages, neurodegenerative conditions, and behavioural effects. While some studies have shown adverse effects, overall, the results do not show a consistent link between these effects and exposure at levels of EMF typical of everyday exposures.

Canada does not have any guidelines or standards for exposures to EMF. Canada, like many countries, uses the international guidelines which are based on the protection from the acute (short-term) effects of EMF. A few countries, states and local authorities have adopted precautionary measures. These limits generally address uses next to the hydro corridor and consider what is technologically achievable. The more strict guidelines (2-10 mG) that have been adopted elsewhere would greatly restrict the use of hydro corridors for parks and recreational activities and would have important economic impacts in Toronto.

Physical activity is essential to health and yet more than 40 percent of people in Toronto report their level of activity as low or none at all. The promotion of physical activity is important in the prevention of chronic disease and in stemming the increase in overweight and obesity among people living in Toronto. Park and recreational uses of hydro corridors provide opportunities for physical activity that would otherwise not be there, including in at-risk neighbourhoods.

The evidence available does not suggest that exposure to EMF at levels normally found in Canadian living and working environments is harmful. However, as noted above, studies have shown an increase in risks of leukemia to children who are exposed to average levels of magnetic fields above 3 or 4 mG. Leukemia

is a rare disease among children: about 25 cases of leukemia are diagnosed among children in Toronto a year. Based on the information available, exposure to EMF might explain 1 to 3 of the leukemia cases in Toronto each year or might increase the life-time risk of childhood leukemia by about 16 in 1 million for every increase in average exposure of 1.0 mG. Increases in risk of cancer of more than 1 in 1 million over a lifetime are often considered sufficient for action.

Prudent avoidance is an application of the precautionary principle. It encourages actions which can increase protection or reduce exposures at little or no additional cost when there is uncertainty about possible risks. Given the possible link between the exposure to EMF and leukemia in children, taking practical actions that can reduce exposures to children is prudent.

If people are exposed to relatively high levels of EMF for a short period of time this will increase their overall average exposure by a smaller amount. Each of the following examples would result in an increase in total average exposure by about 1 mG:

- Crossing a hydro corridor twice a day (about 1 hour a week for 12 months of the year) where average levels of EMF are 170 mG
- Playing on a sports field for about 3 hours in a week during 8 months of the year where average levels of EMF are 85 mG
- Playing on and around a play structure for 10 hours per week during 10 months of the year where average EMF levels are 20 mG

This suggests that spending some time in hydro corridors will not greatly increase the average exposure of most people using them. However, taking some care about where amenities are placed can minimize any such increase in exposure.

An EMF management plan outlines what can be done to reduce exposures to EMF. For example, it can identify the best place for play equipment or other amenities where people are likely to stay a long time. A management plan for a proposed development next to a hydro corridor could identify areas in and outside the building where EMF are highest, such as next to the main electrical circuits. The plan could then identify the best place for the building and children play areas, as well as for the living and sleeping areas where people would spend the most time, so that total exposures to EMF would be minimized.

Table of Contents

Summary.....	i
1.0 Background.....	1
1.1 Electromagnetic Fields.....	1
2.0 Typical Exposures to Electromagnetic Fields.....	2
2.1 EMF Levels in Canada.....	2
2.2 Level of Exposure to EMF in the U.S	2
2.3 EMF Levels in Hydro Corridors	3
2.4 Other Sources of Exposures.....	5
2.5 Typical Exposures.....	6
3.0 Health Effects of Electromagnetic Fields	6
3.1 Acute effects	7
3.2 Cancer	7
3.3 Biological Effects and Mechanisms of Action	9
3.4 Other Health Effects.....	10
3.5 Challenges in EMF Studies	10
3.6 Overall Assessment	11
4.0 Exposure Limits for Electromagnetic Fields.....	11
4.1 Effect Thresholds	11
4.2 International Guidelines	12
4.3 Canada.....	13
4.4 Europe.....	13
4.5 United States	16
5.0 Physical Activity in Toronto.....	17
5.1 Benefits of Physical Activity.....	18
5.2 Barriers to Physical Activity	19
5.3 Community Gardens	20
6.0 Policy for Limiting Exposures to Electromagnetic Fields in Hydro Corridors	21
6.1 Secondary Uses of Hydro Corridors	21
6.2 Rationale for a Policy of Prudent Avoidance.....	21
7.0 References.....	25

List of Tables

Table 1: Average Personal EMF Exposure Levels for Different Activities.....	3
Table 2: Summary of Magnetic Field Levels Taken in Parks.....	4
Table 3: Examples of Jurisdictions that Have Adopted Precautionary Limits	14
Table 4: State Guidelines and Standards for EMF levels in Power Corridors	16
Table 5: School Site Selection Guide for California Schools.....	17
Table 6: Amount of Time Spent at Different Levels of EMF That Result in a 1 mG Increase in Daily Exposure Averaged Over a Year.....	24

1.0 Background

Since a study published in 1979 found that children living near power lines had an increased rate of cancer than those living further away, members of the public have expressed concern about the potential adverse effects of electromagnetic fields or EMF (Portier & Wolfe, 1998). In 1993, the former City of Toronto adopted a policy of prudent avoidance which encouraged the adoption of low-cost actions that could reduce exposures to EMF. This policy was based on the evidence available at that time which indicated the possibility that exposures to EMF could be linked to increase in cancer, childhood leukemia in particular. The City of Toronto currently has agreements for 62 corridor areas, which include 22 soccer fields, 10 garden allotments, 5 playgrounds, 5 cricket pitches, 7 baseball diamonds, and approximately 6,000 metres of trails. A similar additional area within hydro corridors has also been identified as suitable for potential new park and recreational uses. Given this, Toronto Public Health decided to review the current state of knowledge and re-assess the 1993 policy.

In addition to transmission of electricity, hydro corridors in Toronto are used for other purposes, such as transit and transit facilities, trails, parkland, storm water ponds, sanitary sewers, and water mains. The use of hydro corridors for parks and recreation facilities provides opportunities for children and adults to participate in physical activity and social engagement. In some areas of Toronto, parks in hydro corridors are the most accessible venues for physical activity because they are close to where people live or work.

1.1 Electromagnetic Fields

Electric and magnetic fields are invisible lines of force that are part of the spectrum of electromagnetic radiation which includes static electric and magnetic fields, radio waves, microwaves, infrared radiation, visible light, ultraviolet radiation, and X-rays. People are exposed to EMF from both natural and human sources. Natural electric fields exist because of the difference in charge between the upper atmosphere (ionosphere) and the ground. They vary greatly in strength and frequency and are influenced by meteorological phenomena, such as thunderstorms. The strongest electric fields are in the 0-5 Hertz (Hz) frequency range and are associated with lightning and other events. The most important natural magnetic field humans are exposed to is the Earth's own field. While there are variations in the natural magnetic field, it is considered a static field (IARC, 2002).

Power lines, electrical wiring, and electrical equipment all emit EMF. Direct current, such as the electricity obtained from batteries, produces static electric and magnetic fields. The frequency most commonly associated with power lines and electricity in homes is 60 Hz in North America and 50 Hz in many other parts of the world. EMF from this source, which are sometimes referred to as power frequency fields, are in the range called extremely low frequency (ELF). Following common usage, in this report "EMF" is used to refer to electric and magnetic fields at extremely low frequencies, with a focus on 50 and 60 Hz fields produced by the generation, transmission, and use of electricity.

The voltage produces electric fields: the higher the voltage, the stronger the electrical field. Electric fields are shielded by materials including trees, buildings, and human skin. The flow of electricity (current) through wires or electrical equipment creates a magnetic field. The greater the current, the stronger the magnetic field becomes. Magnetic fields are able to pass through most materials and therefore are not easily shielded. The strength of both the electric and magnetic fields decrease rapidly the further away from the source.

Electric and magnetic fields can occur separately or together. Most electrical equipment needs to be turned on for current to flow and magnetic fields to be created. For example, when the power cord for a lamp is plugged into a wall socket, it creates an electric field along the cord. When the lamp is turned on, the flow of current through the cord creates a magnetic field in addition to the electric field.

2.0 Typical Exposures to Electromagnetic Fields

People are exposed to electric and magnetic fields from both natural and human sources. Exposures to EMF from equipment can be thousands of times higher than those from natural ones (IARC, 2002). In a given spot influenced by human sources of EMF, there is less variation in the strength of the electric field since the voltage in electrical equipment remains fairly constant. In contrast, since there is much more variation in the current flowing in these sources, there are greater changes in the strength of the magnetic field.

An electromagnetic field is described by four components: its electrical force, magnetic force, frequency and direction. When EMF measurements are taken in the environment, either the magnetic or the electric field can be measured. The electric field is measured in volts or kilovolts per metre (V/m or kV/m). The strength of magnetic field, as magnetic flux density, is reported in milligauss (mG) or microtesla (μT) – 10 mG is equal to 1 μT .

2.1 EMF Levels in Canada

Some studies have looked at exposures to EMF in Canada. A study of 382 children in various provinces (but not including Ontario) was carried out between 1990 and 1995 (Deadman et al., 1999). The exposures ranged from 0.1-8 mG (geometric mean of 0.85) with 15 percent of exposures above 2 mG. Higher exposures to EMF were associated with electric heating, air conditioning and multi-family dwellings. EMF exposures were also found to be slightly higher in winter than in summer.

A survey of 60 Ontario communities found that levels of EMF were higher in larger communities as compared to smaller ones (Havas, 2002). Daytime levels of EMF in central business districts in communities with populations of over 100,000 averaged 14 mG, while those in communities of under 10,000 people averaged 2.4 mG. The average of 108 measurements taken along Yonge Street (between Front and Bloor Streets) was reported as 19.2 mG, with a median value of 9.1.

2.2 Level of Exposure to EMF in the U.S

Several studies have measured exposures to EMF in the U.S. Two large studies, referred to as the “1000-Home Study” and the “1000-Person Study,” estimated exposures across the U.S. These studies showed that half of the homes had average levels of EMF of 0.6 mG or less (measured over 24 hours in the centre of the room). About 11 percent of homes surveyed had average levels over 2 mG and 2 percent had average levels above 5 mG. Personal exposure levels were found to be a little higher, with average (geometric mean) 24-hour exposures around 0.9 mG (Portier & Wolfe, 1998).¹ Most people in the U.S.

¹ EMF levels are reported in slightly different ways. Since EMF levels vary a lot and the average value (arithmetic mean) is often influenced by a few very high values, the geometric mean is commonly reported since it is considered a better indicator of overall exposure. Another measure, the median, gives the point where half of the measured levels are below and half of the measured levels are above the reported value. When comparing results of different studies, it is important to make sure that levels are presented using the same method.

are exposed to magnetic fields that average less than 2 mG: about 14 percent of the people surveyed had 24-hour exposures above 2 mG and 2.5 percent above 5 mG (NIEHS, 1999). These results are similar to the reported levels in Canada described above.

The reason for the difference between in-home measurements and personal levels is due to exposures around the home (for example times spent near electrical appliances) and exposures outside the home. Table 1 shows the different level of exposures during major activities in a day.

Table 1: Average Personal EMF Exposure Levels for Different Activities

Place	Geometric mean (mG)
At home: In bed	0.5
At home: Not in bed	0.8
In school	0.6
At work	1
Daily travel	1

Source: NIEHS, 1999

Certain types of homes were found to contribute to higher personal exposures: multi-family homes, smaller homes, older homes, homes with metal water pipes, and urban or suburban homes. For example, people living in apartments and duplexes had higher average exposures (1 mG) compared to those who lived in other types of homes (0.5-0.7 mG) (NIEHS, 1999).

Overhead distribution lines also contribute to exposures. Homes close to transmission lines and some types of distribution lines had the strongest fields (median of 0.9-3.8 mG). Personal exposures were also higher for people with homes close to transmission lines and multiple three-phase distribution lines (average exposure at home of 1 mG). Beyond 50 feet (15 metres), the type of power line had little impact on overall personal exposures (NIEHS, 1999).

While personal exposures did not vary by gender, they varied slightly by age: children (both pre-school and school-aged) had an average exposure of 0.8 mG, working-age adults (18-64) an average of 1 mG and adults 64 and over an average of 0.9 mG (NIEHS, 1999).

Personal exposures are also affected by fields from appliances. It is difficult to make general statements about the impact of electrical appliances on average personal exposures because these are influenced not only by the type of appliance, but also by various factors such as the placement of the appliance (including distance), frequency of use, and the manufacturer (NIEHS, 1999).

2.3 EMF Levels in Hydro Corridors

Power lines are described by the strength of the electric current (voltage) they transmit. High-voltage power lines or transmission lines operate at 100 kilovolt (kV) or higher. The design of the power lines has an impact on the EMF fields produced and the strength of the field measured at ground level. For example, lower ground clearance requirements lead to higher fields at ground level under the lines. When there are multiple circuits on a power line, the physical arrangement of these lines can have an impact on

the distribution of the fields. In these cases, the use of transposed phasing (when circuits on one side have a different order than those on the other side) will result in EMF field strength that diminishes more rapidly as the distance from the line increases. Placing power lines underground can also reduce the strength of magnetic field more quickly as the distance from the line increases.

The strongest electric fields that people are likely to encounter in their daily lives are associated with power lines. Levels as high as 11 kV/m have been reported under high voltage transmission lines. The strength of magnetic fields under transmission lines have been reported as 300 mG under 765-kV lines and 100 mG for 390-kV lines. Levels of magnetic field diminish to background levels at about 50-300 m from the power line (IARC, 2002).

To get an indication of the levels of magnetic fields in hydro corridors and to determine how these levels compare to other public spaces, Toronto Public Health undertook a survey in the winter of 2005. A sampling protocol was developed and based on the Institute of Electrical Electronics Engineers “Standard Procedures for Measurement of Power Frequency Electric and Magnetic Fields from AC Power Lines,” “Recommendations for Guidelines for Environment-Specific Magnetic Field Measurement” and consultation with experts.

Eighteen parks in hydro corridors and 18 parks away from hydro corridors were sampled, for a total of 36 sites. Sites were distributed throughout the City and represent a range of park uses including sports fields, trails, community gardens, and playgrounds. Several measurements were taken at “mid-span” (the point between pylons where the power lines dip closest to the ground) along a line at a 90-degree angle to power line. Since hydro corridors are of varying dimensions, measurements were not taken at the same distance from the power lines at all sites. Measurements were also taken at one-hour intervals in one corridor to obtain an indication of the variability in magnetic field strength during the day.

There was a wide range of levels of magnetic fields measured in parks located in hydro corridors. Table 2 illustrates that observed levels were typically highest directly underneath high voltage lines at mid-span and decreased with increased distance from the lines. Measurements taken throughout the day showed that the maximum magnetic field level during the day was about 50 percent higher than the lowest level measured at the same point.

Table 2: Summary of Magnetic Field Levels Taken in Parks

Location	Median (mG)	Range (mG)
In hydro corridors at mid-span ¹	37	4-102
In hydro corridors, 10 metres from the closest power line	17	4-72
Furthest point from power lines, at outer edge of hydro corridor ²	6	1-16
Parks away from hydro corridors	0.4	n.d. ³ to 16 mG

¹Midspan is the point at which at the power line dips closest to the ground. These measurements were taken along a transect at right angles to the power lines.

²Hydro corridors are of varying dimensions. The furthest point from the power lines varies considerably. Therefore, these measurements were not taken at a constant distance.

³not detected

The range of levels of measured magnetic fields in park sites outside the hydro corridors was smaller – from below the detection limit to 16 mG. All measurements above 2 mG were found directly underneath local distribution lines. The average measurement taken in parks outside hydro corridors was 0.9 mG (median 0.4 mG) – levels below 1 mG are considered to be background levels (that is, levels found in an area that are not in close proximity to an electrical source).

The large variation in the levels measured are expected since many factors will influence the strength of the magnetic field in the environment at a specific location: the amount of current flowing through the line, the arrangement and proximity of the lines themselves with respect to each other, the height of the line above or below the ground, and the proximity of the lines to other power lines. The magnetic fields produced are directly proportional to the amount of current flowing through the high voltage or distribution lines. As demand for electricity increases, the amount of current flowing through high-voltage and distribution lines also increases. The level of magnetic fields from both high-voltage transmission lines and distribution lines thus depends on the demand for energy that varies by time of day, the day of the week, the time of year and the ambient temperature.

The levels measured are similar to levels reported in the literature and show that the levels of EMF directly under transmission lines in hydro corridors are higher than elsewhere in the urban environment. They also show that the levels decrease rapidly as we move away from the lines.

2.4 Other Sources of Exposures

Reviews of occupational exposures to EMF have also been undertaken (Portier and Wolfe, 1998). In general, electrical workers, persons working near machines with electric motors and welders tend to have the highest exposures with time-weighted average magnetic field exposure levels in the range of 1 to 40 mG.

Levels of EMF on buses, streetcars and trains (subway and GO transit) have also been reported (Havas, et al. 2004). In Toronto, the subway and streetcars run on direct current. The highest levels were found in the subway and streetcars, with a mean value of 30 mG. The mean value in buses was reported as 11 mG and on a GO train as 2 mG. These are in the lower part of the range of reported values from electrical rail transportation systems elsewhere (ICNIRP, 2003).

Toronto Public Health took some magnetic field measurements along Yonge Street between Front and Bloor Streets and in the Esplanade neighbourhood in the vicinity of the transformer station in order to replicate historical measurements cited in the literature. Underground electricity distribution cables are present in these areas. Both of these sampling zones were characterized by a median measurement of 6 mG, which is lower than the median reported by Havas (2002) along Yonge St. This is possibly the result of the difference in the level of power usage when monitoring occurred.

Appliances also contribute to overall exposures. Magnetic fields generated by appliances vary greatly by type and manufacturer of the appliance. Generally, microwave ovens, toaster ovens, and refrigerators generate the highest fields. The fields right next to an appliance can be as high as several hundred milligauss. However, the contribution of these fields to personal exposure depends upon a number of factors including the distance and location of the appliance in relation to where an individual spends time and the frequency of use.

2.5 Typical Exposures

Personal exposures to EMF vary greatly during the day. Spikes in exposure occur when people walk or drive across power lines or when they are close to electrical appliances. Studies that have looked at exposures to EMF in home and office environments show that building wiring (including distribution circuit and electric ground), conducting pipes, and appliances contribute to the magnetic field exposure that most people receive. Depending on wiring configuration, plumbing lines can create “hot spots” of high magnetic field. Background EMF levels have been reported as a 24-hour average of 0.7-0.8 mG (geometric mean) or 1.1 mG (arithmetic mean) in the U.S. Levels in the U.K. are about half those in the U.S. – a geometric mean of 0.36-0.39 mG and an arithmetic mean of 0.5 mG. Certain wiring practices result in particularly low magnetic field strengths in homes (IARC, 2002). People living close to high voltage transmission lines tend to have higher overall exposures (NIEHS, 2002), but high-voltage power lines are not the most common source of magnetic fields, even in homes with above average magnetic fields (IARC, 2002). The ratio between background and personal exposures, which are influenced by exposure from appliances, has been estimated as 1.4 (range of 1.0 to 2.3) (IARC, 2002).

Studies from the U.S and Canada suggest that the majority of people (85 percent) are exposed to an average of less than 2 mG per day. Very few people have an average exposure above 5 mG.

3.0 Health Effects of Electromagnetic Fields

Concerns have been raised by some studies that daily exposure to EMF may cause adverse health effects. Although electrical equipment, appliances, and power lines produce both electric and magnetic fields, much of the EMF literature either focuses exclusively on magnetic fields, or does not distinguish between effects potentially stemming from the electric or the magnetic component of the fields. Since 1979, a large number of studies have been conducted to determine if EMF exposure can influence cancer development, depression, amyotrophic lateral sclerosis (ALS), and reproductive effects. The summary of health effects presented in this report is mostly based on the International Agency for Research on Cancer (IARC, 2002) and International Commission on Non-Ionizing Radiation Protection (ICNIRP, 2003) reviews. In December 2007, the International Programme on Chemical Safety (IPCS) published a new environmental health criteria monograph. This review did not change the overall assessment.

The International Commission on Non-Ionizing Radiation Protection (ICNIRP) is a non-governmental organization which is recognised as the leading international agency in assessing the health impacts of exposures to non-ionizing radiation. In 1997, ICNIRP established guidelines for limiting EMF exposure that provide protection against known adverse health effects (ICNIRP, 1998). This was based on a review of the literature on biological and health effects of exposure to non-ionizing radiation. Subsequently in 2003, ICNIRP published a review of the scientific evidence that summarized the state of knowledge concerning the acute (short-term) and chronic (long-term) health effects of exposures to static and alternating current EMF.

The International Agency for Research on Cancer (IARC) is an agency of the World Health Organization that evaluates the carcinogenic risk of chemicals, mixtures, lifestyle factors, specific occupations and biological and physical agents to humans and publishes evaluations of the evidence (called monographs). IARC published its review on EMF in 2002.

From its review of literature pertaining to non-cancer health effects, ICNIRP concluded that consistent evidence of an association is not present between exposures to EMF and reproductive outcomes,

neurodegenerative outcomes, hypersensitivity, sleep, genetic, cellular, endocrine system, and immune system effects. ICNIRP's review of the literature revealed a relationship between exposure to EMF and stimulation of the peripheral nerves and muscle tissue, stimulation of the central nervous system (CNS), behavioural/cognitive effects, cardiovascular effects, mood, and faint flickering visual sensations. However, ICNIRP determined these effects are only observed at very high exposure levels not within the range typical of everyday situations.

3.1 Acute effects

At very high exposure levels EMF can affect the nervous systems of people exposed to them. EMF can affect memory, cognition and other brain functions. These acute effects are unlikely to occur at the low exposure levels in the general and most working environments. Exposure to EMF can also induce a surface electric charge which can lead to perceptible, but non-hazardous effects such as microshocks.

3.2 Cancer

Ever since the first epidemiological findings showing an association between exposures to EMF and cancer, a large number of studies have been done to verify this and to understand the ways in which EMF could cause cancer.

Adult Leukemia, Brain Cancer, and Breast Cancer

Epidemiological research has focused on potential associations with adult leukemia and brain and breast cancers. Many of these studies have methodological limitations including approximation of exposure, poor response rate, use of job classifications, and confounding by other workplace exposures. Overall (for both residential and occupational studies) evidence of an association with adult leukemia and brain cancer are similar. Aggregate risk estimates are in the range of 1.1 to 1.3 which may be indicative of a small effect. However, individual studies exhibit wide variation in their risk estimates, and results could be explained by confounding, misclassification, and selection bias. IARC determined from its review of studies that at present there is no consistent relationship between exposure to EMF and adult leukemia (IARC, 2002).

Residential studies have not been able to detect a consistent association between exposure to EMF and breast cancer. Occupational studies have focused on electrical occupations but face sample size difficulties in that the incidence of male breast cancer is rare, and few females work in these occupations. While some studies have reported an association, the majority have indicated no effect (IARC, 2002; ICNIRP, 2003).

Rats are considered a good model to test for mammary cancer in humans. Some studies have found an association between exposure to magnetic fields and increased growth of chemically induced mammary cancers, but attempts to replicate these studies have not been successful, making it difficult to interpret the results. Overall, animal studies do not support the hypothesis that magnetic fields initiate the development of cancer. However, it is possible that they act as a promoter for cancerous cells. A few animal studies involving exposure to EMF in conjunction with a known carcinogen have found a significant effect, but it is unclear whether the observed positive findings were real or due to chance.

Many studies have been undertaken to investigate a potential relationship between exposure to EMF and various cancers including brain, and adult leukemia. IARC has determined that there is no consistent

relationship between exposure to EMF and these cancers. The IPCS (2007) review concluded that the current evidence suggests that exposure to EMF does not cause breast cancer.

Childhood Leukemia

IARC's evaluation of ELF magnetic fields in terms of carcinogenicity identified a potential link to childhood leukemia. Childhood leukemia has the potential to affect children aged 0 to 19.

Two studies of pooled analyses² provide the best evidence of an association³ between exposure to EMF and childhood leukemia. In one pooled analysis based on nine studies, no excess risk was seen for exposure to EMF below 4 mG and a statistical association was observed for a doubling of risk of childhood leukemia and power-frequency (50 or 60 Hz) magnetic field strengths above 4 mG (Ahlbom et al., 2000; IARC, 2002). The other pooled analysis included 15 studies with magnetic field measurements and found an excess risk of 1.7 for exposure above 3 mG (Greenland et al., 2000). Results from the two studies are closely consistent. Green and colleagues (1999) and Lowenthal and colleagues (2007) reported a stronger association between exposure to EMF and diagnosis of leukemia before the age of six.⁴ This would suggest that younger children could be more vulnerable to the impacts of EMF, or that pre-natal exposures are of particular importance when it comes to the development of leukemia.

Studies in experimental animals have not revealed a consistent carcinogenic or co-carcinogenic⁵ effect of exposures to EMF. An explanation has not been established for the observed association of increased childhood leukemia risk with increasing residential magnetic field exposure (IARC, 2002).

Using the standard IARC classification that weighs human, animal and laboratory evidence, EMF were classified as "possibly carcinogenic to humans" based on the pooled studies of childhood leukemia. "Possibly carcinogenic to humans" is a classification used to denote an agent for which there is limited evidence of carcinogenicity in humans and less than sufficient evidence for carcinogenicity in experimental animals (IARC, 2002). The IPCS (2007) review did not recommend a change in the IARC classification and concluded that "on balance, the evidence [for childhood leukemia] is not strong enough to be considered causal, but sufficiently strong to remain a concern."

No similar associations have been reported for electric fields or static magnetic fields (for example, from the earth's magnetic field). IARC's evaluation for static magnetic fields, static electric fields, and extremely low frequency electric fields is "not classifiable," meaning that the available studies are of insufficient quality, consistency or statistical power to conclude the presence or absence of a causal association between exposure and cancer, or no data on cancer in humans are available (IARC, 2002).

² Pooled analyses integrate and analyze the original data from relevant studies.

³ The term "association" is used in epidemiology to denote that there is a statistical relationship between a given exposure and disease outcome, without implying that the relationship is necessarily one of cause and effect (Weisenberger, 1993).

⁴ Green and colleagues (1999) analysed data for childhood leukemia and acute lymphoblastic leukemia (ALL) specifically. Lowenthal and colleagues (2007) considered lymphoproliferative disorders which includes ALL. In this group of diseases, ALL is the most common diagnosis in children.

⁵ A substance or factor that will not promote cancer by itself but can enhance or increase the effect of cancer when acting with carcinogenic agents.

3.3 Biological Effects and Mechanisms of Action

Findings from *in vitro* (cellular)⁷ and some *in vivo* (animal studies)⁸ are used to generate hypotheses about potential mechanisms of action.⁹ These findings are useful in determining whether an observed effect is biologically plausible. Of the various mechanisms that have been suggested as possible modes by which EMF could cause health effects, only the induction of electrical currents is well understood and generally accepted. While studies in cells have shown magnetomechanical and resonance interactions, they have not been shown to be important in animals such as humans (ICNIRP, 2003).

Genotoxic Effects

Genotoxic effects refer to the ability to cause mutations in genes. Such effects include chromosome damage and suppression of DNA repair. There is general consensus that these types of mechanisms (if present) are causally related to the development of cancer. Most *in vitro* and animal studies have not found evidence that magnetic fields are capable of exerting genotoxic effects, with exceptions from two studies conducted on mice. Continuous exposure to 5,000 mG magnetic fields for 14 days was associated with DNA damage (Svedenstal, 1999 in Swiss Federal Council, 2000). Magnetic fields of 2 to 4,000 G have increased mutation rates in cell exposed to ionising radiation (Portier & Wolfe, 1998). Magnetic fields of 4,000 G by themselves also caused mutations in human cells. IPCS (2007) concluded that is unlikely that exposure to EMF alone causes tumours but that more study is needed to see if EMF might amplify the effect of cancer causing agents.

Non-Genotoxic Effects

Non-genotoxic effects refer to mechanisms that work to enhance cancer, but do not cause it directly. Examples of these types of mechanisms include cell signalling and cell proliferation. The evidence suggests that if EMF do play a role in cancer they may act as tumour promoters rather than initiators especially since they are not known to cause chromosome damage (IARC, 2002).

Ornithine decarboxylase (ODC) is an enzyme controlled by signalling pathways. An association has been observed between increased activity of ODC and the proliferation (growth and division) of normal and cancerous cells. It has been hypothesised that exposure to EMF increases the activity of ODC, thereby contributing to the development of tumours. However, the supporting evidence is unclear. Some *in vitro* studies have demonstrated a dose-dependent increase in activity of ODC with exposure to magnetic fields (60Hz, 10-1,000 mG), but attempts at replicating these studies have not always been successful. One *in vivo* study found a doubling of ODC activity in mammary tissue but not in other types of tissues (Mevissen et al., 1995 in IARC, 2002). Other studies observed a reduction in ODC activity with exposure to magnetic fields of similar frequency and intensity (Kumlin et al., 1998 in IARC, 2002).

Various studies have looked at the effects of exposure to EMF on the functioning of cells. Some of these are discussed below. ICNIRP (1998) concluded that measurement of biological responses to electric fields in laboratory studies and in volunteers has provided little suggestion of adverse effects of low-frequency fields at levels to which people are commonly exposed.

⁶ *In vitro* studies refer to those performed in a test tube or other laboratory apparatus.

⁷ *In vitro* studies refer to those performed in a test tube or other laboratory apparatus.

⁸ *In vivo* refers to biological processes that take place within a living organism or cell.

⁹ The way in which a substance or agent produces an effect on a living organism.

Many studies have focused on investigating potential effects of magnetic fields on calcium homeostasis. Calcium ions serve as messengers between cells and are involved in the regulation of many biological processes. Some in vitro studies have found that exposure to 50 Hz magnetic fields facilitate changes in calcium ion transport across membranes and of the intracellular concentration of calcium ions. However, other studies have demonstrated that these effects may be confounded by ultraviolet radiation used in the monitoring of calcium by fluorescence, and by the method of fixing cells to glass plates (Barbier et al., 1996 in IARC 2002; Galvanoskis et al., 1996 and 1999 in ICNIRP, 2003). Overall, findings on the potential effect of magnetic fields on calcium homeostasis have not been consistent.

Evidence for EMF having either a direct or indirect (e.g. via intracellular signalling) effect on cell proliferation is unclear. The available studies investigating this used a variety of exposures and cell types. Some studies demonstrated an increase in cell proliferation and others a decrease (IARC, 2002).

While there is some evidence that EMF of more than 1000 mG can increase mutations in cells or results in other effects – cell proliferation or disruption of cell signalling – that are commonly associated with the development of cancer, there is still no explanation of how EMF at low levels could cause childhood leukemia or other long-term effects at levels to which people are typically exposed (Portier & Wolfe, 1998).

IPCS (2007) considered three direct mechanisms more plausible than other ones that have been proposed: induced electric fields in neural networks, radical pairs and magnetite. However, these mechanisms are only plausible at EMF levels much higher than typical exposures. It concluded that there is still no mechanism that can explain how EMF could cause adverse health effects at low levels of exposure.

3.4 Other Health Effects

The effect of EMF that are caused by induced currents are well known and include perception, pain and/or burn from electric shock, difficulty in breathing, cardiac effects, and tissue damage (ICNIRP, 2003). The effects of long-term low-level exposure to EMF are much less clear. Studies have also looked a variety of potential health effects of low-level exposure to EMF, including the following:

- behaviour such as depression and suicide,
- cardiovascular effects, including heart rate, hypertension, and mortality,
- endocrine effects, such as effects on melatonin and stress-related hormones,
- effects on the immune system and other blood disorders,
- neurodegenerative disease, such as, Alzheimer's, Parkinson's and amyotrophic lateral sclerosis (ALS), and
- reproduction and development, such as miscarriages and birth defects.

IPCS (2007) concluded that current evidence suggests that exposure to EMF is not a cause of cardiovascular disease. While data suggests that exposure to EMF is not associated with Parkinson's disease or adverse reproductive effects, overall the data is still inadequate for these and other effects to draw firm conclusions.

3.5 Challenges in EMF Studies

There are many challenges in assessing the effects of EMF on health. As well, it is difficult to design exposure studies in a way that can be easily interpreted and replicated. While the induction of currents is

a well established way by which EMF can cause adverse effects at relatively high levels of exposure, it is still not clear how low EMF exposures at levels people are generally exposed to might cause adverse health effects. For example, it is not known which aspect of EMF is the most important: the electric or magnetic field, the frequency, the intensity, or a combination of these. Nor is it known if short-term spurts of high exposure are more important than total average exposures over a period of time. Not knowing how EMF might cause disease makes it more difficult to design studies.

Given the demand for electricity, individuals are exposed to a constant and relatively low-intensity EMF in built environments. Fields produced by appliances are more intense, but for the most part are experienced only periodically and for short durations. Researchers have not devised a standard method for measuring overall actual exposure in studies, partly due to large variability in EMF emitted in different environments. This factor contributes to difficulties in replicating scientific studies. Most studies on children suggesting an association between magnetic fields and childhood leukemia have involved low to moderate intensity long-term exposures (24 hours or longer). It is unclear how these outcomes might relate to fluctuating or higher intensity exposures that occur for shorter duration, such as those from appliances or magnetic fields in hydro corridors.

3.6 Overall Assessment

Many studies have looked at health effects of exposures to EMF in humans. Studies available suggest EMF is not a cause of breast cancer or cardiovascular disease (IPCS, 2007). There is some evidence of an association between occupational exposures and amyotrophic lateral sclerosis (ALS); however, it is possible that other factors could explain this link (ICNIRP, 2003). For other effects, such as adult leukemia, brain cancer, suicide, depression or reproductive effects, the epidemiological evidence is not sufficient to confirm whether or not an association is actually present.

The strongest evidence comes from studies that found an association between exposures to extremely low frequency magnetic fields and childhood leukemia. While this association is unlikely due to chance, there are still questions regarding the relevance of this observation (ICNIRP, 2003). This is in part because it is not understood how EMF could result in leukemia and because there is inadequate evidence in experimental animals for the carcinogenicity of EMF (partially due to the lack of an appropriate model). Based on the evidence of childhood leukemia, IARC (2002) classified extremely low frequency magnetic fields as a possible carcinogen. Some studies have shown that EMF have the potential to increase the effects of known mutagens, and further research in this area has been recommended.

4.0 Exposure Limits for Electromagnetic Fields

Regulatory bodies have adopted a variety of different approaches to protect people from the potential health effects of EMF. Individual country policies respecting EMF may be mandatory or voluntary and consider a combination of health-based evidence, cost, technical, and social considerations. Differences between individual standards are largely due to different approaches in assessing the scientific uncertainty in the health literature, and incorporating this uncertainty into the form of a policy.

4.1 Effect Thresholds

Typically, when establishing an exposure limits, an agency will consider the lowest level at which an adverse effect is seen which is the effect threshold. Exposures below this threshold are not thought to

cause an adverse health impact. In some cases, the data suggests that there is no threshold – that is, all levels of exposure result in a risk of adverse effect.

ICNIRP (1998) has identified 100 mA/m² as the threshold current density for adverse acute (short-term) impacts on the nervous system. Current densities of 10-100 mA/m² have been consistently observed to cause functional and other tissue changes including minor and reversible nervous system effects, such as the appearance of visual phosgenes and small reduction in heart rate. Electrical fields above 25 kV/m can result in current densities greater than 10 mA/m². Magnetic fields of several thousands milligauss would be needed to induce such current densities.

As yet, no agency has identified a threshold for chronic or long-term effects. While epidemiological studies have detected an increase in rates of childhood leukemia at levels around 3-4 mG, the data are considered insufficient to truly determine a threshold.

4.2 International Guidelines

The International Commission for Non-ionising Radiation Protection (ICNIRP) guidelines are the most widely adopted EMF exposure limits. In 1997, ICNIRP proposed guidelines for exposure to EMF that provided protection against established¹⁰ adverse health effects. ICNIRP regards an adverse health effect to be “detectable impairment of the health of the exposed individual or of his or her offspring” and notes that “biological effects may or may not result in an adverse health effect” (ICNIRP, 1998). ICNIRP reviewed both acute (short-term) and chronic (long-term) health effects in its assessment.

Only established health effects were used as the basis for the proposed exposure restrictions. The exposure limits resulted from a review of the scientific literature that determined the only established mechanism for health hazard occurrence from EMF exposure was through the induction of significant electric currents inside the body. Although other health effects were documented in studies, ICNIRP determined that these findings were not strong or consistent enough on which to base exposure guidelines. ICNIRP has established general public exposure guidelines of 833 mG for the magnetic field and 4.2 kV/m for the electric field at a frequency of 60 Hz.

ICNIRP’s exposure guidelines are intended to protect against short-term effects on central nervous system tissues in the head and trunk of the body, and to prevent short-term immediate health effects, such as stimulation of peripheral nerves and muscles, shocks and burns caused by touching conducting objects, and elevated tissue temperatures resulting from absorption of energy during exposure to EMF (ICNIRP, 1998; Matthes, 1998).

In the case of potential long-term effects of exposure, such as an increased risk of cancer, ICNIRP recognized that epidemiological research has provided suggestive evidence of an association between possible carcinogenic effects and exposure to 50 or 60 Hz magnetic fields. ICNIRP considers that, without support from experimental research, the conclusions from the epidemiological research on EMF field exposure and cancer, including childhood leukemia, are not sufficiently strong to form a scientific basis for setting exposure guidelines. ICNIRP based all its recommendations on the conventional scientific approach of requiring more than 90% confidence before any possible effect is taken into account (WHO, Regional Office for Europe, 2001).

¹⁰ An ‘established’ health effect would be an adverse effect that is observed consistently in several studies with strong methodology.

Given that there is insufficient evidence to conclude a causal link between EMF and childhood leukemia, IPCS (2007) also did not recommend setting exposure limits based on the epidemiological evidence. However, it did indicate that some precautionary measures are justified.

4.3 Canada

Canada has no national guidelines for occupational or residential exposure to EMF (Health Canada, 2004). The Federal-Provincial-Territorial Radiation Protection Committee (FPTRPC) released a review of the scientific literature concerning health effects and exposure guidelines related to EMF in 2005 (FPTRPC, 2005). In its position statement, the Committee concluded that epidemiological studies have not established an association between exposure to EMF and the development of cancer in adults. The Committee also determined that the evidence associating exposure to EMF with childhood leukemia remains inconclusive (FPTRPC, 2005).

As a result of their findings, the FPTRPC (2005) concluded that “adverse health effects from exposure to power-frequency EMF, at levels normally encountered in homes, schools and offices have not been established. Protection of the public against acute effects such as minor shocks that may occur from contact with conducting objects under high-voltage power lines can be achieved through awareness initiatives undertaken by the electrical power industry.” The FPTRPC (2005) stated that “since there is no conclusive evidence that exposure to EMF at levels normally found in Canadian living and working environments is harmful, FPTRPC is of the opinion that moderate measures and participation in the process of acquiring new knowledge are sufficient. These types of activities are consistent with the Canadian government framework on precaution.”

4.4. Europe

The European Council recommends that member states adopt exposure limits to EMF in accordance with the ICNIRP guidelines (European Commission, 1999). Most member states have adopted this recommendation without additional protective measures (European Commission, 2002). While basing their limits on ICNIRP’s guidelines, a few countries have adopted some precautionary elements. A few of these are described in Table 3.

4.4.1 Denmark

Denmark does not have regulations that limit EMF exposures to the general public. Since 1993, a policy of prudent avoidance has been in effect which states that new high-voltage installations should not be built close to existing residential dwellings. It also indicates that new residential developments should be avoided close to high-voltage installations (Eurelectric, 2006). While no specific distance is specified, the right-of-way usually extends 50 m on each side of a 400 kV transmission line (Johansen, 2006, personal communication)

Table 3: Examples of Jurisdictions that Have Adopted Precautionary Limits

	Description	Magnetic Field Strength
Tuscany (Italy)	Quality target time-weighted-average level	2 mG (annual average)
Netherlands	Goal for EMF exposures in areas where children may be exposed for long durations (for example residences, schools and daycares)	4 mG (annual average)
Switzerland	Installation limit values for “places of sensitive use” (apartments, schools, hospitals, permanent workplaces, and children’s playgrounds)	10 mG
Israel	Environmental guideline	10 mG (24-hr average)
Italy	Attention value	100 mG (24-hr average)
	Quality goal (children’s playgrounds, residential dwellings, school premises, and in areas where people are staying for 4 hours or more per day)	30 mG (24-hr average)
Slovenia	New sources in areas with sensitive uses (hospitals, health resorts, residential areas, tourist facilities, daycares, schools, playgrounds, public parks and recreational areas)	100 mG
Costa Rica	At border of right-of-way	150 mG
Florida	Maximum load at edge of right-of-way	150 mG (69-230 kV lines)
		200 mG (500 kV lines)
		250 mG (certain existing RoW)
New York	Maximum load at edge of right-of-way	200 mG
Argentina	Edge of right-of-way and perimeter	250 mG
International guidelines (ICNIRP)		833 mG (at frequency of 60 Hz)
		1000 mG (at frequency of 50 Hz)

4.4.2 Italy

In 2003, Italy adopted ‘exposure limits’ ‘attention values’ and ‘quality goals’ (Italy, 2003). For 50 Hz magnetic fields, ‘exposure limits’ are identical to the ICNIRP guideline and must be adhered to in all public spaces without exception. An “attention value” of 100 mG (measured as a median value over 24 hours) has been established for children’s playgrounds, residential dwellings, school premises, and in areas where people are staying for 4 hours or more per day. A ‘quality goal’ of 30 mG (measured as a median value over 24 hours) has also been adopted for the design of new power lines in the vicinity of these sensitive sites and the planning of new developments near existing electrical installations. There is also a requirement for owners to label their facilities indicating exposure levels, recommended limits, and safety distances (European Commission, 2005).

Some local and regional authorities have also adopted limits that are stricter than the national ones. For example, Tuscany has a quality target time-weighted-average level of 2 mG. While it is not always

possible to meet this target, modifications can significantly reduce exposures. In one instance, the re-routing of the line reduced exposures from 20 to 2 mG. The additional revenues obtained from being able to build residential buildings in the area made up for the increased cost of € 500,000 (Licitra and Colonna, 2003).

4.4.3 Netherlands

There are no regulations that govern exposures to EMF. Exposures are limited in accordance with EU recommendations. In 2005, the Ministry of Housing, Spatial Planning and the Environment issued a circular that advised local authorities and power companies on goals for the protection of children. It establishes a goal of limiting annual average EMF exposures from power lines to 4 mG in areas where children may be exposed for long durations (for example, residences, schools, and daycares). These apply to new power lines and buildings where reasonably possible (Eurelectric, 2006).

4.4.4 Slovenia

To address public concern, Slovenia established exposure limits for new sources in areas with sensitive uses which are 10 times lower than ICNIRP's guidelines for the general public (European Commission, 2002). Local planning authorities have to consider these limits when making decisions about where various types of buildings or activities are allowed. Uses affected include hospitals, health resorts, residential areas, tourist facilities, daycares, schools, playgrounds, public parks, and recreational areas.

4.4.5 Sweden

There are no standards for EMF in Sweden but the General Advice on the Limitation of Exposure to the General Public to Electromagnetic Fields provides limits of exposures to EMF based on ICNIRP's guidelines (European Commission, 2005).

Since 1996 decisions related to exposures to EMF from power lines have been guided by the document Low-Frequency Electrical and Magnetic Fields: the Precautionary Principle for National Authorities – Guidance for Decision-Makers. This document states: "If measures generally reducing exposure can be taken at reasonable expense and with reasonable consequences in all other respects, an effort should be made to reduce fields radically deviating from what could be deemed normal in the environment concerned. Where new electrical installations and buildings are concerned, efforts should be made already at the planning stage to design and position them in such a way that exposure is limited." Normal levels of EMF in Swedish urban areas are in the range of 1-2 mG, with 0.5 percent of housing having levels above 2 mG. Authorities are encouraged to consider the cost-per-case-avoided of the proposed preventive measures and compare this with the cost of measures taken to reduce known hazards such as traffic and ionising radiation. It is then possible to estimate if the cost is proportionate to the potential risk avoided and which is the lowest cost alternative. In June 2005, the National Board of Health and Welfare issued a circular that reaffirmed the 1996 policy of prudent avoidance (Socialstyrelsen, 2005).

4.4.6 Switzerland

Switzerland has adopted an Ordinance for the Protection against Non-Ionizing Radiation (ORNI). The Ordinance is a legal standard to protect against the potential harmful effects associated with EMF (Switzerland, 1999). The standard is comprised of two components: the exposure limit and the installation limit value.

The exposure limit values are an adoption of the ICNIRP guideline and are based on health effects for which there is strong evidence (that is, acute health effects). These limits apply to all public spaces, and refer to the overall exposure (from all sources at a given location). The installation limit values (ILV) apply to “places of sensitive use” and refer to the radiation that is produced by a single installation (not overall exposure). Electric power lines, transformer stations and substations have an ILV of 10 mG. Trams and electric railways operating on alternating current have an ILV of 10 mG averaged over 24 hours. Sensitive uses refer to places where humans may be exposed for a prolonged duration such as apartments, schools, hospitals, permanent workplaces, and children’s playgrounds.

In cases where there are problems complying with the ILV, the ordinance provides for exemptions to be granted, provided that all measures that are technically and operationally possible and economically acceptable, including optimal phasing, have been taken to limit radiation. This standard has an impact on city planning – new building zones can only be designated in areas where the ILV of an existing or planned structure is not exceeded.

4.5 United States

There are no federal regulations or guidelines for EMF exposures in the United States. A few states have adopted standards related to power line right-of-ways (Table 4).

Table 4: State Guidelines and Standards for EMF levels in Power Corridors

State	Electric Field		Magnetic Field
	On R.O.W.*	Edge R.O.W.	Edge R.O.W.
Florida	8 kV/m (For 69-230 kV lines) 10 kV/m (500 kV lines)	2 kV/m	150 mG (69-230 kV lines max. load) 200 mG (500 kV lines max. load) 250 mG (on certain existing R.O.W. max. load)
Minnesota	8 kV/m	-	-
Montana	7 kV/m	1 kV/m (can be waived by the landowner)	-
New Jersey	-	3 kV/m	-
New York	11.8 kV/m 11.0 kV/m (Maximum for private road crossings) 7.0 kV/m (Maximum for highway crossings)	1.6 kV/m	200 mG (max. load)
Oregon	9 kV/m	-	-

*R.O.W. = right-of-way (or in the Florida standard, certain additional areas adjoining the right-of-way). Adapted from NIEHS (2002)

In addition some states have implemented policies that aim at limiting the exposures in power corridors. The Connecticut Siting Council (2006) has recently proposed a screening level at edge of the right-of-way: practical mitigation measures are to be implemented if levels in the right-of-way are above 100 mG. Massachusetts Energy Facilities Siting Board uses 85 mG at the edge of a right-of-way as a benchmark

(Boston Edison Company, 2005). The Hawaii Department of Health recommended a policy relating to power-frequency sources in 1994 – “reasonable, practical, simple, and relatively inexpensive actions should be considered to reduce exposure.”

In January 2006, the California Public Utilities Commission reaffirmed its 1993 policy of the application of low or no-cost measures to reduce EMF from electricity transmission lines and substations: the benchmark for low-cost measures is 4 percent of the cost of the project and a 15 percent reduction of EMF at the edge of the right-of-way is considered significant. Land uses where reduction measures are given priority are schools, licensed daycares, and hospitals, with residences as a second priority. No reduction measures are required in agricultural, rural and undeveloped land, unless housing or schools already exist (CPUC, 2006). Other states that have precautionary policies or practices include Colorado, Maryland, New Jersey, Ohio and Pennsylvania (Eurelectric, 2006).

California Department of Education

The California Department of Education has developed guidelines for evaluating potential sites for locating schools. These guidelines include 1) determining whether it is necessary for the school district to acquire a property near a right-of-way; 2) establishing whether other options are available; 3) ensuring that the school district has discussed with the utility company any plans to increase the voltage of the transmission lines or build additional infrastructure on the right-of-way, and 4) identifying whether the nearby lines are transmission or distribution lines (California Department of Education, 2005).

The California Department of Education, in consultation with the State Department of Health Services, may apply setback distances for locating any part of a school site property line near the edge of high-voltage transmission line rights-of-way. The setback distances are given in Table 5.

Table 5: School Site Selection Guide for California Schools

Line	Recommended Setback Distance
50-133 kV	100 feet [30 metres]
220-230 kV	150 feet metres [45 metres]
500-550 kV	350 feet [105 metres]

If recommended setbacks from rights-of-way are not feasible, a site-specific EMF Management Plan is implemented. This Plan provides a list of EMF site mitigation measures undertaken on the school property that address both external and internal EMF sources. Implementation of the EMF Management Plan recommendations will result in projected average EMF levels across the entire useable portion of the site to a level that does not exceed the average residential background EMF levels in the vicinity of the proposed school site, as determined by an EMF consultant. EMF mitigation measures must be implemented prior to student occupancy (California Department of Education, 2005).

5.0 Physical Activity in Toronto

Physical activity is essential to health. Recent studies have indicated that the Canadian population as a whole, and children in particular, are not as physically active as recommended by health professionals (Ontario Ministry of Health and Long-Term Care, 2003). In 2005, more

than 40 percent of people in Toronto reported their level of activity as either low or none at all (Toronto Public Health, 2007). The Chief Medical Officer of Health for Ontario reported that in 2003, almost one out of every two adults in Ontario was overweight or obese. Between 1981 and 1996, the number of obese children in Canada between the ages of 7 and 13 tripled. This is contributing to a dramatic rise in illnesses such as type-2 diabetes, heart disease, stroke, hypertension and some cancers.

A factor in this is the lack of opportunity for children to be physically active on a daily basis (Ontario Ministry of Health and Long-Term Care, 2004).

5.1 Benefits of Physical Activity

Public health experts emphasize that the most effective approach to achieving lifelong physical activity is to lay a foundation for physical activity in the childhood years that will be carried through adolescence and into adulthood. Ensuring that children and youth develop the foundational skills and habits for lifelong physical activity is a primary strategy in chronic disease prevention and in stemming exponential increases in the number of overweight and obese children and adults (Toronto Public Health, 2003).

The World Health Organization (2002) summarizes the wide-ranging benefits of physical activity for all aspects of health, well-being, and vitality as follows:

“Regular physical activity provides young people with important physical, mental and social health benefits. Being active has the potential to help children and young people develop coordination; build and maintain healthy bones, muscles and joints; control body weight and reduce fat; and develop efficient function of the heart and lungs. Play, games and other physical activities give young people opportunities for self-expression, building self-confidence, feelings of achievement, social interaction and integration. It also helps prevent and control feeling of anxiety and depression.”

Studies have shown that people who are inactive are twice as likely to have symptoms of depression than those who are more active. In addition, physical activity may not only relieve symptoms of depression, but may protect against its development. Physical activity is also beneficial in relieving symptoms of anxiety and in improving mood (Toronto Public Health, 2003). Moderate exercise has also been found to raise self-esteem and reduce injuries from falls, which can be seriously disabling, especially in older people.

The Canadian Parks and Recreation Association identifies the benefits of participation in sport and recreation as going beyond enhancing individual physical and mental health to include areas such as the facilitation of racial harmony and building community involvement and citizenship. This perspective is supported by survey findings of the Canadian Fitness and Lifestyle Research Institute that show Canadians strongly believe that physical activity opportunities make a positive contribution to the quality of life in their communities. It is believed that such opportunities increase citizen involvement and help people of different backgrounds to get along (Toronto Public Health, 2003).

Canadian research has provided good evidence of a positive relationship between physical activity and improved academic performance. Participation in structured recreation reduces boredom and deviant behaviour. Students involved in such activities are also less likely to drop out of school. This supports

the inclusion of child and youth recreation initiatives in local and national community safety strategies (Toronto Public Health, 2003).

Activities played on sports fields (field hockey, soccer, football, rugby) by children and adults offer significant health benefits associated with aerobic physical activity and team building (Health Promotion Resource Center, 1990). Regular physical activity for school children, of whatever intensity, is thought to contribute to growth, maturation, coordination, flexibility, fitness and overall functioning (Keays, 1993). Participating in team sports can ensure that children stay active on a regular basis. Team sports can also foster self-esteem, problem solving skills, and camaraderie (American Physical Therapy Association, 2000).

Canadians listed access to affordable facilities and programs and access to paths, trails and green spaces as the top three publicly provided resources they needed to be active (Toronto Public Health, 2003). Significant health benefits are also associated with cycling, running, and walking on continuous trails. Cycling is ranked among the top three exercises for improving cardiovascular fitness (NYC Department of City Planning, 2005). Cycling reduces the risk of serious conditions such as heart disease, high blood pressure, obesity and type-2 diabetes.

A team of researchers at St. Louis University and the U.S. Centers for Disease Control and Prevention looked at the possible impact of trails on physical fitness levels (Brownson et al., 2000). They interviewed people who lived in rural Missouri. More than half of the people who reported using trails also indicated that they increased the amount of walking since starting to use the trails. Women and people with less education were more likely to report such an increase.

Outdoor activity such as walking is important for children as it provides an informal learning environment that can contribute to the development of physical, practical, emotional and social skills (Queensland Government, 2005). Young people with access to activity equipment (including bike trails) are more likely to be active. Spending time outdoors promotes physical activity and studies have shown that children who spend the most time outside are the most active (Toronto Public Health, 2003).

A recent study of fourth graders in an urban school indicates that fidgeting and a general inability to focus is dramatically reduced on days when children are given the opportunity to go outside and play (Natural Playgrounds, 2005). The Association for Childhood Education International (2002) provides a summary of the benefits of children's play. Play is an essential part of children's growth, development and learning across all ages and cultures. Outdoor play in particular provides many benefits for children. Play structures encourage the use of large muscle groups, which is often impossible or impractical indoors, and provide children with opportunities to expand their range of activity. Play structures encourage curiosity and creativity by allowing children to explore, climb, hide, and move about. When challenging playground equipment is available, outdoor play offers children the opportunity to increase physical activity, and thus develop muscle strength and coordination.

5.2 Barriers to Physical Activity

Multiple barriers to physical activity have been identified. These include income inadequacy, language, culture, religion, and issues of racism and discrimination. Such barriers are potential causes of unequal participation in physical activity for close to half of Toronto's residents, and are connected with the perpetuation of health inequities among and between population groups in Toronto (Toronto Public Health, 2003).

In 2001, the Canadian Council on Social Development documented that low-income families face many barriers that prevent their children and youth from participating in quality recreation programs. The leading barriers include: user fees and equipment costs; lack of transportation, family support and awareness of opportunities; inadequate or no facilities in their communities; and lack of safe places to play (Toronto Parks, Forestry and Recreation, 2005).

Lack of access to facilities is an especially important barrier to physical activity. People tend to be more active if recreational facilities are near their homes, and nearly twice as many people choose to walk or cycle in neighbourhoods that are designed for these activities compared with those designed mainly for automobile transportation (Cervero and Gorham, 1995). Troped and colleagues (2001) found that access and perceived access to hiking and biking trails were positively related to their use.

Recreational facilities in hydro corridors near residences and work places can provide additional opportunities to engage in regular exercise. While use of some of the recreational facilities available in hydro corridors entail a cost (for example, organized sports teams), others, such as, trails, play structures and basketball courts, are accessible at no extra cost to the user.

In 2004, the Chief Medical Officer of Health for Ontario recommended that action be taken to create communities that promote regular physical activity (MOHLTC, 2004). Recreational facilities such as trails and sports fields that are close to where people live or work may encourage people to increase their level of physical activity.

Given the considerable cost burden associated with physical inactivity, it is important to enable the public to engage in affordable recreational activities. In certain areas, recreational facilities in hydro corridors offer low or no cost opportunities for physical activity that are close to where people live or work.

5.3 Community Gardens

Historically, urban garden plots managed by individuals have been a part of a poverty reduction strategy. Community gardens provide an alternative for people to simultaneously improve food security and their participation in a local food system. Urban gardens are a source of nutritious produce at relatively low cost. Access to community gardens is an important strategy for improving vegetable consumption, gaining control over the quality and variety of produce consumed, and facilitating community relationships and development (Blair et al., 1991). The Toronto Food Policy Council has advocated increased urban agriculture through community gardens for individuals. Hydro corridors have been suggested as viable spaces in Toronto for long-term community gardening (POV, 2004).

Community gardening has been shown to play a role in revitalizing inner city urban neighbourhoods and preventing crime (Francis et al., 1984; Trust for Public Land, 1994). This transformation has taken place when community gardens engage sustained community involvement by youth, families, seniors, intergenerational, ethnic, and multicultural groups. It has been reported that vandalism, documented crime, graffiti, and negative park use have declined in Toronto where community gardens have been created (Toronto Parks, Forestry and Recreation, undated).

6.0 Policy for Limiting Exposures to Electromagnetic Fields in Hydro Corridors

6.1 Secondary Uses of Hydro Corridors

Various documents have a bearing on the use of hydro corridors in Toronto. These include the following:

- Official Plan: The Official Plan designates hydro and rail corridors as utility corridors to be used primarily for the movement and transmission of energy, information, people and goods. Public and private secondary uses for hydro corridors are supported provided they are compatible with the primary use of the corridor. The Official Plan also indicates that secondary uses must be consistent with existing and proposed use of the adjacent lands, and protect for potential road and public transit corridors, pedestrian and bicycle trails (Toronto Urban Development Services, 2005).
- Parkland Acquisition Strategy: The 2001 Parkland Acquisition Strategic Directions report has identified hydro corridors as an important open space resource for Toronto (Toronto Economic Development, Culture and Tourism, 2001). The spatial characteristics of hydro corridors provide a unique opportunity to augment recreational facilities requiring large areas (for example sports fields) or linear uses (such as cycling paths or walking trails).
- “Get Your Move On”: Making recreational facilities more accessible to a larger number of people advances the goals of the Get Your Move On physical activity campaign. A healthy community has facilities that are accessible for community-use, and maximizes the affordable use of existing space efficiently and effectively. By ensuring that space is provided at no or low cost, governments are nurturing the community to develop and sustain a range of activities, programs, events and services that improve the lives and well-being of Toronto residents (Toronto Public Health, 2003).
- City of Toronto’s Bike Plan: The 2001 Bike Plan includes hydro corridors as areas for bike trail expansion in the City. Using hydro corridors for cycling provides a method of linking various parts of the City and can be a safer alternative to cycling on congested streets from an injury prevention and air quality perspective.
- Toronto’s Food Charter: City Council has affirmed its commitment to urban agriculture, more productive use of city parkland and open space, and community economic development. In February 2001, the City of Toronto was the first Canadian municipality to develop a multi-sectoral food security plan and Food Charter which encouraged community gardens (City of Toronto, 2001). There is an extensive waiting list for allotment gardens in the City of Toronto. Given this situation, hydro corridors may present an opportunity for the community to access more land for community gardens (Black, 2000).

6.2 Rationale for a Policy of Prudent Avoidance

The 2007 Environmental Health Criteria Monograph concluded that implementing precautionary approaches to reduce exposures is reasonable and warranted provided that these do not compromise the health, social and economic benefits of electrical power, and the cost of these measures are kept low (IPCS, 2007). The types of approaches identified included the following:

- Very-low cost measures when constructing new facilities and designing new equipment and appliances;
- Changes to engineering practices from equipment or devices that involve little or no cost or provide benefits such as increased safety;
- Enforcement of wiring codes to reduce unintentional ground currents in new buildings or when buildings are rewired; and
- Communication strategy to inform individuals on ways to reduce their own exposures.

Former City of Toronto Policy

In 1993, the former City of Toronto adopted a policy of prudent avoidance based on studies showing an association between exposures to EMF and increased incidence of cancer (Toronto Public Health, 1993). Prudent avoidance was conceptualized at the Carnegie Mellon University in 1989 and refers to taking individual or societal actions that are simple, easy to achieve, and low cost to minimize exposure even when the risk of a situation is not confirmed. It can be seen as an application of the precautionary principle (Kheifets, 2001).

Elements of the 1993 policy included requesting that utilities use technology to mitigate magnetic fields, amending site plans to reduce exposure to EMF by locating playgrounds and day care centres away from power lines and transformers, and ensuring that new residential units were as far away from the power lines as possible and at least as far as other residences in the area. Situations were assessed on a case-by-case basis. When implementing the policy, consideration was also given to the health and social benefits of uses in hydro corridors. For example, community gardens were permitted in hydro corridors because their food security benefits were seen to outweigh any risk. The policy also encouraged education so that residents could be aware of steps to reduce exposure to EMF in the home.

Current assessment

In its review, Toronto Public Health has carefully considered the complexities involved including the following:

1) The current health evidence:

Data available to date on the health effects of EMF show that exposure to EMF at levels normally experienced in daily life in Canada is not a risk. However, some data suggest that people exposed to higher levels of EMF might be at higher risk of developing certain diseases, in particular childhood leukemia. There are no standards for limiting exposures to EMF to the general public in Canada. In practice reference is made to ICNIRP's Guidelines for Limiting Exposure to Time-Varying Electric, Magnetic, and Electromagnetic Fields up to 300 GHz. The levels typically found in hydro corridors, while meeting public exposure guidelines, are higher than the levels at which an association between exposures to EMF and childhood leukemia have been observed (3 or 4 mG).

2) The challenges of planning additional recreational and gardening:

There are constraints on the amount of land that may be purchased at a reasonable cost for expanding recreational facilities in the City of Toronto to meet the needs of the current and growing population. In some parts of the City, hydro corridors are the only remaining space suitable for large-scale facilities such as soccer fields and cycling or walking trails.

3) The health benefits of parkland:

Public recreational and gardening facilities provide considerable health benefits and need to be accessible to all citizens. These benefits have been recognized in several City of Toronto policy directions including the Official Plan, Toronto Public Health's Call to Action on physical activity, the Parkland Acquisition Strategic Directions Report, and the Food Charter. Hydro corridors provide space for additional recreational facilities in the City of Toronto.

Risk Estimation

Leukemia is a rare outcome among children. While a causal link between EMF exposure and childhood leukemia has not yet been confirmed, some studies have tried to estimate the number of leukemia cases that could be related to ELF magnetic field exposure if this link actually exists. IPCS (2007) estimates that, world-wide, EMF might cause between 0.2 to 4.9 percent of leukemia cases. The California Electric and Magnetic Fields Program (2000) estimated that children who live next to hydro corridors in the state might experience an additional three cases of leukemia per 100,000 children.

Using 1991-2001 data from Toronto, there are approximately 25 new cases of leukemia diagnosed among children aged 0-19 years each year in the city (Cancer Care Ontario, 2003). The number of children (0-19 years) living in Toronto each year over the same time frame is approximately 500,000 to 600,000 (Cancer Care Ontario, 2003). Thus, the leukemia rate among children aged 0-19 years (in Toronto) is between 4.3 and 5.5 cases per 100,000 children per year. This rate appears comparable to the rates reported elsewhere.

Estimates of the population attributable risk (the percentage of leukemia cases that may be prevented if magnetic field exposures were eliminated) range from 3 to 11% of cases depending on the study (Ahlbom et al., 2000; Greenland et al., 2000; Wartenberg, 2001). Using this attributable risk, exposure to EMF might explain 1 to 3 of the leukemia cases in Toronto each year.

In addition, Ahlbom and colleagues (2000) provide a value for the continuous relative risk estimate of 1.2 (95% confidence interval 1.0 – 1.3) for every 2.0 mG increase in exposure. This is equivalent to an increase in the life-time risk of childhood leukemia by about 16 in 1 million for every increase in average exposure of 1 mG. Increases in risk of cancer of more than 1 in 1 million over a lifetime are often considered sufficient for action.

Given that levels of EMF in hydro corridors are generally higher than those found elsewhere in the urban environment, time spent under or near transmission lines will usually increase the overall average level of EMF that a person is exposed to. The size of the increase will depend on the strength of the field and the amount of time spent in that field. Table 6 illustrates situations that would result in a 1 mG increase in overall average exposure. This shows that short-term exposures to relatively high levels of EMF in or next to hydro corridors will have a small impact on the 24-hour average exposures.

Table 6: Amount of Time Spent at Different Levels of EMF That Result in a 1 mG Increase in Daily Exposure Averaged Over a Year

Example of activity	Average level of EMF (mG)	Time spent that would result in 1 mG increase in average exposure
Walking on a path across (perpendicular) the corridor and hydro lines to and from school.	170	1 hour a week or approximately 4 minutes twice a day, 12 months per year
Gardening in an allotment	100	30 minutes per day, most days of the week, 6 months of the year
Playing on sports on a field in the hydro corridor	45	6 hours per week for 8 months of the year
Playing on and around a play structure in a playground	20	1.5 hours per day (10 hours per week), for 10 months of the year
Cycling, running or walking along the length of the corridor several evenings per week, with a longer ride/run on weekends	15	About 12 hours per week, year-round
Outdoor play during the week and on weekends in a yard next to the hydro corridor	10	3 hours a day, 7 days per week year-round

For example, walking directly under hydro wires to pass from one side of the hydro corridor to the other will not greatly increase the 24-hour average exposure level even when levels are quite high. However, as the time spent in or next to the hydro corridor increases, a lower level of magnetic field exposure will result in an equivalent increase in total exposure. A walking and cycling trail could be planned within the hydro corridor, provided that most sections are not built directly underneath the high voltage lines. In this way, it would be possible to minimize the increase to a regular user's 24-hour average exposure.

An EMF management plan outlines what can be done to reduce exposures to EMF. For example, it can identify the best place for play equipment or other amenities where people are likely to stay a long time. Land next to the right-of-way of a transmission line may have slightly higher levels of EMF than most other areas in the city. Given that the wiring in a building can be an important source of exposure to EMF, a management plan for a proposed development next to a hydro corridor would identify areas in and outside the building where EMF are highest, such as next to the main electrical circuits. The plan could then identify the best place for the building and children play areas, as well as for the living and sleeping areas where people would spend the most time, and in this way, help to minimise total exposures to EMF when on the site.

It is estimated that the overall increase of exposure to EMF from the use of parks, recreational facilities, trails, and community gardens in or next to hydro corridors can continue without raising a user's 24-hour average exposure level more than 1 or 2 mG if exposure assessments are used to guide the placement of

amenities. Toronto Public Health concludes that under such circumstances, the benefits outweigh any potential risk that might result from the increase in exposure to EMF.

7.0 References

Ahlbom A, Day N, Feychting M, Roman E, Skinner J, Dockerty J, Linet M, McBride M, Michaelis J, Olsen JH, Tynes T, Berkasalo PK (2000). A pooled analysis of magnetic fields and childhood leukaemia. *British Journal of Cancer* 83(5): 692-698.

American Conference of Governmental Industrial Hygienists (ACGHI) 2001. Documentation of the Threshold Limit Values for physical agents (7th edition). ACGHI: Cincinnati.

American Physical Therapy Association. American Physical Therapy Association Promotes Participation in Team Sports. 2000. http://www.kidsource.com/kidsource/content2/news2/schoolspirit9_3_96.html

Association for Childhood Education International (ACEI). 2002. Play: essential for all children. <http://www.acei.org/playpaper.htm> (Accessed May 24, 2006)

Barbier, E. B. Dufy, B. Veyret. 1996. Stimulation of Ca²⁺ influx in rat pituitary cells under exposure to a 50 Hz magnetic field. *Bioelectromagnetics* 17: 303-311 in International Agency for Research on Cancer, 2002, op. cit.

Black, S. Nurturing your green thumb: making the most of a little space. *National Post*. May 10, 2000. Foodshare. http://www.foodshare.net/media_archive02.htm (Accessed December 20, 2005)

Blair, D., C.C. Giesecke and S. Sherman. 1991. A dietary, social and economic evaluation of the Philadelphia urban gardening project. *Journal of Nutrition Education* 23(4): 161-167. Available from: University of California Sustainable Agriculture Research and Education Program. <http://www.sarep.ucdavis.edu/newsltr/v7n3/sa-10.htm>

Boston Edison Company. 2005. Petition of Boston Edison Company d/b/a NSTAR Electric for a determination by the Department of Telecommunications and Energy, under provisions of G.L.c. 164, § 72, that the relocation of 3 miles of 115 kV transmission line in Framingham, Natick and Sherborn is necessary and will serve the public convenience and is consistent with the public interest (March 31, 2005). D.T.E. 04-71. www.mass.gov/dte/electric/04-71/323framdraft.pdf (Accessed September 1, 2006)

Brownson, R.C., Housemann, R.A., Brown, D.R., Jackson-Thompson, J., King, A.C., Malone, B.R. and Sallis J.F. (2000) Promoting physical activity in rural communities: Walking trail access, use, and effects *Am. J. Prev. Med.* (18/3): 235-241. As cited in: Morris, H. (2000) research links increased physical activity levels with trails. *Connections* (The National Transportation Enhancements Clearinghouse Newsletter) (3/2): 3,6. <http://www.enhancements.org/download/connections/vol3no2.pdf>

California Department of Education. 2005. School Site Selection and Approval Guide. <http://www.cde.ca.gov/ls/fa/sf/schoolsiteguide.asp>

California Electric and Magnetic Fields Program. 2000. Electric and magnetic fields measurements and possible effect on human health – what we know and what we don't know in 2000. Oakland, CA:

California Dept. of Health Services and the Public Health Institute.
<http://www.dhs.ca.gov/ps/deodc/ehib/emf/longfactsheet.PDF>

California Public Utilities Commission. 2006. Opinion on commission policies addressing electromagnetic fields emanation from regulated utility facilities (Decision 06-01-041 January 26, 2006; Rulemaking 04-08-020). San Francisco: The Commission. (See also PUC Actions Regarding EMF www.cpuc.ca.gov/static/energy/environment/electromagnetic+fields/action.htm)

Cancer Care Ontario. 2003. Prepared from standard files by Toronto Public Health Metrics and Planning staff, April 2006.

Cervero, R. and R. Gorham. 1995. Commuting in transit versus automobile neighbourhoods. *Journal of the American Planning Association* 61: 210-225 in R.K. Dishman, R.A. Washburn and G.W. Heath. 2004. *Physical Activity Epidemiology. Human Kinetics: United States of America.*

City of Toronto. 2001. Toronto's Food Charter.
http://www.city.toronto.on.ca/food_hunger/pdf/food_charter.pdf

Connecticut Siting Council. 2006. Electric and Magnetic Field Best Management Practices for the Construction of Electric Transmission Facilities in Connecticut (Draft, 4 May 2006).
http://www.ct.gov/csc/lib/csc/emf_bmp/may_4_draft.doc (Accessed September 1, 2006)

Deadman, J.E., B.G. Armstrong, M.L. McBride, R. Gallagher, G. Thériault. 1999. Exposures of children in Canada to 60-Hz magnetic and electric fields. *Scand J Work Environ Health*. 25 (4): 368-75

Eurelectric. 2006. EMF exposure standards applicable in Europe and elsewhere. Brussels: Union of the Electricity Industry (Eurelectric). Available at:
www.jrc.cec.eu.int/emf-net/doc/Reports/Euroelectric%20Exposure%20Standards%202006.pdf

European Commission. 1999. Council Recommendation of 12 July 1999 on the limitation of exposure of the general public to electromagnetic fields (0 Hz to 300 GHz). 1999/519/EC.

European Commission. 2002. Implementation report on the Council Recommendation limiting the public exposure to electromagnetic fields (0 Hz to 300 GHz). European Commission, DG Health and Consumer Protection. Available at
http://ec.europa.eu/health/ph_determinants/environment/EMF/implement_rep_en.pdf

European Commission. 2005. European information system on electromagnetic fields exposure and health impacts – final report. Ispra, Italy: E.C. Joint Research Centre, Institute for Health and Consumer Protection. Available at
http://ec.europa.eu/health/ph_projects/2002/pollution/fp_pollution_2002_frep_01.pdf

Federal-Provincial-Territorial Radiation Protection Committee – Canada (2005). Health Effect and Exposure Guidelines Related to Extremely Low Frequency Electric and Magnetic Fields – an overview. Available at <http://www.bccdc.org/content.php?item=196>

Francis, M., Cashdan, L., & Paxsin, L. (1984). Community Open Spaces: Greening neighborhoods through community action and land conservation. Island Press, Washington, D.C. In Dishman, R.K., R.A. Washburn and G.W. Heath. 2004. Physical Activity Epidemiology. Human Kinetics: Champaign, Illinois.

Galvanoskis, J., J. Sandblom, B. Bergqvist, S. Galt, Y. Hamnerius. 1996. The influence of 50-Hz magnetic fields on cytoplasmic Ca^{2+} oscillations in human leukemia T-cells. *Sci Total Environ.* 180:19-33. In International Commission on Non-Ionising Radiation Protection, 2003, op. cit.

Galvanoskis, J., J. Sandblom, B. Bergqvist, S. Galt, Y. Hamnerius. 1999. Cytoplasmic Ca^{2+} oscillations in human leukemia T-cells are reduced by 50-Hz magnetic fields. *Bioelectromagnetics* 20: 269-276. In International Commission on Non-Ionising Radiation Protection, 2003, op. cit.

Green, L.M., Miller, A.B., Agnew, D.A., Greenberg, M.L. Li, J., Villeneuve, P.J., Tibshirani, R. (1999a) Childhood leukemia and personal monitoring of residential exposures to electric and magnetic fields in Ontario, Canada. *Cancer Causes and Control* 10: 233-243.

Green, L.M., Miller, A.B., Villeneuve, P.J., Agnew, D.A., Greenberg, M.L. (1999b) A case-control study of childhood leukemia in southern Ontario, Canada, and exposure to magnetic fields in residences. *Int. J. Cancer* 82: 161-170.

Greenland S, Sheppard A.R., Kaune W.T., Poole C, Kelsh M.A. (2000). A pooled analysis of magnetic fields, wire codes and childhood leukemia. *Epidemiology* vol 11: 624-634.

Havas, M. 2002. Electric and magnetic fields within the business district of sixty communities in south-central Ontario. *The Science of the Total Environment* 298:183-206.

Havas, M. Shum, S., Dhalla R. 2004. Passenger exposure to magnetic fields on GO-trains and on buses, streetcars and subway run by the Toronto Transit Commission, Toronto, Canada. 3rd International Workshop on Biological Effects of EMFs (Kos, Greece: 4-8 October 2004): 1065-1071.

Hawaii Department of Health. 1994. DOH policy relating to electric and magnetic fields from power-frequency sources. In *Undergrounding Public Utility Lines*, by Pamela Martin (Report No. 2, 1999). Honolulu: Legislative Reference Bureau. Available at: <http://www.hawaii.gov/lrb/rpts99/undrgr.pdf>

Health Canada. 2004. Electric and Magnetic Fields at Extremely Low Frequencies factsheet. http://www.hc-sc.gc.ca/iyh-vsv/enviro/magnet_e.html (Accessed February 26, 2006)

Health Promotion Resource Center Stanford Center for Research in Disease Prevention Stanford University School of Medicine. 1990. Promotion of physical activity in the community: a manual for community health professionals. King, A.C., W.L. Haskell, N. Miller, S. Blair (eds.).

International Agency for Research on Cancer (IARC). 2002. Non-Ionizing Radiation, Part I: Static and Extremely Low-frequency (ELF) Electric and Magnetic Fields (IARC Monographs on the evaluation of carcinogenic risks to humans, vol. 80). Lyon: IARC Press.

International Commission for Non-Ionizing Radiation Protection (ICNIRP). 1998. Guidelines for limiting exposure to time-varying electric, magnetic, and electromagnetic fields (up to 300 GHz). Health Physics Society.

International Commission for Non-Ionizing Radiation Protection (ICNIRP). 2003. Exposure to static and low frequency electromagnetic fields, biological effects and health consequences (0-100 kHz): review of the scientific evidence on dosimetry, biological effects, epidemiological observations, and health consequences concerning exposure to static and low frequency electromagnetic fields (0-100 kHz). R. Matthes, A. McKinlay, J.H. Bernhardt, P. Vecchia, B. Veyret (eds.). Oberschleissheim, Germany:ICNIRP.

International Programme on Chemical Safety (IPCS). 2007. Extremely Low Frequency Fields (Environmental Health Criteria Monograph No.238). Geneva: World Health Organisation. Available at http://www.who.int/peh-emf/publications/elf_ehc/en/index.html

Italy, President of the Council of Ministers. 2003. Establishment of exposure limits, attention values, and quality goals to protect the population against power frequency (50 Hz) electric and magnetic fields generated by power lines. Decree of the President of the Council of Ministers, 8 July 2003 (Unofficial translation). Originally published in the Official Gazette of the Italian Republic, August 29, 2003. http://www.who.int/docstore/peh-emf/EMFStandards/who-0102/Europe/Italy_files/table_datoteke/Italy_DPCM_50Hz_eng.pdf (Accessed August 25, 2006)

Johansen, Christoffer. 2006. Personal communication. Copenhagen: Institute of Cancer Epidemiology.

Keays, J. 1993. The effects of regular (moderate to vigorous) physical activity in the school setting on students' health, fitness, cognition, psychological development, academic performance and classroom behaviour. North York Community Health Promotion Research Unit.

Kheifets, L.I. 2001. The precautionary principle and EMF. WHO Meeting on EMF Biological Effects and Standards Harmonization in Asia & Oceania (Seoul, South Korea: 22-24 October 2001)

Kumlin, T., V.M. Kosma, L., Alhonen, J. Janne, H. Homulainen, S. Lang, T. Rytomaa, K. Servomaa, J. Juutilainen. 1998. Effects of 50 Hz magnetic fields on UV-induced skin tumorigenesis in ODC-transgenic and non-transgenic mice. Int. J. Radiat. Biol. 73:113-121 in International Agency for Research on Cancer. 2002 op.cit.

Licitra, G. and Colonna, N. (2003) Applicability of the precautionary principle to power lines: some successful case studies in Tuscany. Presented at the Conference on the application of the precautionary principle to electromagnetic fields (Luxemburg: 24-26 February 2003).

Lowenthal, R.M., D.M. Tuck, I.C. Bray. 2007. Residential exposure to electric power transmission lines and risk of lymphoproliferative and myeloproliferative disorders: a case-control study. Internal Medicine Journal 37(9): 614-9.

Matthes, R. 1998. Response to questions and comments on ICNIRP: guidelines on limiting exposure to time-varying electric, magnetic, and electromagnetic fields (up to 300 GHz). Health Physics 75:4. 438-439.

Mevissen, M., M. Kietzmann, W. Loscher. 1995. In vivo exposure to of rats to a weak alternating magnetic field increases ornithin decarboxylase activity in the mammary gland by a similar extent as the carcinogen DMSA. *Cancer Lett.* 90. 207-214.

National Institute of Environmental Health Sciences (NIEHS). 1999. NIEHS report on health effects from exposure to power-line frequency electric and magnetic fields. Research Triangle Park, N.C.

National Institute of Environmental Health Sciences (NIEHS). 2002. EMF: Electric and magnetic fields associated with the use of electric power – Questions & Answers. Research Triangle Park, N.C.
<http://www.niehs.nih.gov/emfrapid/booklet/home.htm>

Natural Playgrounds. Young people, children, and nature. 2005.
http://www.naturalplaygrounds.com/resources_article_young-people-children-nature.php

New York City Department of City Planning. 2005. Bicycle network development.
<http://www.nyc.gov/html/dcp/html/bike/benefit.html>

Ontario Ministry of Health and Long-Term Care. 2004. Healthy weights, healthy lives 2004 Chief Medical Officer of Health Report.
http://www.health.gov.on.ca/english/public/pub/ministry_reports/cmoh04_report/cmoh_04.html

Portier, C.J., M.S. Wolfe (eds.). 1998. Assessment of health effects from exposure to power-line frequency electric and magnetic fields - NIEHS Working Group Report NIH Publication No. 98-3981. Research Triangle Park: National Institute of Environmental Health Sciences. Available at <http://www.niehs.nih.gov/emfrapid/html/WGReport/emf.pdf>

POV. 2004. Designed for production: addressing poverty through landscape. <http://www.pov-design.com/papers/designed%20for%20production.pdf>

Queensland Government. 2005. The benefits of walking.
http://www.roadsafety.qld.gov.au/qt/LTASinfo.nsf/index/rs_pedestrians_benefitsofwalking

Socialstyrelsen [Swedish National Board of Health and Welfare]. 2005. Elektromagnetiska fält från kraftledningar (Meddelandeblad, Juni 2005) [Electromagnetic fields from power lines (Circular, June 2005)]. Stockholm: Swedish National Board of Health and Welfare.

Svedenstal, B.M., K.J. Johanson, K.H. Mild. 1999. DNA damage induced in brain cells of CBA mice exposed to magnetic fields. *In Vivo*, 13: 551-552 in Swiss Federal Council. Ordinance relating to Protection from Non-Ionising Radiation of 23 December 1999 (as of 1 February 2000). Article 814.710.
<http://www.environment-switzerland.ch/imperia/md/content/luft/nis/vorschriften/2.pdf>

Switzerland. 1999. Ordinance relating to protection from non-ionising radiation (ONIR) and Explanatory report. Bern: Swiss Agency for the Environment, Forests and Landscape. Available at http://www.umwelt-schweiz.ch/imperia/md/content/recht/umweltrecht/nisv_vo-en.pdf and <http://www.environment-switzerland.ch/imperia/md/content/luft/nis/vorschriften/3.pdf>

Toronto Economic Development, Culture and Tourism (2001) Parkland acquisition strategic directions report. Report from the Commissioner of Economic Development, Culture, and Tourism to the Economic Development and Parks Committee, 22 October 2001.

<http://www.city.toronto.on.ca/legdocs/2001/agendas/committees/edp/edp011022/it020.pdf>.

Toronto Parks, Forestry and Recreation (no date) Community gardens in the City of Toronto.

<http://www.city.toronto.on.ca/parks/programs/community.htm> (Accessed May 24, 2007)

Toronto Parks, Forestry and Recreation (2005) Interim report on options for free recreation programs for children and youth. June 21 Staff report to the Economic Development and Parks Committee. City of Toronto. <http://www.toronto.ca/legdocs/2005/agendas/committees/edp/edp050704/it010.pdf>.

Toronto Public Health (TPH). 1993. Policy respecting electric and magnetic fields (EMFs). Staff report to the Board of Health, June 28, 1993.

Toronto Public Health (TPH). 2003a. Achieving an active population: a call for action. The health benefits of physical activity. Technical Report. Toronto Public Health, Planning and Policy.

Toronto Public Health (TPH). 2003b. Physical activity and public health: A call to action. Available at: http://www.toronto.ca/health/pdf/pa_boh.pdf

Toronto Public Health (TPH). 2007. Rapid Risk Factor Surveillance System – 2005 Toronto Indicators Report. Toronto: TPH. Available at: http://insideto.toronto.ca/health/planning/pdf/rrfss_tip2005.pdf

Toronto Urban Development Services (2005) Proposed public uses in hydro corridors
30 March Staff report to Planning and Transportation Committee. City of Toronto. Available at: <http://www.toronto.ca/legdocs/2005/agendas/committees/plt/plt050425/it008.pdf>.

Troped, P.J., R.P. Saunders, R.R. Pate, B. Reininger, J.R. Ureda, S.J. Thompson. 2001. Associations between self-reported and objective physical environmental factors and use of a community rail-trail. *Preventive Medicine* 32(2): 191-200. In Dishman, R.K., R.A. Washburn and G.W. Heath. 2004. *Physical Activity Epidemiology*. Human Kinetics: Champaign, Illinois.

Trust for Public Land (TPL). 1994. *Healing America's Cities: Why we must invest in urban parks*, A Green Cities Initiative Report, San Francisco, Ca. Available at:

http://www.tpl.org/tier3_cdl.cfm?content_item_id=888&folder_id=728.

Vitatech Engineering. EMF fundamentals. 2000. http://www.vitatech.net/emf_fundamentals.php4#Flux (Accessed May 31, 2006)

Watenberg, D. 2001. Residential EMF exposure and childhood leukemia: meta-analysis and population attributable risk. *Bioelectromagnetics Suppl.* 5: S86-S104.

Weisenberger DD. 1993. Reply. *Human Pathology* 24: 1384-86.

World Health Organization (WHO). 2002. Move for health.

<http://www.paho.org/English/hpp/hpn/whd2002.htm> (Accessed December 20, 2005)

World Health Organization (WHO) Regional Office for Europe. 2001. Precautionary policies and health protection: Principles and applications. Report on a WHO Workshop. Rome, May 28-29, 2001.
<http://www.euro.who.int/document/e75313.pdf> (Accessed February 13, 2006)