Health Sciences
Electrical and Semiconductor Engineering

Exponent®

Investigation Regarding Costain *et al* v. Maritime Electric Company Limited

Complaint re Transmission Line, Locke and Howlan Roads
Docket UE20324

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Executive Summary

The Island Regulatory and Appeals Commission retained Exponent to assist their staff in the review of a complaint by residents along Howlan, Locke, and O'Leary Roads about potential health risks of electric and magnetic fields (EMF) associated with a transmission line built to carry electricity generated by the West Cape Wind Farm. Exponent engineers reviewed measurements of EMF provided to residents by Maritime Electric and modeled the levels of EMF associated with the current and future operation of the line. Health scientists examined the documents submitted by the residents in support of their complaint.

The measurements reviewed and calculations performed did not suggest that the transmission line currently operated at 69 kV is a large contributor to the **average magnetic field exposure** of residents given the relatively low levels of magnetic fields associated with the line and the distance of the residences from the line, though the closer to the line, the greater the magnetic field at nearby residences. When the wind-farm generating capacity is increased in November 2008 the transmission line will be operated at 138 kV. The greater load on the line will increase the magnetic field level near the line, but this will be much less than if the line continued to operate at 69 kV.

The documents submitted by the residents were found to consist of materials copied from a variety of non-scientific sources, i.e., print and media and unpublished documents. The opinions expressed in these documents are not supported by the weight of the scientific evidence, as summarized in the reviews of EMF research by national and international scientific and health agencies including those in Canada. These agencies, based on the weight of the evidence, have not uncovered credible and reliable scientific evidence that exposures to EMF at levels found in daily life, including those associated with the operation of the Maritime Electric transmission line, are hazardous to health.

The relevance and applicability of the precautionary principle was reviewed, and based upon Canadian and international precedents, there seems to be no precautionary action (aside from increasing the voltage on the transmission line, as has been planned), that would be appropriately proportional to the small degree of scientific uncertainty about assessments of the

evidence. Certainly, neither the scientific evidence nor the precautionary principle justify the removal or relocation of the transmission line.

To improve the understanding of the public about EMF for future projects, Maritime Electric should be requested to provide additional information about transmission projects, including calculations of EMF, and the Commission or other governmental agency should provide information about EMF health research on its website.

Background

The Island Regulatory and Appeals Commission (Commission) is an independent tribunal that hears appeals on issues relating to land use and ownership, and certain taxes and rates. In addition, the Commission regulates the Maritime Electric Company, Limited (Maritime Electric) and all small water and wastewater utilities on Prince Edward Island.

Complaint and Commission-initiated investigation

The Commission received a letter of complaint from Mr. J. William Costain and residents of Locke/Howlan Roads, dated September 13, 2007 (Costain letter), regarding a 138,000-volt (138-kV) transmission line constructed and operated by Maritime Electric that carries power generated by the West Cape Wind Farm.[1] Mr. Gordon Ramsay submitted similar letters and petitions to Maritime Electric and provincial officials (Ramsay letters) on behalf of concerned residents prior to construction of the line in 2006.[2] These letters and petitions expressed opposition of some residents to the transmission line along Howlan, Locke and O'Leary Roads because of concerns about human health and recommended that the transmission line be relocated on another route. In November 2007, the Commission issued a Request for Proposal for an independent expert to assist the Commission's staff to:

1. Review the relevant technical specifications of the transmission line in dispute;
2. Perform a site inspection of the transmission facilities and the locations of the residences along the transmission route;
3. Prepare a written report containing analyses, comments, conclusions and potential health effects of this transmission facility;

[1] Letter from J. William Costain to Mr. Donald Sutherland, Director of Island Regulatory and Appeals Commission, 13 September 2007.

[2] Letter from Gordon Ramsay to Ministers, Members of Provincial Legislature, administrators of Ventus Energy, Inc. and Maritime Electric, 6 December 2006. Letter from Gordon Ramsay to Maritime Electric and Ventus Energy, Inc., 11 December 2006.

4. Provide any recommendations on remedies which may be available depending upon the conclusions reached; and
5. Draw to the attention of the Commission such other issues and make such other comments and recommendations on related matters, as the expert considers advisable.

The Commission retained Exponent on November 29, 2007 to perform the above listed tasks, and the scope of Exponent's retention was expanded on February 12, 2008 to include electric and magnetic field (EMF) modeling and the review of additional filings. This report summarizes the results of Exponent's investigation of the J. William Costain *et al.* complaint and related concerns expressed in letters from Mr. Ramsay.

Nature and characteristics of EMF

EMF are produced by both natural and man-made sources that surround us in our daily lives. The earth itself produces a static magnetic field – it is this field that is used for compass navigation. Man-made EMF is found wherever electricity is generated, transmitted, or used. Power lines, wiring in homes, workplace equipment, electrical appliances, and motors all produce EMF.

Electric fields are the result of voltages applied to electrical conductors and equipment. The electric field is expressed in measurement units of volts per meter (V/m) or kilovolts per meter (kV/m); 1 kV/m is equal to 1000 V/m.

Magnetic fields are produced by the flow of electric currents. Electricity produced by generating stations flows through transmission and distribution lines and provides power to the many appliances and electrical devices we use in our homes, schools, and workplaces. A magnetic field is produced only when the current is flowing (e.g., when an appliance is turned on). The strength of magnetic fields is expressed as magnetic flux density in units called gauss (G), or in milligauss (mG), where 1 G is equal to 1000 mG.

Electrical operations in Canada and the rest of North America produce alternating current EMF that changes direction and intensity 60 times per second - a frequency of 60 Hertz (Hz). These fields are in the extremely low frequency (ELF) range (30-300 Hz) on the electromagnetic spectrum. Fields at this frequency are quite different from higher frequency electromagnetic fields such as radio and television signals, microwaves from ovens, and radiofrequency fields from cellular phones (which can have frequencies up to billions of Hz).

The frequency of electromagnetic energy is a key factor in its interaction with living things. ELF fields, for instance, because of their long wavelengths do not couple well to organisms. Radiofrequency fields, on the other hand, have wavelengths on the order of centimeters and this allows for more efficient coupling and, at sufficiently high intensities, can heat tissues.

One of the most important characteristics of both electric and magnetic fields is that their strength diminishes as you move away from the source of the field. This is similar to the way that the heat from a candle or campfire will diminish as you move away. Although ordinary objects do not block magnetic fields, they can be shielded by using special materials and techniques. In contrast, intervening objects, especially those that conduct electricity, can block electric fields.

Investigation

Protocol

The investigation included the collection of information from the complaints, the inspection of the facilities and viewing of residences of the complainants, review of magnetic field measurements at residences of the complainants provided by Maritime Electric to the Commission, the characterization of existing and future EMF under different assumptions regarding current flow and distance from the transmission line by modeling, and a review and commentary on the documents submitted by the residents. This protocol was followed in the investigation described in the following section of the report.

Complaints from residents

The Costain letter recommends a "moratorium on all further construction of wind turbines and upgrades to the transmission lines and the eventual removal of the newly constructed lines on the Locke/Howlan Roads." Three statements support this request:

1. "We base our concerns on careful analysis of many recent research papers from around the world which suggest adverse health effects are probable to those exposed to intense electromagnetic fields (emf) for long periods of time."

2. "If the proposed upgrade is allowed to proceed a Maritime Electric official told us the emf level could reach 39 milligauss (mg.). Valid research tells us that when the level of exposure increases from 2mg to 4mg the risk of childhood leukemia doubles."

3. "Both The World Health Organization and The Canadian Environmental Protection Act advise when high voltage transmission lines are constructed adhering to "The Precautionary Principle" should be paramount. This suggests where there is possibility of harm all precautions be taken."

This investigation evaluates the evidence relating to these statements. Since the magnetic field is the focus of the residents' concerns and the Task Force assembled by the World Health Organization (WHO, 2007a) has concluded "that there are no substantive health issues related to ELF electric fields at levels generally encountered by members of the public," electric fields were not considered part of this investigation.

Inspection of transmission line and adjacent properties

On December 18 and 19, 2007, Dr. William Bailey met with Mark Lanigan of the Commission to obtain additional information about the residents' complaints and to view the transmission line and adjacent properties. In addition, Mr. Lanigan arranged for a meeting with Steve D. Loggie, Vice President of Customer Service and Ron LeBlanc, P.E., Manager of Production & Energy Supply at Maritime Electric. At this meeting, Dr. Bailey requested data about the construction, design, and operating conditions of the transmission line. Maritime Electric subsequently supplied these data, provided a file of EMF measurements taken at and around adjacent residences, and at Dr. Bailey's request provided measurements of the distance from the line to residences where EMF measurements had been taken.

The typical appearance of the transmission line is shown in Figure 1. The specifications for the transmission line are consistent with the Canadian Standards Association (CSA, 2007).

Figure 1. Photograph of transmission line.

Measurements of magnetic fields at residences

Among the residents who had expressed concerns about EMF, a large percentage had requested that Maritime Electric take measurements on their properties. The company took pre-construction measurements of magnetic fields at the property of one resident on March 8, 2007, another resident on March 12, 2007, and a third residence on April 11, 2007. In addition, measurements were made at 13 other properties including residences and St. Anthony's Church that were measured on April 5, 2007, before the transmission line was energized on April 12, 2007. Post-construction (Phase I) magnetic field measurements were taken again at these same

locations on November 1, 2007[3] and the loading on the transmission line was logged at the time of measurement.[4] The line's measured load was 19.1 MW, which will be discussed further in the following section.

Measurements of the total resultant rms magnetic field were made with a Swedish three-axis EnviroMentor AB, model "Field Finder" meter at various locations outside each residence. At each residence, measurements were taken under the transmission line, under a low voltage distribution line, in the yard, at the front step or door, and near the electrical service entrance to the residence, and some other locations. Indoor measurements were taken in multiple rooms and locations that varied at each residence.

The magnetic field levels near electrical service entrances were the highest measured, ranging from about 100 to 400 mG. Measurements at electrical service poles were lower than levels at electrical service entrances, but still higher than those at all other locations.

All but one of the 17 properties had measurements taken at the front step or door and, measurements at these locations were compared pre- and post-construction. Although the average post-construction measurements were higher than pre-construction measurements (0.57 mG, N=16 and 1.65 mG, N=16, respectively), the difference was almost statistically significant (t-test, p=0.054), i.e., greater than would be expected by chance alone. Measurements taken at the front step or door were similar to the indoor measurements at each residence.

Another analysis was performed that related the magnetic field levels measured at the front step or door post-construction to the distance of the residence from the center phase of the transmission line. These distances were not part of the original data file, but were provided at a later date to Exponent after the Commission relayed a request from Exponent to Maritime Electric for these data. Figure 2 shows that, as expected, the closer the residence is to the transmission line, the higher the spot measurement of magnetic fields at the front step or door and the larger the increase between pre- and post-construction measurements. Thus, the

[3] Measurements were also taken at one residence on August 10, 2007 and again on November 5, 2007.

[4] A few spot measurements of electric fields were also made at several residences, but the data were insufficient for analysis and, therefore, are not discussed further.

influence of the magnetic fields from the nearby transmission line is clearly evident in the post-construction measurements taken at the front door or step of homes closest to the transmission line. A similar, but much weaker, relationship between pre-construction measurements and distance reflects the magnetic field from distribution sources.

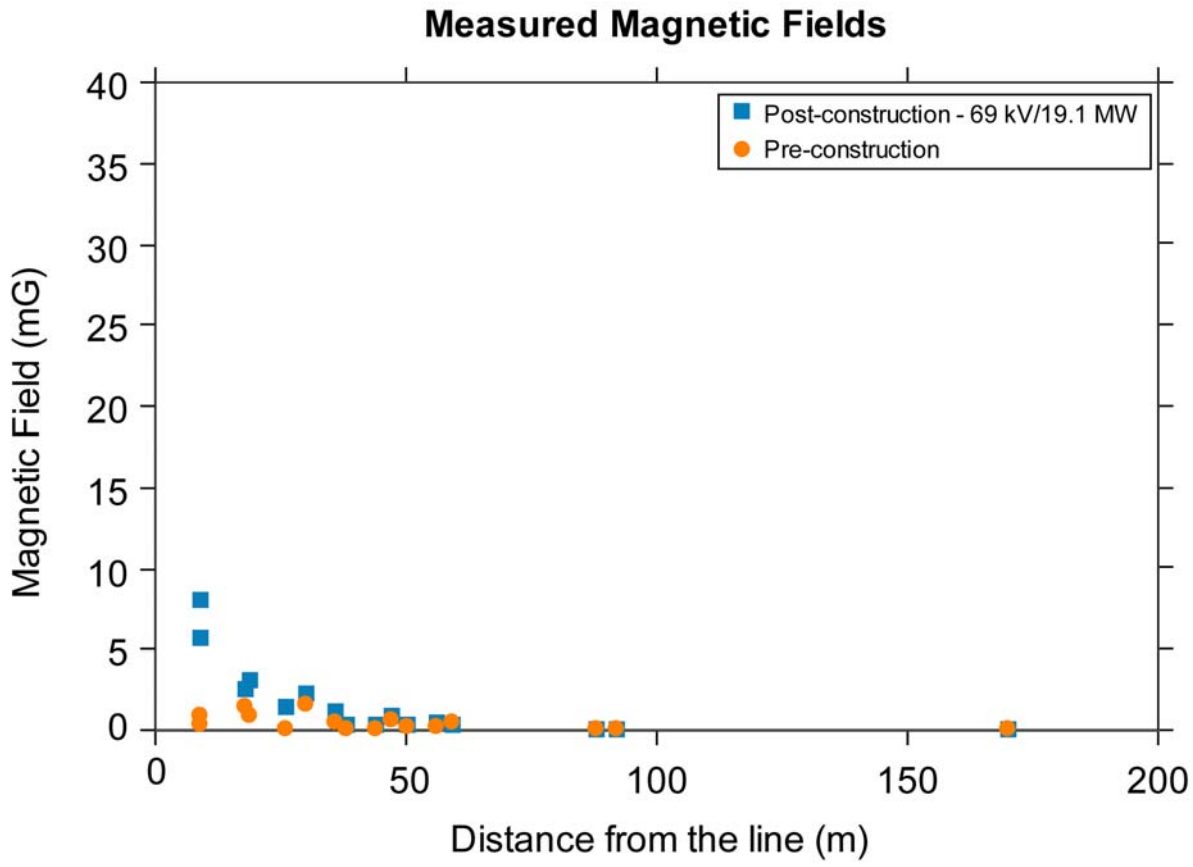

Figure 2. Magnetic field levels measured at front door/step of residences before (pre-construction), and after construction of transmission line (post-construction, Phase I). Measured loading of 19.1 MW on transmission line operating at 69 kV.

Drawing conclusions from these data is difficult because the current flow on the transmission line was provided only for the measurements taken after construction. It is also uncertain whether the pre- and post-construction readings were taken at exactly the same locations. Nevertheless, the measurements suggest that the line is a source of magnetic fields for the residences closest to the line, e.g., those within about 35 meters (m) of the centerline. To

provide a more accurate description of the effect of the transmission line on both electric and magnetic field levels as a function of distance, modeling of these fields was performed as described in the next section.

Modeling of existing and future EMF levels

Methods

Exponent engineers modeled the levels of EMF from the T27 transmission line as it is currently operated at 69 kV, and after conversion to operation at 138 kV in the future when the line will be known as the Y115 transmission line. The field levels were modeled using a computer program developed by the Bonneville Power Administration, an agency of the U.S. Department of Energy (BPA, 1991). This program has been shown to accurately predict EMF measured near power lines. The inputs to the program are data regarding voltage, current flow, phasing, and conductor configurations. The fields associated with power lines were estimated along profiles perpendicular to the overhead line at the point of lowest conductor sag (i.e., closest to the ground). All calculations were referenced to a height of 1 m above ground according to standard practice (IEEE-644, 1994). The program assumed balanced currents on phases, horizontal conductors, and flat terrain. The electric field from the overhead conductors was also calculated at the point of lowest conductor sag, at a voltage assumed to be 5% above nominal values. This 5% increase accounts for situations where the operating voltage may be slightly higher than nominal values. At Exponent's request, Mr. Lanigan obtained the input data for these calculations from Maritime Electric.

The current flow on this transmission line is not constant because the load is supplied from wind-powered generators. The higher and more constant the wind speed, the greater the current flow; conversely, the lower and less constant the wind speed, the lower the current flow. Hence, the loading on this line will fluctuate by hour and season over a wider range than a line supplied by a fossil fuel generator plant. Magnetic fields were modeled at the effective annual average load levels shown in Table 1.

Table 1 Summary of Loadings Assumed on Transmission Line for Magnetic Field Modeling

	Voltage (kV)	Installed Capacity (MW)	Annual Average Load Factor (%)	Effective Loading (MW)	Comment
Phase I	69	20	40	8	Current annual average line loading
	69	20	100	20	Maximum short-term output for installed capacity
Phase II	138	100[5]	40	40	Future annual average line loading
	138	100[5]	100	100[5]	Maximum short-term output for installed capacity

The loading in megawatts (MW) most relevant to long-term exposure is not the maximum possible load, but rather the average annual load, which based on historical data, corresponds to about 40% of installed capacity. This load factor accurately describes the range of most hours of the year because the times of maximum output of the generators (highest winds) and minimum output of the generators (lowest winds) are infrequent. At present, the effective average load is 8 MW.

On the day that Maritime Electric took post-construction measurements (November 1, 2007), the line's measured load was 19.1 MW, very close to the 20 MW maximum. On November 1, 2008, the installed capacity is planned to increase to 99 MW (rounded here for calculations to 100 MW), so the effective annual average load would rise close to 40 MW.

Modeling of pre- and post-construction field levels

Electric Field. The calculated electric fields associated with the transmission line under Phase I and Phase II operating conditions are compared in Figure 3. Figure 3 demonstrates that,

[5] Actual value is 99 MW. Value rounded to 100 MW for calculation.

as expected, the electric field levels are highest under the conductors, diminish with increasing distance from the centerline, and will be higher when the operating voltage increases from 69 to 138 kV. Since electric fields are not affected by changes in current flow, these electric field levels will be essentially constant at each voltage level.

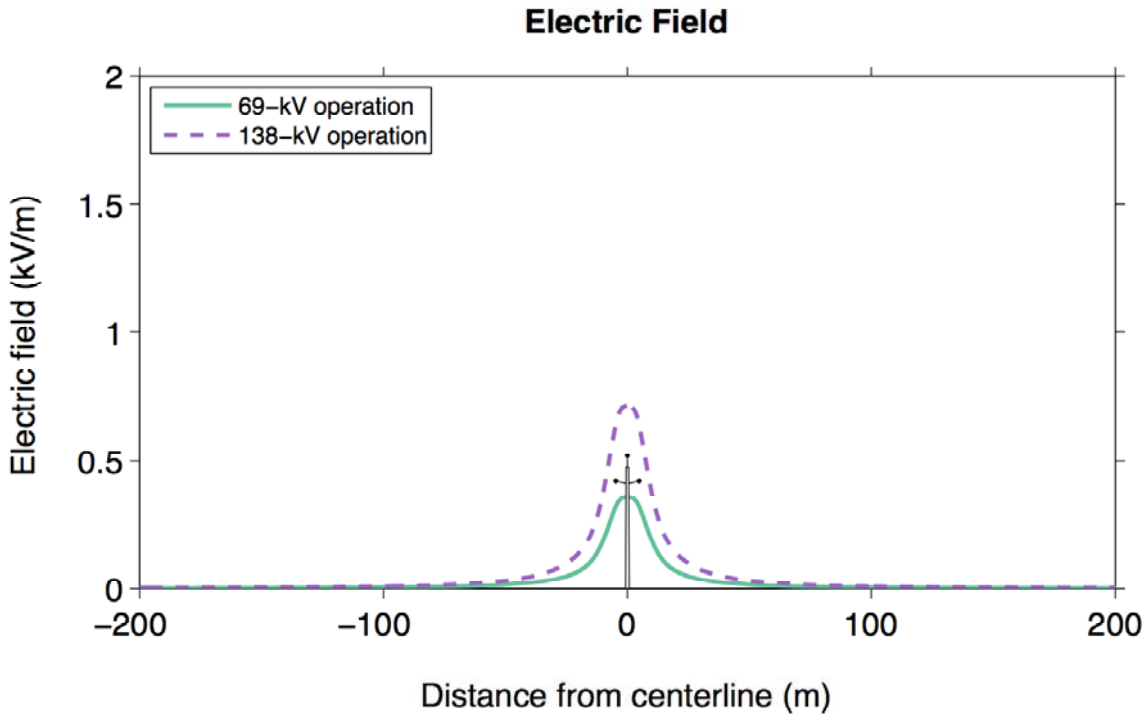

Figure 3. Profile of calculated electric field perpendicular to the transmission line operating at 69 kV (post-construction, Phase I), and 138 kV (future, Phase II).

Magnetic Field. To illustrate the agreement between measured and calculated magnetic field levels, the measured values shown in Figure 2 were plotted along with calculated magnetic field levels at a load level of 20 MW in Figure 4. This load is comparable to the 19.1 MW load measured on the line when post-construction measurements were taken. As seen in Figure 4, there is reasonable agreement between the measured and calculated magnetic field levels of 19.1 MW and 20 MW, respectively.

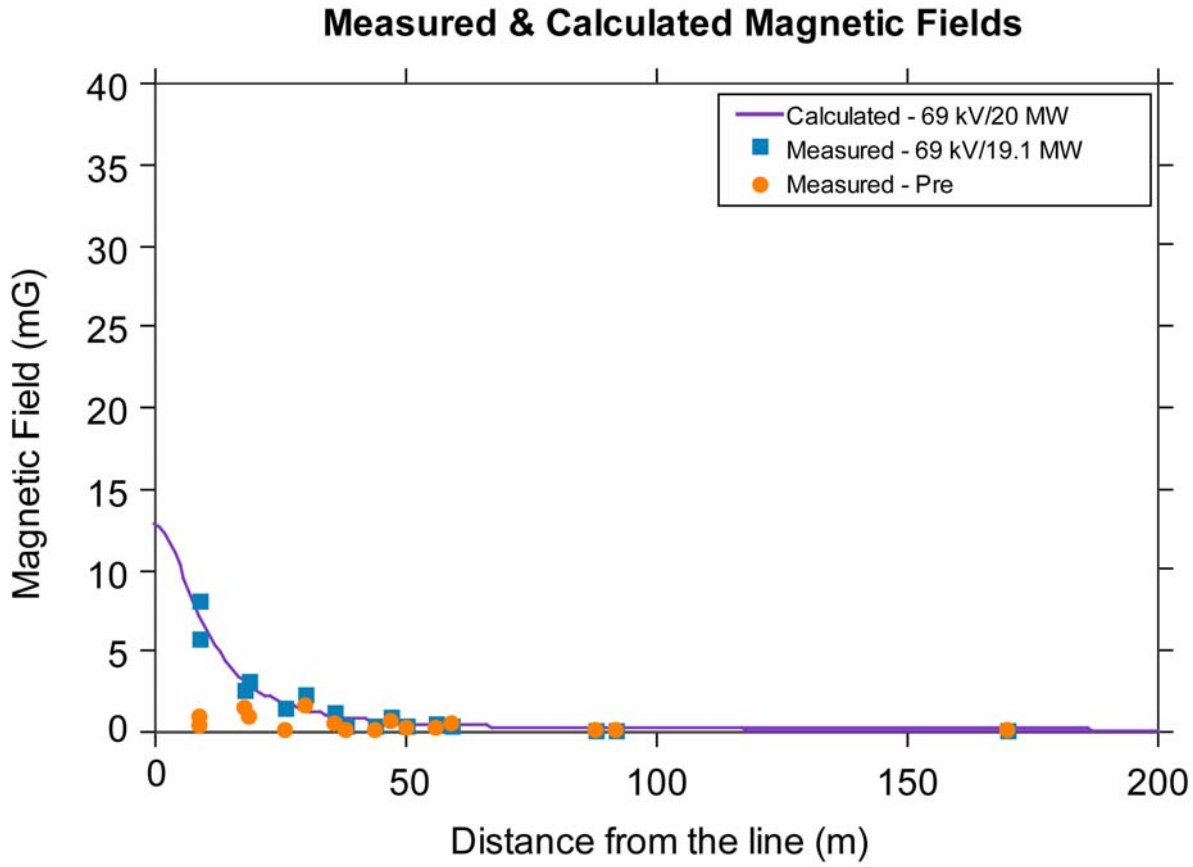

Figure 4. Magnetic field levels measured at front door/step of residences pre- and post-construction (Phase I). A load of 19.1 MW was measured on the 69 kV line at time of post-construction measurements. Also shown is the calculated magnetic field profile for the 69 kV line carrying 20 MW (current maximum loading).

A comparison of the magnetic fields associated with average (8 and 40 MW, respectively) and maximum (20 and 100 MW, respectively) post-construction loading assumptions for operation at 69 kV and 138 kV is shown in Figure 5. As expected, the magnetic field increases in proportion to the loading increases from average to maximum operation at 69 kV. In Phase II, the wind-farm capacity will increase to approximately 100 MW and the voltage on the line will increase to 138 kV.

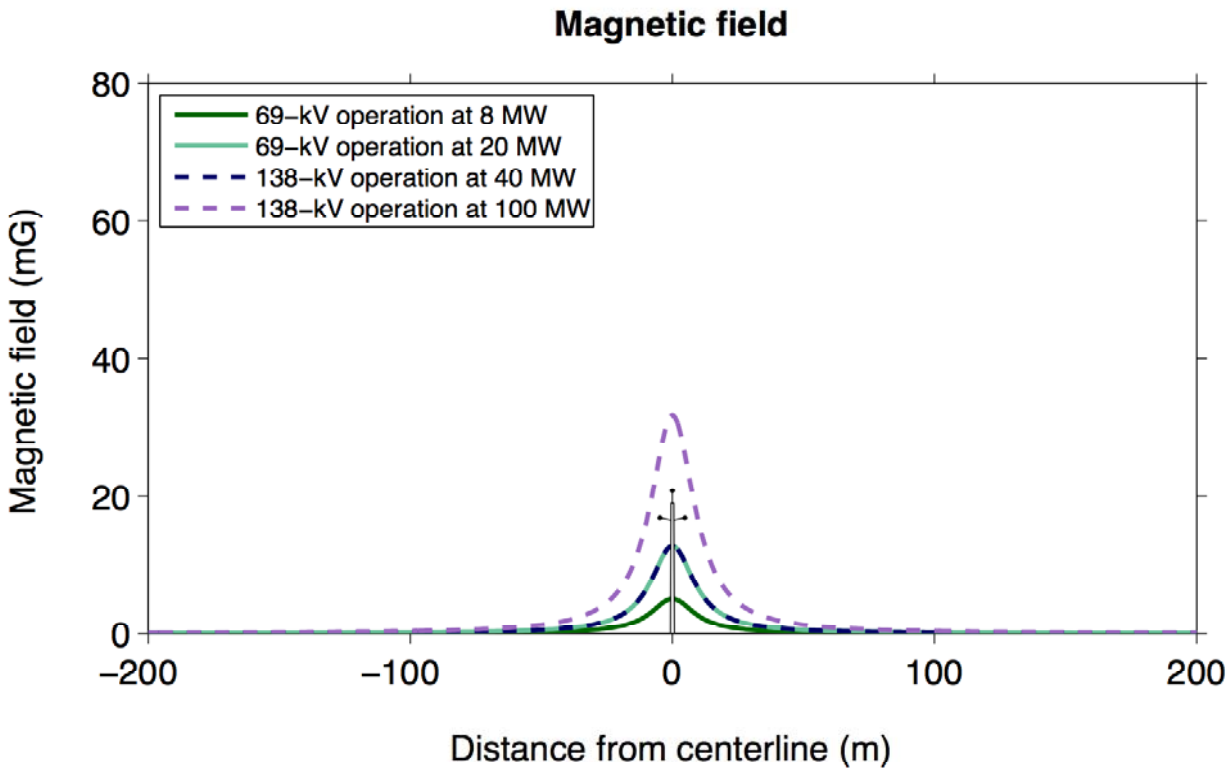

Figure 5. Profiles of calculated magnetic field perpendicular to the transmission line operating at 69 kV with loadings of 8 and 20 MW (Phase I), and operating at 138 kV with loadings of 40 MW and 100 MW (Phase II). Note profile for 69-kV operation with 20 MW load is the same for 138-kV operation with a 40 MW load.

In Figure 5, the magnetic field profile that best describes the typical levels expected during Phase I operation is the dark green colored profile (69-kV operation at 8 MW). For Phase II operation, the dark blue dashed profile (138-kV operation at 40 MW) indicates typical annual average magnetic field values. Thus, under either 69-kV or 138-kV operation, annual average magnetic field values would be similar to or lower than values measured at residences on November 7, 2007, subject of course to variations in wind conditions. The calculated field values for Phase 1 and Phase 2 operations are within the range of expected values for a transmission line of this voltage, with levels below 1 mG within approximately 21 m of the transmission line at average loading conditions at 69 kV and 35 m at average loading conditions at 138 kV.

Note that the magnetic field profiles associated with 69-kV operation (at 20 MW capacity) and 138-kV operation (at 40 MW capacity) are the same, despite the different wind-generation capacities and associated loadings. The product of current times voltage determines the power transfer capacity of a power line. The transmission line currents at 20 MW and 40 MW generate magnetic fields of the same strength because the higher voltage on the 138-kV line delivers twice the power at the same current. Thus, supplying the same amount of power at 138 kV, rather than 69 kV, results in a lower magnetic field in the vicinity of the conductors.

This relationship is illustrated in Figure 6. This figure shows the magnetic field at the closest residence for annual average loading up to 8 MW (69-kV operation) and up to 40 MW (138-kV operation). The dashed line represents the magnetic field levels that would be produced by the transmission line if it continued to be operated at 69 kV after the new wind farm capacity is added in November 2008.

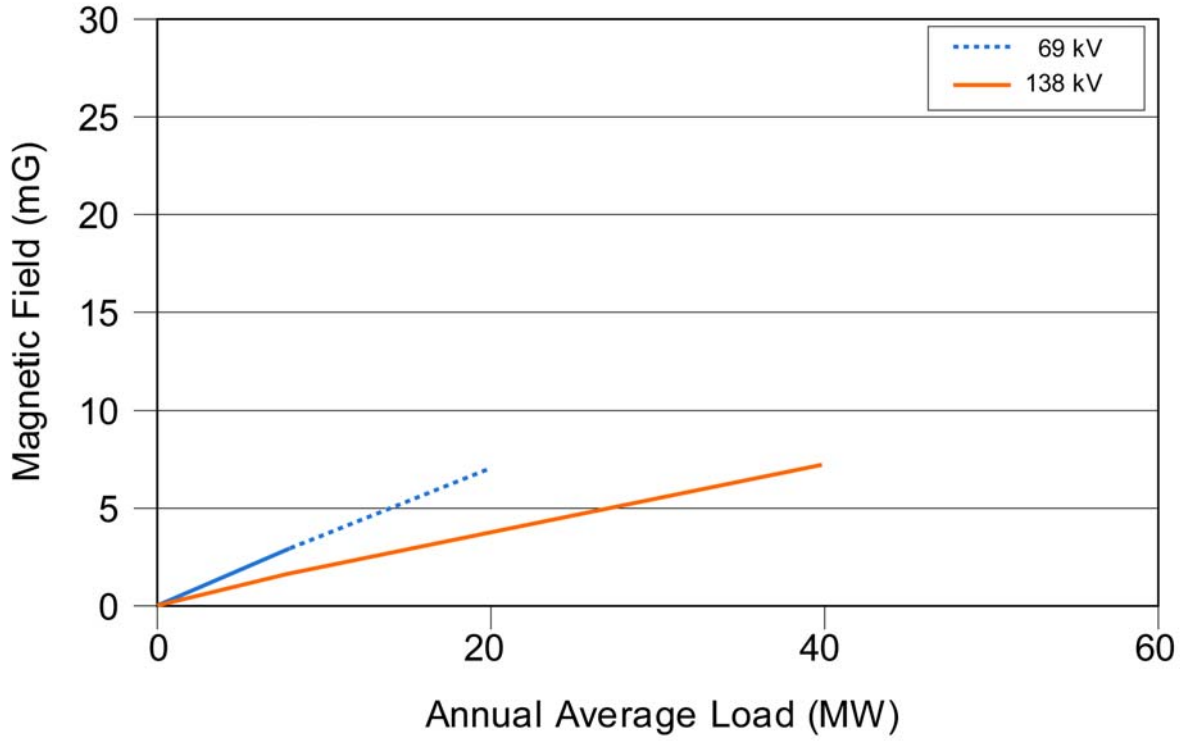

Figure 6. Calculated magnetic field level at the closest residence up to annual average load levels for operation at 69 kV (8 MW) and 138 kV (40 MW). The dashed line represents the magnetic field level that would be produced by the line if it were not converted to 138 kV in the future.

Documents submitted regarding potential health effects of EMF

Documents from private citizens

Two letters from private citizens and a print out of a presentation were submitted to the Commission. In both letters, the senders attached the spot readings of EMF taken by Maritime Electric on their property in April and November 2007. Below is a summary of the issues raised in each letter and a commentary.

1. In documentation from John Gallant, two post-construction measurements, apart from the service entrance and mast measurements, were greater than 12 mG, under the 69 kV line in the middle of the yard (12.3 mG) and by a pole from the 69 kV line (12.2 mG). Another measurement in the middle of the yard was 2.1 mG, and the remaining seven measurements (two outside the house and five inside the house) were less than 1 mG. Mr. Gallant raises two issues in his letters. He states, "It was ridiculous to see Maritime Electric take measurements by placed [sic] the meter on the service entrance and mast. Less than 2 ½ feet away the level was zero."

Regarding the transmission line as a source of magnetic fields, the post-construction measurements of magnetic fields taken indoors at this residence, which are more indicative of potential long-term exposures, ranged from no increase to a high of 0.3 mG over pre-construction values (Maritime Electric measurements).

2. In the letter from Gordon Ramsey, he noted that three post-construction measurements at his residence, apart from the service entrance and mast, were greater than 11 mG (under a pole from the 69 kV transmission line (12.7 mG), in the middle of the driveway (11.7 mG), and in the driveway under the 69 kV transmission line (14.3 mG)). The measurement by the house number sign was 3.1 mG. The remaining 10 measurements (5 inside and 5 outside) were less than 1 mG. Mr. Ramsey stated, "The 99th percentile for general Public was 6.16 mg [unknown value or source] whereas my front yard is 11.7, 12.7, & 14.3 mg… Our families are exposed for 24 hr a day 365 days a year."

The 6.16 mG measurement is not found in the measurements attached to Mr. Ramsay's letter but likely represents an average level over a long period of time such as a 24-hour period, but is compared to spot measurements taken in the yard. Mr. Ramsey's argument is limited because it is unlikely that individuals in his family are in the same location in the front yard at all times, and 10 other spot measurements taken on his property were all less than 2 mG. In addition, according to Maritime Electric's measurements taken post-construction, the magnetic field levels within his residence were all 0.2 mG or less.

With respect to average exposure to EMF, it is worth noting that considering EMF from the perspective of specific sources or environments (e.g., field from a transmission line) does not fully reflect the variations in an individual's personal exposure as encountered in everyday life. A person going to the post office, visiting the library, walking along the street, getting ice cream, browsing in a bicycle shop, stopping in a sweet shop, going to the bank ATM, driving along streets, shopping in a supermarket, stopping for gas, and eating at a fast food restaurant, for example, might encounter an average magnetic field of 4-5 mG, with peak values over 90 mG (unpublished measurements). These observations show that, from moment to moment in everyday life, individuals encounter magnetic fields with varying intensity over a wide range. Incidental exposure even to very high magnetic field levels at locations where a person spends a brief period of time contributes little to their long-term average magnetic field exposure. Although no national or international scientific or health agency has determined that values of magnetic fields encountered in daily environments pose health risks (see section below), these agencies have been interested in why in a number of surveys of children with leukemia were more frequently classified as having time averaged exposures > 4 mG than children in the control group (e.g., IARC, 2002).

3. The document entitled "Howlan Residents Demand Electrosmog Free Properties" was a presentation to the general public at Hernewood Intermediate School given by an unknown person on March 1, 2007. This documentation is similar to the media and Internet postings described below, in that the presentation does not provide a comprehensive review of the scientific evidence nor has the content been peer reviewed. The presentation discusses exposure from the line, but also presents selective and misleading information about EMF heath research that has been excerpted from advocate Internet sites. In this regard, the caution from the World Health Organization (WHO) in 2005 is appropriate:

> Science is a powerful tool and has earned its credibility by being predictive. However, its usefulness depends on the quality of the data, which is related to the quality and credibility of the scientists. It is important to verify the knowledge and integrity of so called "experts", who may look and sound extremely convincing but hold unorthodox views that the media feel justified in airing "in the interests of balance". In fact giving weight to these unorthodox views can disproportionately influence public opinion. For the public, often the best sources of information are from panels of independent experts who periodically provide summaries of the current state of knowledge (WHO, 2005, pp. 3738).

Media and Internet postings

Six media and Internet postings were submitted as evidence regarding the possible health effects of EMF.

1. "Call to cut magnetic field exposure in home" is a lay article presented in the "News in Science" section of the online Australian Broadcasting site (Salleh, 2007). It describes what Australian authorities will be doing, but not yet have done. The article comments, "Australian authorities will advise the public on how to reduce their exposure to electromagnetic fields from common household appliances... ." But, the article indicates that the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) does not plan to set lower exposure limits than those recommended by the International Commission on Non-Ionizing Radiation Protection (ICNIRP), a position supported by the WHO.

2. A press report transcript of testimony by a lay journalist Paul Brodeur on behalf of an EMF citizen-activist group, People Organized for Wise Energy Representation (POWER), to the National Resources Committee of the Nebraska State legislature was among the documents submitted by residents (Wave Guide, 1995). This testimony focuses on specific health outcomes, particularly childhood leukemia. Mr. Brodeur's outdated testimony relies heavily on studies of children living near sources of magnetic fields. He also emphasizes the number of studies with significant findings, but fails to present details regarding the methodology, and thus any potential limitations, of each study. His testimony is neither peer-reviewed nor provides a weight-of-evidence review of the scientific literature.

3. In a *Micro Wave News* article, "The case for EMF precautionary policies," a journalist discusses eight reasons that stricter exposures have not been adopted and presents a case for why each one of these reasons is wrong (MWN, 2004). In support of the arguments for why these reasons are wrong, the author cites a limited number of sources and does not present a comprehensive review of the evidence.

4. A press release was submitted from World-Wire (World-Wire, 2007). World-Wire is an on-line source for pay-for-submission press releases from "environmentally relevant organizations and corporations." Press releases are posted on-line and transmitted to Environment News Service subscribers. The press release provided brief comments on a small portion of the BioInitiative report and did not provide detailed scientific evidence. The BioInitiative report, which was also submitted by the residents, is discussed further below.

5. The document, "Government responds to Ventus Energy Comments," contained no comments regarding the potential health effects of EMF (GN&L, 2006).

6. The residents also submitted a polemical interpretation of the Draper et al. (2005) study issued as a press release on the Internet by a scientist who was not part of the research team. This press release provides only a select overview of the results of this study. It does not provide a comprehensive overview of the methodology and limitations of the study. Limitations regarding the methodology are discussed in the WHO (2007b) weight-of-evidence review, and include the dependence of the results on the chosen control group and that the study used distance from power lines, which is known to be a poor predictor of magnetic field exposure, as an exposure assessment. The authors of the Draper et al. study themselves caution that the magnetic field does not appear to be the basis for the reported association of leukemia with distance. They wrote,

> Our increased risk seems to extend to at least 200 m, and at that distance typical calculated fields from power lines are < 0.1 µT [1 mG], and often < 0.01 µT [0.1 mG] — that is, less than the average fields in homes from other sources. Thus our results do not seem to be compatible with the existing data on the relation between magnetic fields and risk (Draper et al., 2005, p. 3).

Altogether, these postings provide no evidence for making scientific or policy decisions because the content has not been written by scientists with expertise in this field or peer reviewed by other scientists. Publications considered in a health risk assessment are routinely required to have been evaluated by other scientists in the field before being evaluated by scientific and

health agencies (e.g., IARC, 2002; WHO, 2007b). None of the documents submitted provide reliable scientific evidence for the possible adverse health effects associated with EMF. Rather, the submitted documents are opinion pieces written by media and others with the pre-existing opinion that EMF are harmful to health.

Journal articles and reports

One review article was submitted.

1. The article by Magda Havas (2000), an environmental scientist, compares reviews of the scientific literature by the U.S. National Academy of Sciences (NAS) (NRC, 1997) and by the National Institute for Environmental Health Sciences (NIEHS) (NIEHS, 1998). These reviews were performed by panels of scientists assembled by these agencies to review and evaluate the strength and limitations of peer-reviewed research studies (i.e., evaluate the weight-of-evidence) published on EMF up to approximately 1996 and 1998, respectively. Dr. Havas commented on the process involved in preparation of these reports, the consensus of the scientific panels, and what she believes are the flaws of these reviews and the scientific method in general. The report provides a brief summary of the research related to EMF and possible effects on cancer, reproduction, depression, Alzheimer's disease, and electromagnetic sensitivity. Dr. Havas also adds her own thoughts about higher frequency EMF, biomagnetism, and magnetobiology, which are not relevant to an assessment of the effect of ELF EMF on health, as described above.

Dr. Havas disagrees with the conclusions of the reviews performed for the NAS and the NIEHS. She contends that the conclusions are inaccurate because they do not consider the full range of relevant topics: "The evidence is considerably stronger than appears in this evaluation if a much broader literature is examined." The "broader literature" to which Dr. Havas refers includes the beneficial effects of EMF on bone repair, the ability of different species to perceive EMF, and the evaluation of health effects of higher frequency EMF. None of these topics are relevant to a scientific evaluation of the possible effects of power frequency fields on health. Dr. Havas also expresses the opinion that mechanistic and animal research was given too much weight in the overall evaluations. Her conclusions are at odds with the evaluations conducted

by scientific panels (such as those organized by the NAS and NIEHS), which were balanced, objective and considered the full range of relevant research. Overall, most of the conclusions and recommendations that Dr. Havas makes are not adequately supported with citations or supporting analyses, which suggests that they are not founded on scientific inference but, instead, reflect her opinions.

Unpublished reports

Four unpublished reports varying in length from one page to several hundred pages were submitted. As with the media and Internet postings, these documents have not been published by scientific or health agencies and have been peer-reviewed only partially or not at all.

1. A report from the BioInitiative working group was posted on an Internet website in August of 2007 (Sage, 2007). A private advocate, Ms. Cindy Sage, convened the contributors to the report. Ms. Sage is not a health scientist as would be recognized by any scientific authority. She assembled 14 individuals from academic institutions and public interest groups to submit documents for posting. The report is a collection of sections on various topics each authored by one to three persons from the working group. Six individuals, who represent academic institutions, private consulting, and lay press news sources, reviewed only parts of the report.

One key limitation of the approach taken in the BioInitiative report is that research studies vary greatly in their design and quality. Valid scientific conclusions are based on weight-of-evidence reviews, which entail a systematic evaluation of the entire body of scientific evidence in three areas of research (i.e., epidemiology, *in vivo* research and *in vitro* research) by a panel of experts in these relevant disciplines. In contrast, the conclusions in the BioInitiative report deviate substantially from those of reputable scientific organizations because they were not based on standard, scientific methods. The policy responses proposed in the report are cast as consistent with the precautionary principle, i.e., taking action in situations of scientific uncertainty before there is strong proof of harm. A central tenet of the precautionary principle, however, is that precautionary recommendations are proportional to the perceived level of risk and that this perception is founded largely on the weight of the available scientific evidence. The

BioInitiative report recommends precautionary measures on the basis of argument, rather than sound peer-reviewed scientific evidence.

2. A student prepared a review of international guidelines and legislation related to extremely low frequency (ELF) EMF exposure for a citizen's group opposing a transmission line in British Columbia (Wu, 2005). In this document, the author emphasizes the need for eliminating unnecessary exposure, but does not provide a definition for unnecessary exposure. The author focuses on situations in which countries have made recommendations, in addition to implementing exposure guidelines established by ICNIRP and the International Committee on Electromagnetic Safety (ICES). In this student's review, those countries are considered to be taking actions consistent with the precautionary principle. But based on comprehensive review of the scientific evidence, the WHO (WHO, 2007b) and other health agencies have not concluded that there is a scientific basis for exposure limits below those recommended by ICNIRP (1998) and ICES (2002).

3. In 2006, a group of scientists met and posted on the Internet a document termed the "Benevento Resolution." This document is a summary of seven resolutions by the Precautionary EMF Approach: Rationale, Legislation and Implementation group. Similar to the BioInitiative report, these resolutions state they are based upon the precautionary principle. This document does not provide a comprehensive review of the scientific evidence and even comments in the first resolution, "What is needed, but not yet realized, is a comprehensive, independent and transparent examination of the evidence pointing to this emerging, potential public health issue." The WHO's weight-of-evidence review published in 2007 provides a comprehensive, independent and transparent examination, but does not recommend setting ELF EMF standards below those recommended by the ICNIRP and ICES.

4. The paper posted on the Internet by Neil Cherry, a politician and weather scientist, "Evidence that electromagnetic fields from high voltage powerlines and in buildings, are hazardous to human health, especially to young children" (Cherry, 2001), is not peer-reviewed and represents a selective compilation of studies to support his conclusions. He provides no basis in public health practice to support his recommendations regarding desirable levels of magnetic fields in homes, schools, and workplaces.

Public health agency documents

Only one document from a public health agency was submitted.

1. A "Framework for developing health-based EMF standards" was developed by the WHO in 2006 because "[l]arge disparities between national limits and international guidelines can foster confusion for regulators and policy makers and increase public anxiety." This Framework addresses how to develop science-based quantitative EMF exposure limits. It is intended for national advisory and regulatory bodies that either are developing new standards for EMF or are reviewing the basis of their existing standards.

This report provides a description of the process by which public health agencies evaluate scientific evidence and develop standards for EMF. The results of the WHO's own review and evaluation of the scientific evidence are contained in the 2007 report "Extremely Low Frequency Fields. Environmental Health Criteria, Vol. 238," which are discussed in a later section.

Legal documents

Two legal or legal-related documents were submitted as evidence against power lines.

The Didow v. Alberta Power Ltd (1988) case concerned trespass from overhanging cross-arms. The other legal submission concerned effects of widening an easement and construction of a steel tower on property value (Lansink, 2005). Neither of these documents address or provide evidence for evaluating the possible health effects associated with EMF.

Scientific Assessment of EMF Research

Since the late 1970s, scientists have been studying whether long-term exposure to 60-Hz magnetic fields at levels below those known to cause neurostimulatory effects in the laboratory could cause long-term adverse health effects. The first group of studies looked at childhood cancer, and over time hundreds of epidemiologic[6] studies have been conducted on a variety of health outcomes, including adult leukemia, lymphoma, brain cancer, breast cancer, cardiovascular disease, neurodegenerative diseases, and miscarriage. Some of these studies looked for statistical associations[7] of these diseases with magnetic fields produced by nearby power lines (estimated through calculations or distance), while other studies actually measured personal magnetic field exposures from all magnetic field sources. In addition to these epidemiologic studies, experimental studies were conducted in the laboratory to examine whether high magnetic field exposures caused any long-term health effects in animals (*in vivo*) or on the normal functioning of cells and tissues (*in vitro*). Thus, there is a large and high quality body of research from which conclusions can be drawn on the possible long-term adverse health effects of magnetic field exposure.

The standard process of evaluating a body of research to understand the potential health implications of exposure is referred to as health risk assessment.[8] A health risk assessment consists of several, sequential steps. The process starts with systematically evaluating the body of research and identifying any possible risks associated with an exposure (**hazard identification**). A follow-up question to hazard identification is, "if the exposure does cause any health risks, at what level do they occur?" (**dose-response assessment**). A risk assessment then characterizes the exposure circumstances of the situation under analysis (**exposure**

[6] Epidemiology is the study of the distribution and determinants (or causes) of disease. Epidemiologic studies observe people going about their ordinary lives, estimate their exposures, and correlate these exposures with diseases that the study subjects have or later develop.

[7] One quantitative result of an epidemiologic study is a measure of the statistical association between the disease and the exposure being studied. In general, statistical associations compare the estimated risk of disease among exposed persons to the risk of disease among unexposed persons as a ratio. A ratio of 1.0 means that the estimated risk is the same in both groups, and a ratio greater than 1.0 indicates a positive association between the disease and the exposure.

[8] Some of the scientific panels that have considered EMF have described the risk assessment process in the introductory sections of their reviews or in separate publications (ICNIRP, 2002; IARC, 2006; SCENIHR, 2007; SSI, 2007; WHO, 2007).

assessment). For example, in this report, we consider the magnetic fields associated with a transmission line operating at 69 kV and 138 kV. Finally, using the findings from the hazard identification and dose-response assessment as a basis to evaluate the projected exposures, a summary evaluation is provided (**risk characterization**).

In this health risk assessment, the first two steps have been conducted by panels of scientists organized by scientific agencies around the world, as discussed in the next section. Calculations of the electric and magnetic fields expected at varying distances from the transmission line have been performed and were briefly summarized earlier in this report. The conclusions of these scientific reviews and the exposure assessment are the basis for the risk characterization and the final evaluation provided at the end of this report.

Hazard identification begins with a systematic review of published, peer-reviewed scientific research in three disciplines: epidemiology, animal studies (*in vivo*), and studies in cells and tissues (*in vitro*). Studies are not equal – they vary widely in terms of the sophistication and validity of their methods. Therefore, each study from each discipline must be critically evaluated. A final conclusion is then reached by considering the cumulative weight of the evidence individually within each area of research and then collectively from all three disciplines (epidemiology, *in vivo* studies and *in vitro* studies).

Risk assessment requires that each type of research study be carefully evaluated since each provides a distinct and valuable piece of information; it is only when the entire body of research is evaluated together, however, that conclusions can be generated. Epidemiologic investigations enroll people into studies and measure their exposures as they go about their daily routines to determine whether people with specific exposures develop diseases more often than those without the exposure, or whether people with a certain disease have a history of a selected exposure more often than people without that disease. Since epidemiologists do not have control over the many other factors to which people are exposed (e.g., diet, pollution, infections, etc.) and diseases are caused by the complex interaction of many factors, the results of epidemiologic studies must be interpreted carefully. A single epidemiologic study is rarely unequivocally supportive or non-supportive of causation; rather, weight is assigned to the study based on the validity of its methods. Epidemiologic support for causality is based on high-

quality studies reporting consistent results in a dose-response fashion across many different populations and study designs.

Scientists also consider experimental studies in animals and in cells and tissues because of the inherent weaknesses of observational epidemiology. *In vivo* studies expose laboratory animals to very high levels of a chemical or physical agent to determine whether exposed animals develop cancer at higher rates than unexposed animals, while tightly controlling for all other factors that could possibly affect disease rates (e.g., diet, genetics, etc.). *In vitro* studies are also important because they study how the exposure (e.g., magnetic fields) could initiate the disease process at the cellular level. Thus, the risk assessment process requires support from several types of questions. First, does the exposure cause a response in cells or tissues that could lead to a disease process? Second, do we observe this process in highly-controlled experimental studies of animals? And, finally, do we observe that people with the exposure have higher rates of the disease? It is the comprehensive consideration of these questions that leads to a valid risk assessment.

The conclusion of a health risk assessment typically includes some uncertainty, and cannot be a definitive statement of no risk. Scientific research cannot prove the absence of a health risk; rather, the science evolves toward a conclusion that the cumulative body of research does not support a cause-and-effect relationship. At different points in the evolution of the research, different questions remain unanswered and, in many cases, unconfirmed.

Reviews by National and International Scientific and Health Agencies

Since exposure to magnetic fields is ubiquitous and questions about potential health risks have been raised by some studies, major scientific organizations throughout the world have appointed panels of experts to carefully review the body of available research and offer conclusions on the status of the science. This section describes the scientific organizations and health agencies that have assembled independent panels of experts reflecting the full diversity of research experience required to conduct valid weight-of-evidence reviews.

In Canada, the **Federal Provincial Territorial Radiation Protection Committee (FPTRPC)** operates under the auspices of the Canadian Nuclear Safety Commission, **Health Canada** and the divisions responsible for non-ionizing radiation protection within the Provinces and Territories. Within the FPTRPC, a Working Group with expertise in ELF EMF was assembled. The mandate of this 7-person Working Group is to carry out periodic reviews of the literature and recommend appropriate actions. In addition, Health Canada's own scientists have long been active in reviewing and performing research relating to EMF.

In the United States (US), the government mandated the formation of a program for research on EMF in 1992, in response to public concern about the safety of magnetic fields. This program was referred to as the EMF RAPID Program and included more than 100 animal and laboratory studies. At the conclusion of the RAPID program in 1998, the **NIEHS** assembled a 30-person Working Group to review the cumulative body of epidemiologic and experimental data and provide conclusions and recommendations to the US government (NIEHS, 1998, 1999).

Several international, scientific organizations have conducted thorough evaluations of the research on EMF; the **IARC** completed a full carcinogenic evaluation of magnetic fields in 2002 and the **ICNIRP**[9] published a report in 2003. The **WHO** released a review in June 2007 as part of its International EMF Program, established in 1996 to assess the scientific evidence of possible health effects of EMF in the frequency range from 0 to 300 GHz.

[9] ICNIRP is the formally recognized organization for providing guidance on the safety of non-ionizing radiation for the **WHO**.

In Europe, the **Scientific Committee on Emerging and Newly Identified Health Risks (SCENIHR)** issued a report in March 2007 updating previous conclusions (SSC, 1998; CSTEE, 2001) to the Health Directorate of the European Commission. National scientific organizations in Europe have also assembled panels: the **National Radiological Protection Board** (**NRPB**)[10] of the United Kingdom issued full evaluations of the research in 1992, 2001 and 2004, with supplemental updates (1993, 1994a) and topic-specific reports (1994b; 2001b; HPA, 2006) published in the interim; the **Health Council of the Netherlands** (**HCN**) evaluated the cumulative body of research in 1992, followed by updates in 2000, 2001, 2004 and 2005; and, finally, in 2007 the **Swedish Radiation Protection Authority (SSI)**, using other major scientific reviews as a starting point, evaluated recent studies in consecutive annual reports beginning in 2003.

The conclusions of these reviews are used as the basis in this assessment for summarizing the current state of the science, given that these panels consisted of individuals with extensive experience in the relevant areas and were organized by nationally and internationally recognized scientific agencies. While both electric and magnetic fields are the subject of the aforementioned reviews, only magnetic fields are considered in this report, since magnetic fields are the main focus of the residents' complaint about the transmission line.

Summary of review panels' conclusions

Overall, the conclusions of the aforementioned scientific review panels have been consistent. None of the panels concluded that magnetic fields are a known or likely cause of any long-term adverse health effect and, as a result, no standards or guidelines have been recommended for magnetic fields at the strengths normally encountered in our environment. Most of the uncertainty and controversy surrounding magnetic fields is related to the research on childhood leukemia. Some epidemiologic studies reported that children with leukemia were more likely to live closer to power lines or have higher estimates of magnetic field exposure, compared to children without leukemia; other epidemiologic studies did not report this statistical association.

[10] The NRPB merged with the **Health Protection Agency (HPA)** in April 2005 to form its new Radiation Protection Division.

When all of the relevant studies were combined in a single analysis, a weak association was reported between childhood leukemia and estimates of average magnetic field exposures greater than 3-4 mG (Ahlbom et al., 2000; Greenland et al., 2000). These calculations, referred to as pooled analyses, provide some evidence for an association between magnetic fields and childhood leukemia; however, because of the inherent uncertainty associated with observational epidemiologic studies, the results of these pooled analyses were not considered to provide strong epidemiologic support for a causal relationship. Further, *in vivo* studies have not found that magnetic fields induce or promote cancer in animals exposed under highly controlled conditions for their entire lifespan, nor have *in vitro* studies found a cellular mechanism by which magnetic fields could induce carcinogenesis.

Considering all the evidence together, panels issuing conclusions following the publication of the pooled analyses characterized magnetic fields as a *possible* cause of childhood leukemia (NRPB, 2001a; IARC, 2002; ICNIRP, 2003; HCN, 2004). The term "*possible*" denotes an exposure in which epidemiologic evidence points to a statistical association, but other explanations cannot be ruled out as the cause of that statistical association (e.g., bias and confounding)[11] and experimental evidence does not support a cause-and-effect relationship.

Recent evaluations of the latest research have concluded that the classification of "possible carcinogen" remains accurate (SCENIHR, 2007; SSI, 2007; WHO, 2007). These recent reviews have stressed the importance of reconciling the epidemiologic data on childhood leukemia and the negative (i.e., no hazard) experimental findings through innovative research. Just like any other cancer, researchers believe that the development of childhood leukemia is influenced by a multitude of different factors, including genetics, environmental exposures, and infectious agents.

Both the IARC and ICNIRP concluded that the epidemiologic evidence does not support a cause-and-effect relationship between magnetic fields and adult leukemia/lymphoma or brain cancer; recent studies have not altered that conclusion (SCENIHR, 2007; WHO, 2007). Breast

[11] Bias refers to any systematic error in the design, implementation or analysis of a study that results in a mistaken estimate of an exposure's effect on the risk of disease. A confounder is something that is related to both the disease under study and the exposure of interest such that we cannot be sure what causes the observed association - the confounder or the exposure of interest.

cancer has received attention because of some initial epidemiologic and experimental findings suggesting that magnetic fields may alter levels of the hormone melatonin, leading to the development of breast cancer (i.e., the melatonin hypothesis). A review by the HPA in 2006 concluded that the evidence to date did not support the hypothesis that exposure to magnetic fields affects melatonin levels, or the risk of breast cancer (HPA, 2006). Recent, well-conducted epidemiologic studies have added support to the conclusion that magnetic fields are not associated with breast cancer (SCENIHR, 2007; WHO, 2007). With regard to miscarriage, two epidemiologic studies reported a statistical association between peak magnetic field exposure and miscarriage (Lee et al. 2002; Li et al. 2002), although a serious bias in how these studies were conducted was identified and the scientific panels concluded that these biases precluded making any conclusions about the effect of magnetic fields on miscarriage (HCN, 2004; NRPB, 2004; WHO, 2007). Some epidemiologic studies on neurodegenerative diseases (including Alzheimer's disease and Amyotrophic Lateral Sclerosis [ALS]) have reported associations with estimates of occupational magnetic field exposure. The scientific panels have recommended more research in this area, particularly with regard to ALS, as the initial studies were of relatively low quality (NRPB, 2001b; SCENIHR, 2007; WHO, 2007).

Taking into account all of the research reviewed in their report, the Canadian FPTRPC released the following conclusion in their position statement:

> Based on the available scientific evidence to date, the Federal Provincial Territorial Radiation Protection Committee (FPTRPC) concludes that adverse health effects from exposure to power-frequency EMFs, at levels normally encountered in homes, schools and offices, have not been established (p. 268, FPTRPC, 2005a).

Health Canada, which participates in FPTRPC, states the following on their website:

> There have been many studies about the effects of exposure to electric and magnetic fields at extremely low frequencies. Scientists at Health Canada are aware that some studies have suggested a possible link between exposure to ELF fields and certain types of childhood cancer. However, when all studies are evaluated, the evidence appears to be very weak… (Health Canada, 2004).

In summary, the national and international scientific agencies with the responsibility of protecting the health of Canadians have stated that the evidence does not indicate that EMF causes any adverse health effect. They recognize that the main source of uncertainty lies with weak and inconsistent associations observed in epidemiology studies that are not confirmed or

explained in experimental studies. They recommended further well-designed research studies and will continue to monitor the research and re-examine their position periodically as new data becomes available.

In summary, risk assessments conducted by scientific panels, including a review in Canada in 2005 and a comprehensive and up-to-date review by the WHO published in June 2007, concluded that the cumulative body of research to date does not suggest that magnetic fields cause any long-term adverse health effects at the levels we encounter in our everyday environments.

Standards and guidelines

Following a thorough review of the research, scientific agencies develop exposure standards to protect against known health effects. The major purpose of the health risk assessment is to identify the lowest exposure level below which no health hazards have been found (i.e., a threshold). Exposure limits are then set well below the threshold level to account for any individual variability or sensitivities that may exist.

The ICNIRP reviewed the epidemiologic and experimental evidence through 1997 and concluded that there was insufficient evidence to warrant the development of standards or guidelines on the basis of hypothesized long-term adverse health effects such as cancer; rather, the guidelines put forth in their 1998 document set limits to protect against acute health effects (i.e., the stimulation of nerves and muscles) that occur at much higher field levels. The ICNIRP recommends a residential screening value of 833 mG and an occupational exposure screening value of 4,200 mG (ICNIRP, 1998). If exposures exceed these screening values, then additional dosimetry evaluations are needed to determine whether basic restrictions on induced current densities are exceeded.

The ICES also recommends limiting magnetic field exposures at high levels because of the risk of acute effects, although their guidelines are higher than ICNIRP's guidelines; the ICES recommends a residential exposure limit of 9,040 mG and an occupational exposure limit of 27,100 mG (ICES, 2002). The ICNIRP and ICES guidelines provide guidance to national

agencies and only become legally binding if a country adopts them into legislation. The WHO strongly recommends that countries adopt the ICNIRP guidelines, or use a scientifically sound framework for formulating any new guidelines (WHO, 2006).

The levels of measured and calculated fields associated with the Maritime Electric transmission line are far lower than the above referenced exposure limits.

Precautionary approaches

The conclusions reached by national and international scientific and health agencies from their evaluation of EMF research, and the guidelines for exposure they have recommended above, make clear that exposures to EMF that people encounter in their daily life, including those from transmission lines like the one at issue here, do not pose any recognized long-term health risks.

The residents, however, advance the argument that even "possibility of harm" should be enough to justify the removal or relocation of the transmission line. They claim that both the WHO and the Canadian Environmental Protection Act (CEPA) advise adherence to the precautionary principle in the construction of transmission lines.

The essence of the precautionary principle is to take steps to reduce exposures that are proportional to the perceived level of risk associated with that exposure, with the current scientific consensus as a basis for establishing that level of risk. While CEPA contains no reference to transmission lines, it does reference the precautionary principle. For example, it specifies that "The conclusion of the [risk] assessment is based on the application of the precautionary principle and a weight of evidence approach" CEPA (1999).

The FPTRPC Committee has also considered the precautionary principle in issuing its guidance on EMF:

> There have been increasing requests from concerned citizens that the precautionary principle (PP) be used in a number of areas, including exposure to EMFs. It should be noted that the extent of PP covers a variety of measures ranging from moderate methods such as monitoring scientific developments and providing information, through participation in the process of acquiring new knowledge by carrying out research, to stronger measures such as lowering exposure limits. Since there is no conclusive evidence that exposure to EMFs 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 activity are consistent with the Canadian government framework on precaution (FPTRPC, 2005b).

Health Canada similarly recommends:

> You do not need to take action regarding typical daily exposures to electric and magnetic fields at extremely low frequencies. There is no conclusive evidence of harm at levels normally found in Canadian living and working environments" (HC, 2004).

The Commission of the European Union Commission has also provided guidance to decision makers on the application of the precautionary principle (CEC, 2000). The European Council also recommended with respect to EMF, that the precautionary principle should not be invoked "because there are no clear scientific indications that the possible effects on human health may be potentially dangerous" (EC, 1999). The WHO supports this interpretation of the precautionary principle with respect to EMF and recommends in a recent fact sheet, "When constructing new facilities … low-cost ways of reducing exposures may be explored. Appropriate exposure reduction measures will vary from one country to another. However, policies based on the adoption of arbitrary low exposure limits are not warranted" (WHO, 2007a).

Conclusions

The investigation of the complaint by Mr. J. William Costain and other residents of Locke/Howlan Roads supports the following conclusions:

1. The residents have a limited understanding of how spot measurements of magnetic fields relate to their overall magnetic field exposure and what measurements are relevant to exposure metrics discussed in epidemiology studies. This misunderstanding can be expected when members of the public compare a single measured (or calculated) magnetic field value, whether located under a transmission line or some other location, to an epidemiologic estimate of time-averaged magnetic field exposure. In epidemiology studies, exposure involves consideration of the frequency and the duration of exposure, in addition to the magnitude of the field. To account for the frequency and duration of exposure, epidemiologists have typically estimated magnetic field exposure using a time-weighted average (TWA) metric, which gives measurements more or less weight depending upon the amount of time a person spends in the location where the measurement was taken or calculated. Although scientific research has not confirmed any aspect of magnetic field exposure that might be biologically relevant to the development of cancer or any other disease process (e.g., NIEHS, 1998; IARC, 2002; Swanson and Kheifets, 2006), most epidemiology studies have focused on estimates of long-term average exposure.

2. The measurements reviewed and calculations performed as part of this investigation suggest that the transmission line at present is not a large source of magnetic field exposure for most residents, but the closer the residence is to the line, the greater the magnetic field. As more wind generating-units are connected to this transmission line, the current flow and, therefore, the magnetic field from the line will increase. The expected conversion of the line to operation at 138 kV in the future, however, will minimize the increase in the magnetic field from the transmission line associated with the addition of additional wind energy capacity. Under any of the loading conditions examined, the magnetic field would not exceed 18 mG at the closest of the residences considered; most of the time the magnetic field level is expected to be far lower.

3. The information provided by residents in support of the allegation that magnetic fields from the transmission line pose a health hazard consists of materials copied from a variety of non-scientific sources, i.e., print and electronic media sources and unpublished documents posted to the Internet by scientists and non-scientists. Of all the material submitted, only a single paper was published in a peer-reviewed scientific journal (Havas, 2002) and only one document referenced a report by a public health agency (WHO, 2006). By relying upon non-scientific or non-peer reviewed sources, the residents have been misled. While it is commendable that the residents have endeavored to learn more about EMF health research, it is indeed unfortunate that their search did not focus on the reviews of the research and policy recommendations provided by national and international health agencies, including those in Canada. These agencies, based on the weight of the evidence, have not uncovered credible and reliable scientific evidence that exposures to EMF at levels found in daily life, including those associated with the Maritime Electric transmission line, are hazardous to health. The Appendix contains information about EMF and health provided by Health Canada, the WHO, and the US National Cancer Institute as useful references for the general public.

4. With regard to the residents' claim that the precautionary principle should have been applied in the siting and construction of the transmission line, the Canadian and international applications of the precautionary principle would not support a different technical approach to the siting and construction of the line than has occurred. In the absence of the weight of evidence review supporting risk and substantial uncertainty about the nature and magnitude of a risk,[12] there is no precautionary action, save increasing the voltage on the transmission line as has been planned, that seems proportionate to the degree of uncertainty. In November 2008 when additional wind farm capacity will be connected to the transmission line and increase load, the magnetic field per MW of power transferred will be less than if the line continued to operate at 69 kV. The scientific evidence and the precautionary principle do not justify the removal or relocation of the transmission line.

[12] The precautionary principle is "particularly applicable to circumstances of a risk of serious or irreversible harm about which there is significant scientific uncertainty." Environment Canada (EC). A Canadian Perspective on the Precautionary Approach/Principle Proposed Guiding Principles, September 2001.

Recommendations

The concerns raised by residents along the route of the transmission line could have been mitigated had better information about the transmission line been available from Maritime Electric. Taking measurements for customers is a good proactive approach, but is not a substitute for providing a more global understanding and context of the project and its associated EMF levels. In addition, had independent information about EMF and health research been available from a provincial agency such as the Commission, the residents might have been less likely to seek out non-scientific and less objective sources of information. Practical measures to implement these goals might include:

1. Requesting Maritime Electric provide more information about future transmission projects, including calculations of EMF.

2. Providing information about EMF health research to the public on the website of the Commission or other governmental agency. An example of what might be a useful posting is the information "Power Frequency Electric and Magnetic Fields and Health" on the BC Centre for Disease Control website (http://www.bccdc.org/print.php?page=content.php&item=57).

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Appendix A

Health Canada - It’s Your Health

Health Canada Santé Canada

It's Your Health

ELECTRIC AND MAGNETIC FIELDS AT EXTREMELY LOW FREQUENCIES

The Issue

There are concerns that daily exposure to electric and magnetic fields (EMFs) may cause health problems. These concerns are reflected in a number of reports that have attempted to link EMF exposure to a variety of health issues, including childhood cancer.

Background

Electricity plays a central role in modern society. It is used to light homes, prepare food, run computers and operate other household appliances, such as TVs and radios. In Canada, appliances that plug into a wall socket use electric power that flows back and forth at a frequency of 60 cycles per second (60 hertz).

Every time you use electricity and electrical appliances, you are exposed to electric and magnetic fields (EMFs) at extremely low frequencies (ELF). The term "extremely low" is used to describe any frequency below 300 hertz. EMFs produced by the transmission and use of electricity belong to this category.

Electric and Magnetic Fields (EMFs)

Electric and magnetic fields are invisible forces that surround electrical equipment, power cords, and wires that carry electricity, including outdoor power lines. You cannot see or feel EMFs.

Electric Fields: These are formed whenever a wire is plugged into an outlet, even when the appliance is not turned on. The higher the voltage, the stronger the electric field.

Magnetic Fields: These are formed when electric current is flowing within a device or wire. The greater the current, the stronger the magnetic field.

Electric and magnetic fields can occur separately or together. For example, when you plug the power cord for a lamp into a wall socket, it creates an electric field along the cord. When you turn the lamp on, the flow of current through the cord creates a magnetic field. Meanwhile, the electric field is still present.

The Strength of EMFs

Electric and magnetic fields are strongest when close to their source. As you move away from the source, the strength of the fields fades rapidly. This means you are exposed to stronger electric and magnetic fields when standing close to a source (e.g., right beside a transformer box or under a high voltage power line), and you are exposed to weaker fields as you move away. When you are indoors at home, the magnetic fields from high voltage power lines and transformer boxes are very weak when compared to the fields from electrical household appliances.

Typical Canadian Exposures to EMFs at ELF

On a daily basis, most Canadians are exposed to EMFs generated by household wiring, fluorescent lighting, and any electrical appliance that plugs into the wall, including hair dryers, vacuum cleaners and toasters. In the work-place, common sources include video display terminals (computer monitors), air purifiers, photocopiers, fax machines, fluorescent lights, electric heaters and electric tools in machine shops, such as drills, power saws, lathes and welding machines.

Canada

Typical Exposures Present No Known Health Risks

Research has shown that EMFs from electrical devices and power lines can induce weak electric currents to flow through the human body. However, these currents are much smaller than those produced naturally by your brain, nerves and heart, and are not associated with any known health risks.

There have been many studies about the effects of exposure to electric and magnetic fields at extremely low frequencies. Scientists at Health Canada are aware that some studies have suggested a possible link between exposure to ELF fields and certain types of childhood cancer. However, when all of the studies are evaluated, the evidence appears to be very weak.

After a recent evaluation of the scientific data, the International Agency for Research on Cancer classified ELF magnetic fields as "possibly carcinogenic" to humans based on studies of childhood cancer. However, the evidence is not strong enough to conclude that EMFs definitely cause cancer in children. More studies are needed to draw firm conclusions.

Concerns about Electromagnetic Interference

At typical exposure levels, EMFs may cause interference with electronic devices. For example, office workers may notice image movement (jitter) on their computer screens if the computer is in an area where magnetic fields are slightly above typical levels found in offices. Some sources that generate these slightly elevated levels are the cables that bring electrical power into an office area, and common electrical equipment, such as power transformers.

Magnetic fields that cause jitter on computer screens are well below the levels that would cause human health effects. To solve the jitter problem, simply move the computer to another part of the room where the magnetic fields are weaker.

Minimizing Your Risk

You do not need to take action regarding typical daily exposures to electric and magnetic fields at extremely low frequencies. There is no conclusive evidence of any harm caused by exposures at levels normally found in Canadian living and working environments.

Health Canada's Role

Health Canada, along with the World Health Organization, monitors scientific research on EMFs and human health as part of its mission to help Canadians maintain and improve their health. At present, there are no Canadian government guidelines for exposure to EMFs at ELF. Health Canada does not consider guidelines necessary because the scientific evidence is not strong enough to conclude that typical exposures cause health problems.

Some national and international organizations have issued exposure guidelines for EMFs at ELF. However, these guidelines are not based on a consideration of risks related to cancer or other health problems. Rather, the point of the guidelines is to make sure that the electric currents in the body caused by exposure to EMFs are not stronger than the ones produced naturally by the brain, nerves and heart. For the most part, typical EMF exposures in Canadian homes, offices and other work sites, are far below these guidelines.

Need More Info?

For further information contact:
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Telephone: (613) 954-6699
Fax: (613) 952-7584
E-mail: CCRPB-PCRPCC @hc-sc.gc.ca

Also, see the following Fact Sheets on the World Health Organization (WHO) Web site:

- Electromagnetic Fields and Public Health: Extremely Low Frequency(ELF) at www.who.int/docstore/peh-emf/publications/facts_press/efact/efs205.html
- Electromagnetic Fields and Public Health: Extremely Low Frequency Fields and Cancer at www.who.int/docstore/peh-emf/publications/facts_press/efact/efs263.html

And visit these Web sites:

The International Agency for Research on Cancer (IARC), Static and extremely low-frequency (ELF) electric and magnetic fields. Report No. 80 at http://193.51.164.11/htdocs/monographs/vol80/80.html

The U.S. National Institute of Environmental Health Sciences (NIEHS), Questions and Answers about EMF at www.niehs.nih.gov/emfrapid/booklet/home.htm

Also, see:

It's Your Health, Safety of Exposure to Electric and Magnetic Fields from Computer Monitors and Other Video Display Terminals at http://www.hc-sc.gc.ca/english/iyh/products/vdt.html

Additional It's Your Health articles can be found at:
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Canada

Appendix B

WHO Fact Sheet

World Health Organization

Fact sheet N°322
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Electromagnetic fields and public health
Exposure to extremely low frequency fields

The use of electricity has become an integral part of everyday life. Whenever electricity flows, both electric and magnetic fields exist close to the lines that carry electricity, and close to appliances. Since the late 1970s, questions have been raised whether exposure to these extremely low frequency (ELF) electric and magnetic fields (EMF) produces adverse health consequences. Since then, much research has been done, successfully resolving important issues and narrowing the focus of future research.

In 1996, the World Health Organization (WHO) established the International Electromagnetic Fields Project to investigate potential health risks associated with technologies emitting EMF. A WHO Task Group recently concluded a review of the health implications of ELF fields (WHO, 2007).

This Fact Sheet is based on the findings of that Task Group and updates recent reviews on the health effects of ELF EMF published in 2002 by the International Agency for Research on Cancer (IARC), established under the auspices of WHO, and by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) in 2003.

ELF field sources and residential exposures

Electric and magnetic fields exist wherever electric current flows - in power lines and cables, residential wiring and electrical appliances. **Electric** fields arise from electric charges, are measured in volts per metre (V/m) and are shielded by common materials, such as wood and metal. **Magnetic** fields arise from the motion of electric charges (i.e. a current), are expressed in tesla (T), or more commonly in millitesla (mT) or microtesla (μT). In some countries another unit called the gauss, (G), is commonly used (10,000 G = 1 T). These fields are not shielded by most common materials, and pass easily through them. Both types of fields are strongest close to the source and diminish with distance.

Most electric power operates at a frequency of 50 or 60 cycles per second, or hertz (Hz). Close to certain appliances, the magnetic field values can be of the order of a few hundred microtesla. Underneath power lines, magnetic fields can be about 20 μT and electric fields can be several thousand volts per metre. However, average residential power-frequency magnetic fields in homes are much lower - about 0.07 μT in Europe and 0.11 μT in North America. Mean values of the electric field in the home are up to several tens of volts per metre.

Task group evaluation

In October 2005, WHO convened a Task Group of scientific experts to assess any risks to health that might exist from exposure to ELF electric and magnetic fields in the frequency range >0 to 100,000 Hz (100 kHz). While IARC examined the evidence regarding cancer in 2002, this Task Group reviewed evidence for a number of health effects, and updated the evidence regarding cancer. The conclusions and recommendations of the Task Group are presented in a WHO Environmental Health Criteria (EHC) monograph (WHO, 2007).

Following a standard health risk assessment process, the Task Group concluded that there are no substantive health issues related to ELF electric fields at levels generally encountered by members of the public. Thus the remainder of this fact sheet addresses predominantly the effects of exposure to ELF magnetic fields.

Short-term effects

There are established biological effects from acute exposure at high levels (well above 100 μT) that are explained by recognized biophysical mechanisms. External ELF magnetic fields induce electric fields and currents in the body which, at very high field strengths, cause nerve and muscle stimulation and changes in nerve cell excitability in the central nervous system.

Potential long-term effects

Much of the scientific research examining long-term risks from ELF magnetic field exposure has focused on childhood leukaemia. In 2002, IARC published a monograph classifying ELF magnetic fields as "possibly carcinogenic to humans". This classification is 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 (other examples include coffee and welding fumes). This classification was based on pooled analyses of epidemiological studies demonstrating a consistent pattern of a two-fold increase in childhood leukaemia associated with average exposure to residential power-frequency magnetic field above 0.3 to 0.4 μT. The Task Group concluded that additional studies since then do not alter the status of this classification.

However, the epidemiological evidence is weakened by methodological problems, such as potential selection bias. In addition, there are no accepted biophysical mechanisms that would suggest that low-level exposures are involved in cancer development. Thus, if there were any effects from exposures to these low-level fields, it would have to be through a biological mechanism that is as yet unknown. Additionally, animal studies have been largely negative. Thus, on balance, the evidence related to childhood leukaemia is not strong enough to be considered causal.

Childhood leukaemia is a comparatively rare disease with a total annual number of new cases estimated to be 49,000 worldwide in 2000. Average magnetic field exposures above 0.3 μT in homes are rare: it is estimated that only between 1% and 4% of children live in such conditions. If the association between magnetic fields and childhood leukaemia is causal, the number of cases worldwide that might be attributable to magnetic field exposure is estimated to range from 100 to 2400 cases per year, based on values for the year 2000, representing 0.2 to 4.95% of the total incidence for that year. Thus, if ELF magnetic fields actually do increase the risk of the disease, when considered in a global context, the impact on public health of ELF EMF exposure would be limited.

A number of other adverse health effects have been studied for possible association with ELF magnetic field exposure. These include other childhood cancers, cancers in adults, depression, suicide, cardiovascular disorders, reproductive dysfunction, developmental disorders, immunological modifications, neurobehavioural effects and neurodegenerative disease. The WHO Task Group concluded that scientific evidence supporting an association between ELF magnetic field exposure and all of these health effects is much weaker than for childhood leukaemia. In some instances (i.e. for cardiovascular disease or breast cancer) the evidence suggests that these fields do not cause them.

International exposure guidelines

Health effects related to short-term, high-level exposure have been established and form the basis of two international exposure limit guidelines (ICNIRP, 1998; IEEE, 2002). At present, these bodies consider the scientific evidence related to possible health effects from long-term, low-level exposure to ELF fields insufficient to justify lowering these quantitative exposure limits.

WHO's guidance

For high-level short-term exposures to EMF, adverse health effects have been scientifically established (ICNIRP, 2003). International exposure guidelines designed to protect workers and the public from these effects should be adopted by policy makers. EMF protection programs should include exposure measurements from sources where exposures might be expected to exceed limit values.

Regarding long-term effects, given the weakness of the evidence for a link between exposure to ELF magnetic fields and childhood leukaemia, the benefits of exposure reduction on health are unclear. In view of this situation, the following recommendations are given:

- Government and industry should monitor science and promote research programmes to further reduce the uncertainty of the scientific evidence on the health effects of ELF field exposure. Through the ELF risk assessment process, gaps in knowledge have been identified and these form the basis of a new research agenda.
- Member States are encouraged to establish effective and open communication programmes with all stakeholders to enable informed decision-making. These may include improving coordination and consultation among industry, local government, and citizens in the planning process for ELF EMF-emitting facilities.
- When constructing new facilities and designing new equipment, including appliances, low-cost ways of reducing exposures may be explored. Appropriate exposure reduction measures will vary from one country to another. However, policies based on the adoption of arbitrary low exposure limits are not warranted.

Further reading

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Appendix C

U.S. National Cancer Institute Fact Sheet

NATIONAL CANCER INSTITUTE
FactSheet

Magnetic Field Exposure and Cancer: Questions and Answers

Key Points

- Electric and magnetic fields (EMF) are areas of energy that surround any electrical device. EMFs are produced by power lines, electrical wiring, and appliances (see Question 1).
- Electric fields are easily shielded or weakened by walls and other objects, whereas magnetic fields are not. Since magnetic fields are more likely to penetrate the body, they are the component of EMFs that are usually studied in relation to cancer (see Question 1).
- Overall, there is limited evidence that magnetic fields cause childhood leukemia, and there is inadequate evidence that these magnetic fields cause other cancers in children (see Question 2).
- Studies of magnetic field exposure from power lines and electric blankets in adults show little evidence of an association with leukemia, brain tumors, or breast cancer (see Question 3).
- Past studies of occupational magnetic field exposure in adults showed very small increases in leukemia and brain tumors. However, more recent, well-conducted studies have shown inconsistent associations with leukemia, brain tumors, and breast cancer (see Question 4).

1. What are electric and magnetic fields?

Electricity is the movement of electrons, or current, through a wire. The type of electricity that runs through power lines and in houses is alternating current (AC). AC power produces two types of fields (areas of energy)—an electric field and a magnetic field. An electric field is produced by voltage, which is the pressure used to push the electrons through the wire, much like water being pushed through a pipe. As the voltage increases, the electric field increases in strength. A magnetic field results from the flow of current through wires or electrical devices and increases in strength as the current increases. These two fields together are referred to as electric and magnetic fields, or EMFs.

Both electric and magnetic fields are present around appliances and power lines. However, electric fields are easily shielded or weakened by walls and other objects, whereas magnetic fields can pass through buildings, humans, and most other materials. Since magnetic fields are most likely to penetrate the body, they are the component of EMFs that are usually studied in relation to cancer.

The focus of this fact sheet is on extremely low-frequency magnetic fields. Examples of devices that emit these fields include power lines and electrical appliances, such as electric shavers, hair dryers, computers, televisions, electric blankets, and heated waterbeds. Most electrical appliances have to be turned on to produce a magnetic field. The strength of a magnetic field decreases rapidly with increased distance from the source.

2. Is there a link between magnetic field exposure at home and cancer in children?

Numerous epidemiological (population) studies and comprehensive reviews have evaluated magnetic field exposure and risk of cancer in children (1, 2). Since the two most common cancers in children are leukemia and brain tumors, most of the research has focused on these two types. A study in 1979 pointed to a possible association between living near electric power lines and childhood leukemia (3). Among more recent studies, findings have been mixed. Some have found an association; others have not. These studies are discussed in the following paragraphs. Currently, researchers conclude that there is limited evidence that magnetic fields from power lines cause childhood leukemia, and that there is inadequate evidence that these magnetic fields cause other cancers in children (2). Researchers have not found a consistent relationship between magnetic fields from power lines or appliances and childhood brain tumors.

In one large study by the National Cancer Institute (NCI) and the Children's Oncology Group, researchers measured magnetic fields directly in homes (4). This study found that children living in homes with high magnetic field levels did not have an increased risk of childhood acute lymphoblastic leukemia. The one exception may have been children living in homes that had fields greater than 0.4 microtesla (μT), a very high level that occurs in few residences. Another study conducted by NCI researchers reported that children living close to overhead power lines based on distance measurements were not at greater risk of leukemia (5).

To estimate more accurately the risks of leukemia in children from magnetic fields resulting from power lines, researchers pooled (combined) data from many studies. In one pooled study that combined nine well-conducted studies from several countries, including a study from the NCI, a twofold excess risk of childhood leukemia was associated with exposure to magnetic fields above 0.4 μT (6). In another pooled study that combined 15 studies, a similar increased risk was seen above 0.3 μT (7). It is difficult to determine if this level of risk represents a real increase or if it results from study bias. Such study bias can be related to the selection of study subjects or possibly to other factors that relate to levels of magnetic field exposure. If magnetic fields caused

childhood leukemia, certain patterns would have been found such as increasing risk with increasing levels of magnetic field exposure.

Another way that people can be exposed to magnetic fields is from household electrical appliances. Several studies have investigated this relationship (2). Although magnetic fields near many electrical appliances are higher than near power lines, appliances contribute less to a person's total exposure to magnetic fields. This is because most appliances are used only for short periods of time, and most are not used close to the body, whereas power lines are always emitting magnetic fields.

In a detailed evaluation, investigators from NCI and the Children's Oncology Group examined whether the use of household electrical appliances by the mother while pregnant and later by the child increased the risk of childhood leukemia. Although some appliances were associated with childhood leukemia, researchers did not find any consistent pattern of increasing risk with increasing years of use or how often the appliance was used (8). A few other studies have reported mostly inconsistencies or no relation between appliances and risk of childhood cancer.

Occupational exposure of mothers to high levels of magnetic fields during pregnancy has been associated with childhood leukemia in a Canadian study (9). Similar studies need to be done in other populations to see if this is indeed the case.

3. Is there a link between magnetic field exposure in the home and cancer in adults?

Although several studies have looked into the relationship of leukemia, brain tumors, and breast cancer in adults exposed to magnetic fields in the home, there are only a few large studies with long-term, magnetic field measurements. No consistent association between magnetic fields and leukemia or brain tumors has been established.

The majority of epidemiological studies have shown no relationship between breast cancer in women and magnetic fields from electrical appliances. Recent studies of breast cancer and magnetic fields in the home have included direct and indirect magnetic field measurements. These studies mostly found no association between breast cancer in females and magnetic fields from power lines or electric blankets (10, 11, 12, 13). A Norwegian study found a risk for exposure to magnetic fields in the home (14), and a study in African-American women found that use of electric bedding devices may increase breast cancer risk (15).

4. Is there a link between magnetic field exposure at work and cancer in adults?

Several studies conducted in the 1980s and early 1990s reported that people who worked in some electrical occupations (such as power station operators and phone line workers) had higher than expected rates of some types of cancer, particularly leukemia, brain tumors, and male breast cancer (2). Some occupational studies showed very small increases in risk for leukemia and brain cancer, but these results were based on job titles and not actual measurements. More recently conducted studies that have included both

job titles and individual exposure measurements have no consistent finding of an increasing risk of leukemia, brain tumors, or female breast cancer with increasing exposure to magnetic fields at work (14, 16, 17, 18).

5. What have scientists learned from animal experiments about the relationship between magnetic field exposure and cancer?

Animal studies have not found that magnetic field exposure is associated with increased risk of cancer (2). The absence of animal data supporting carcinogenicity makes it biologically less likely that magnetic field exposures in humans, at home or at work, are linked to increased cancer risk.

6. Where can people find additional information on EMFs?

The National Institute of Environmental Health Sciences (NIEHS) Web site has information about EMFs and cancer, as well as information and publications related to the EMF Research and Public Information Dissemination (RAPID) Program. NIEHS can be contacted at:

Address:	National Institute of Environmental Health Sciences Post Office Box 12233 Research Triangle Park, NC 27709
Telephone:	919–541–3345 TTY: 919–541–0731
E-mail:	webcenter@niehs.nih.gov
Internet Web site:	http://www.niehs.nih.gov

Note: Information about cancer risk and EMFs emitted from hand-held cellular phones (i.e., microwave frequencies) can be found in the NCI fact sheet *Cellular Telephone Use and Cancer*, which is available at http://www.cancer.gov/cancertopics/factsheet/Risk/cellphones on the Internet.

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16. Tynes T, Haldorsen T. Residential and occupational exposure to 50 Hz magnetic fields and hematological cancers in Norway. *Cancer Causes & Control* 2003; 14: 715–720.

17. Labreche F, Goldberg MS, Valois M-F, et al. Occupational exposures to extremely low frequency magnetic fields and postmenopausal breast cancer. *American Journal of Industrial Medicine* 2003; 44: 643–652.

18. Willett E, McKinney PA, Fear NT, et al. Occupational exposure to electromagnetic fields and acute leukaemia: Analysis of a case-control study. *Occupational and Environmental Medicine* 2003; 60: 577–583.

# # #

Related Resources

Publications (available at http://www.cancer.gov/publications)

- National Cancer Institute Fact Sheet 3.72, *Cellular Telephone Use and Cancer*

National Cancer Institute (NCI) Resources

Cancer Information Service (toll-free)

Telephone: 1–800–4–CANCER (1–800–422–6237)
TTY: 1–800–332–8615

Online

NCI's Web site: http://www.cancer.gov
LiveHelp, NCI's live online assistance:
https://cissecure.nci.nih.gov/livehelp/welcome.asp

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Appendix D

William H. Bailey, Ph.D.
Curriculum Vitae

Exponent
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William H. Bailey, Ph.D.

Principal Scientist and Director, New York Office

Professional Profile

Dr. William H. Bailey is a Principal Scientist in Exponent's Health Sciences practice and Director of the New York office. Dr. Bailey specializes in applying state-of-the-art assessment methods to environmental and occupational health issues. His 30 years of training and experience include laboratory and epidemiologic research, health risk assessment, and comprehensive exposure analysis. Dr. Bailey has investigated exposures to alternating current, direct current, and radiofrequency electromagnetic fields, 'stray voltage', and electrical shock, as well as to a variety of chemical agents and air pollutants. He is particularly well known for his research on potential health effects of electromagnetic fields and has served as an advisor to numerous state, federal, and international agencies. Currently, he is involved in research on EMF exposure guidelines and respiratory exposures to ultrafine- and nanoparticles. Dr. Bailey is a visiting scientist at the Cornell University Medical College and has lectured at Rutgers University, the University of Texas (San Antonio), and the Harvard School of Public Health. He was formerly Head of the Laboratory of Neuropharmacology and Environmental Toxicology at the New York State Institute for Basic Research, Staten Island, New York, and an Assistant Professor and NIH postdoctoral fellow in Neurochemistry at The Rockefeller University in New York.

Academic Credentials and Professional Honors

Ph.D., Neuropsychology, City University of New York, 1975
M.B.A., University of Chicago, 1969
B.A., Dartmouth College, 1966

Sigma Xi; The Institute of Electrical and Electronics Engineers/International Committee on Electromagnetic Safety (Subcommitee 3, Safety Levels with Respect to Human Exposure to Fields (0 to –3 kHz) and Subcommitte 4, Safety Levels with Respect to Human Exposure to Radiofrequency Fields (3 kHz to 3 GHz); Elected member of the Committee on Man and Radiation (COMAR) of the IEEE Engineering in Medicine and Biology Society, 1998–2001

Publications

Bailey WH, Wagner M. IARC evaluation of ELF magnetic fields: Public understanding of the 0.4μT exposure metric. Exposure Sci Environl Epidemiol, in press.

Bailey WH, Erdreich, L. Accounting for human variability and sensitivity in setting standards for electromagnetic fields. Health Phys 2007; 92:649–657.

Bailey WH, Nyenhuis JA. Thresholds for 60-Hz magnetic field stimulation of peripheral nerves in human subjects. Bioelectromagnetics 2005; 26:462–468.

Bracken TD, Senior RS, Bailey WH. DC electric fields from corona-generated space charge near AC transmission lines. IEEE Transactions on Power Delivery 2005; 20:1692–1702.

Bailey WH. Dealing with uncertainty in formulating occupational and public exposure limits. Health Phys 2002; 83:402–408.

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De Santo RS, Bailey WH. Environmental justice tools and assessment practices. Proceedings, American Public Transit Association, 1999.

Bailey WH, Su SH, Bracken TD. Probabilistic approach to ranking sources of uncertainty in ELF magnetic field exposure limits. Health Phys 1999; 77:282–290.

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Bailey WH. Probabilistic approaches to deriving risk-based exposure guidelines: Application to extremely low frequency magnetic fields. In: Non-Ionising Radiation. Dennis JA and Stather JW (eds), Special Issue of Radiation Protection Dosimetry 1997; 72:327–336.

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Bailey WH, Charry JM. Acute exposure of rats to air ions: Effects on the regional concentration and utilization of serotonin in brain. Bioelectromagnetics 1987; 8:173–181.

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Bailey WH, Charry JM. Behavioral monitoring of rats during exposure to air ions and DC electric fields. Bioelectromagnetics 1986; 7:329–339.

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Gross SS, Guo ZG, Levi R, Bailey WH, Chenouda AA. 1984. Release of histamine by sympathetic nerve stimulation in the guinea pig heart and modulation of adrenergic responses. Circulation Res 1984; 54:516–526.

Dahl D, Bailey WH, Winson J. Effect of norepinephrine depletion of hippocampus on neuronal transmission from perforant pathway through dentate gyrus. J Neurophysiol 1983; 49:123–135.

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Bailey WH, Weiss JM. Effect of ACTH 4-10 on passive avoidance of rats lacking vasopressin (Brattleboro strain). Hormones and Behavior 1978; 10:22–29.

Pohorecky LA, Newman B, Sun J, Bailey WH. Acute and chronic ethanol injection and serotonin metabolism in rat brain. J Pharmacol Exper Therap 1978; 204:424–432.

Koh SD, Vernon M, Bailey WH. Free-recall learning of word lists by prelingual deaf subjects. J Verbal Learning and Verbal Behavior 1971; 10:542–574.

Book Chapters

Bailey WH. Principles of risk assessment and their limitations. In: Risk Perception, Risk Communication and its Application to EMF Exposure. Matthes R, Bernhardt JH, and Repacholi MH (eds), International Commission on Non-Ionizing Radiation Protection, Oberschleißheim, Germany, 1998.

Bailey WH. Biological responses to air ions: Is there a role for serotonin? pp. 151–160. In: Air Ions: Physical and Biological Aspects. Charry JM and Kavet R (eds), CRC Press, Boca Raton, FL, 1987.

Weiss JM, Bailey WH, Goodman PA, Hoffman LJ, Ambrose MJ, Salman S, Charry JM. A model for neurochemical study of depression. pp. 195–223. In: Behavioral Models and the Analysis of Drug Action. Spiegelstein MY and Levy A (eds), Elsevier Scientific, Amsterdam, 1982.

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Bailey WH, Weiss, JM. Avoidance conditioning and endocrine function in Brattleboro rats. Pp 371–395. In: Endogenous Peptides and Learning and Memory Process. Martinez JL, Jensen RA, Messing RB, Rigter H, and McGaugh JL (eds), Academic Press, New York, NY, 1981.

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Technical Reports

Johnson GB, Bracken TD, Bailey WH. Charging and transport of aerosols near AC transmission lines: A literature review. EPRI, Palo Alto, CA, 2003.

Bailey WH. Probabilistic approach to ranking sources of uncertainty in ELF magnetic-field exposure limits. In: Evaluation of Occupational Magnetic Exposure Guidelines, Interim Report, EPRI Report TR-111501, 1998.

Bailey WH, Weil DE, Stewart JR. HVDC Power Transmission Environmental Issues Review. Oak Ridge National Laboratory, Oak Ridge, TN, 1997.

Bracken TD, Bailey WH, Su SH, Senior RS, Rankin RF. Evaluation of occupational magnetic-field exposure guidelines; Interim Report. EPRI Report TR-108113, 1997.

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Bailey WH. Recent neurobiological and behavioral research: Overview of the New York State powerlines project. In: Power-Frequency Electric and Magnetic Field Research, EPRI, 1989.

Bailey WH, Bissell M, Dorn CR, Hoppel WA, Sheppard AR, Stebbings, JH. Comments of the MEQB Science Advisors on Electrical Environment Outside the Right of Way of CU-TR-1, Report 5. Science Advisor Reports to the Minnesota Environmental Quality Board, 1986.

Bailey WH, Bissell M, Brambl RM, Dorn CR, Hoppel WA, Sheppard AR, Stebbings JH. A health and safety evaluation of the +/- 400 KV powerline. Science Advisor's Report to the Minnesota Environmental Quality Board, 1982.

Charry JM, Bailey WH, Weiss JM. Critical annotated bibliographical review of air ion effects on biology and behavior. Rockefeller University, New York, NY, 1982.

Bailey WH. Avoidance behavior in rats with hereditary hypothalamic diabetes insipidus. Dissertation, City University of New York, 1975.

Selected Invited Presentations

Bailey WH, Erdreich LS. Human sensitivity and variability in response to electromagnetic fields: Implications for standard setting. International Workshop on EMF Dosimetry and Biophysical Aspects Relevant to Setting Exposure Guidelines. International Commission on Non-Ionizing Radiation Protection, Berlin, March 2006.

Bailey WH. Research-based approach to setting electric and magnetic field exposure guidelines (0-3000 Hz). IEEE Committee on Electromagnetic Safety, December 2005.

Bailey WH. Conference Keynote Presentation. Research supporting 50/60 Hz electric and magnetic field exposure guidelines. Canadian Radiation Protection Association, Annual Conference, Winnipeg, June 2005.

Bailey WH. Scientific methodology for assessing public health issues: A case study of EMF. Canadian Radiation Protection Association, Annual Conference, Public Information for Teachers, Winnipeg, June 2005.

Bailey WH. Assessment of potential environmental effects of electromagnetic fields from submarine cables. Connecticut Academy of Science and Engineering, Long Island Sound Bottomlands Symposium: Study of Benthic Habitats, July 2004.

De Santo RS, Coe M, Bailey WH. Environmental justice assessment and the use of GIS tools and methods. National Association of Environmental Professionals, 27th Annual Conference, Dearborn, MI, June 2002.

Bailey WH. Applications to enhance safety: Research to understand and control potential risks. Human Factors and Safety Research, Volpe National Transportation Systems Center/Dutch Ministry of Transport, Cambridge, MA, November 2000.

Bailey WH. EMF health effects review. EMF Exposure Guideline Workshop, Brussels Belgium, June 2000.

Bailey WH. Dealing with uncertainty when formulating guidelines. EMF Exposure Guideline Workshop, Brussels Belgium, June 2000.

Bailey WH. Field parameters: Policy implications. EMF Engineering Review Symposium, Status and Summary of EMF Engineering Research, Charleston, SC, April 1998.

Bailey WH. Principles of risk assessment: Application to current issues. Symposium on EMF Risk Perception and Communication, World Health Organization, Ottawa, Canada, August 1998.

Bailey WH. Current guidelines for occupational exposure to power frequency magnetic fields. EPRI EMF Seminar, New Research Horizons, March 1997.

Bailey WH. Methods to assess potential health risks of cell telephone electromagnetic fields. IBC Conference—Cell Telephones: Is there a Health Risk? Washington, DC, June 1997.

Bailey WH. Principles of risk assessment and their limitations. Symposium on Risk Perception, Risk Communication and its Application to EMF Exposure, International Commission on Non-Ionizing Radiation Protection, Vienna, Austria, October 1997.

Bailey WH. Probabilistic approach for setting guidelines to limit induction effects. IEEE Standards Coordinating Committee 28: Non-Ionizing Radiation, Subcommittee 3 (0–3 kHz), June 1997.

Bailey WH. Power frequency field exposure guidelines. IEEE Standards Coordinating Committee 28: Non-Ionizing Radiation, Subcommittee 3 (0–3 kHz), June 1996.

Bailey WH. Epidemiology and experimental studies. American Industrial Hygiene Conference, Washington, DC, May 1996.

Bailey WH. Review of 60 Hz epidemiology studies. EMF Workshop, Canadian Radiation Protection Association, Ontario, Canada, June 1993.

Bailey WH. Biological and health research on electric and magnetic fields. American Industrial Hygiene Association, Fredrickton, New Brunswick, Canada, October 1992.

Bailey WH. Electromagnetic fields and health. Institute of Electrical and Electronics Engineers, Bethlehem, PA, January 1992.

Bailey WH, Weiss JM. Psychological factors in experimental heart pathology. Visiting Scholar Presentation, National Heart Lung and Blood Institute, March 1977.

Presentations

Bailey WH. Clarifying the neurological basis for ELF guidelines. Workshop on Practical Implementation of ELF and RF Guidelines. The Bioelectromagnetics Society 29th Annual Meeting, Kanazawa, Japan, June 2007.

Sun B, Urban B, Bailey W. AERMOD simulation of near-field dispersion of natural gas plume from accidental pipeline rupture. Air and Waste Management Association: Health Environments: Rebirth and Renewal, New Orleans, LA, June 2006.

Bailey WH, Johnson G, Bracken TD. Method for measuring charge on aerosol particles near AC transmission lines. Joint Meeting of The Biolectromagnetics Society and The European BioElectromagnetics Association, Dublin Ireland, June 2005.

Bailey WH, Bracken TD, Senior RS. Long-term monitoring of static electric field and space charge near AC transmission Lines. The Bioelectromagnetics Society, 26th Annual Meeting, Washington, DC, June 2004.

Bailey WH, Erdreich L, Waller L, Mariano K. Childhood leukemia in relation to 25-Hz and 60-Hz magnetic fields along the Washington DC—Boston rail line. Society for Epidemiologic Research, 35th Annual Meeting, Palm Desert CA, June 2002. American Journal of Epidemiology 2002; 155:S38.

Erdreich L, Klauenberg BJ, Bailey WH, Murphy MR. Comparing radiofrequency standards around the world. Health Physics Society 43rd Annual Meeting, Minneapolis, MN, July 1998.

Bracken TD, Senior RS, Rankin RF, Bailey WH, Kavet R. Relevance of occupational guidelines to utility worker magnetic-field exposures. Second World Congress for Electricity and Magnetism in Biology and Medicine, Bologna, Italy, June 1997.

Weil DE, Erdreich LS, Bailey WH. Are 60-Hz magnetic fields cancer causing agents? Mechanisms and Prevention of Environmentally Caused Cancers, The Lovelace Institutes 1995 Annual Symposium, La Fonda, Santa Fe, NM, October 1995.

Bailey WH. Neurobiological research on extremely-low-frequency electric and magnetic fields: A review to guide future research. Sixteenth Annual Meeting of the Bioelectromagnetics Society, Copenhagen, Denmark, June 1994.

Blondin J-P, Nguyen D-H, Sbeghen J, Maruvada PS, Plante M, Bailey WH, Goulet D. The perception of DC electric fields and ion currents in human observers. Annual Meeting of the Canadian Psychological Association, Penticton, British Columbia, Canada, June 1994.

Erdreich LS, Bailey WH, Weil DE. Science, standards and public policy challenges for ELF fields. American Public Health Association 122nd Annual Meeting, Washington, DC, October 1994.

Bailey WH, Charry JM. Particle deposition on simulated VDT operators: Influence of DC electric fields. 10th Annual Meeting of the Bioelectromagnetics Society, June 1988.

Charry JM, Bailey WH. Contribution of charge on VDTs and simulated VDT operators to DC electric fields at facial surfaces. 10th Annual Meeting of the Bioelectromagnetics Society, June 1988.

Bailey WH, Charry, JM. Dosimetric response of rats to small air ions: Importance of relative humidity. EPRI/DOE Contractors Review, November 1986. Charry JM, Bailey WH, Bracken TD (eds). DC electric fields, air ions and respirable particulate levels in proximity to VDTs. International Conference on VDTs and Health, Stockholm, Sweden, June 12–15 1986.

Charry JM, Bailey WH. Air ion and DC field strengths at 10^4 ions/cm^3 in the Rockefeller University Small Animal Exposure Chambers. EPRI/DOE Contractors Review, November 1985.

Charry JM, Bailey WH. DC Electrical environment in proximity to VDTs. 7th Annual Meeting of the Bioelectromagnetics Society, June 1985.

Bailey WH, Collins RL, Lahita RG. Cerebral lateralization: Association with serum antibodies to DNA in selected bred mouse lines. Society for Neuroscience, 1985.

Kavet R, Bailey WH, Charry JM. Respiratory neuroendocrine cells: A plausible site for air ion effects. Seventh Annual Meeting of The Bioelectromagnetics Society, June 1985.

Bailey WH, Charry JM. Measurement of neurotransmitter release and utilization in selected brain regions of rats exposed to DC electric fields and atmospheric space charge. 23rd Hanford Life Sciences Symposium, Richland, WA, October 1984.

Bailey WH, Charry JM, Weiss JM, Cardle K, Shapiro M. Regional analysis of biogenic amine turnover in rat brain after exposure to electrically charged air molecules (air ions). Society for Neuroscience, 1983.

Bailey WH. Biological effects of air ions: Fact and fancy. American Institute of Medical Climatology Conference on Environmental Ions and Related Biological Effects, October 1982.

Goodman PA, Weiss JM, Hoffman LJ, Ambrose MJ, Bailey WH, Charry, JM. Reversal of behavioral depression by infusion of an A2 adrenergic agonist into the locus coeruleus. Society for Neuroscience, November 1982.

Charry JM, Bailey WH. Biochemical and behavioral effects of small air ions. Electric Power Research Institute Workshop, April 1981.

Bailey WH, Alsonso DR, Weiss JM, Chin S. Predictability: A psychologic/ behavioral variable affecting stress-induced myocardial pathology in the rat. Society for Neuroscience, November 1980.

Salman SL, Weiss JM, Bailey WH, Joh TH. Relationship between endogenous brain tyrosine hydroxylase and social behavior of rats. Society of Neuroscience, November 1980.

Bailey WH, Maclusky S. Appearance of creatine kinase isoenzymes in rat plasma following myocardial injury produced by isoproterenol. Fed Assoc Soc Exp Biol, April 1978.

Bailey WH, Maclusky S. Appearance of creatine kinase isoenzymes in rat plasma following myocardial injury by isoproterenol. Fed Proc 1978; 37:889.

Bailey WH, Weiss JM. Effect of ACTH 4-10 on passive avoidance of rats lacking vasopressin (Brattleboro strain). Eastern Psychological Association, April 1976.

Prior Experience

President, Bailey Research Associates, Inc., 1991–2000
Vice President, Environmental Research Information, Inc., 1987–1990
Head of Laboratory of Environmental Toxicology and Neuropharmacology, New York State Institute for Basic Research, 1983–1987
Assistant Professor, The Rockefeller University, 1976–1983

Academic Appointment

- Visiting Fellow, Department of Pharmacology, Cornell University Medical College, New York, NY, 1986–present

Prior Academic Appointments

- Visiting Scientist, The Jackson Laboratory, Bar Harbor, ME, 1984–1985
- Head, Laboratory of Neuropharmacology and Environmental Toxicology, NYS Institute for Basic Research in Developmental Disabilities, Staten Island, NY, 1983–1987
- Assistant Professor, The Rockefeller University, New York, NY, 1976–1983
- Postdoctoral Fellow, Neurochemistry, The Rockefeller University, New York, NY, 1974–1976
- Dissertation Research, The Rockefeller University, New York, NY, 1972–1974
- CUNY Research Fellow, Dept. of Psychology, Queens College, City University of New York, Flushing, NY, 1969–1971
- Clinical Research Assistant, Department of Psychiatry, University of Chicago; Psychiatric Psychosomatic Inst., Michael Reese Hospital, and Illinois State Psychiatric Inst, Chicago, IL, 1968–1969

Teaching Appointments

- Lecturer, University of Texas Health Science Center, Center for Environmental Radiation Toxicology, San Antonio, TX, 1998
- Lecturer, Harvard School of Public Health, Office of Continuing Education, Boston, MA, 1995, 1997
- Lecturer, Rutgers University, Office of Continuing Education, New Brunswick, NJ, 1991–1995
- Adjunct Assistant Professor, Queens College, CUNY, Flushing, NY, 1978
- Lecturer, Queens College, CUNY, Flushing, NY, 1969–1974

Editorship

- Associate Editor, Non-Ionizing Radiation, *Health Physics*, 1996–present

Advisory Positions

- ZonMw – Netherlands Organization for Health Research and Development, 2007, reviewer for National Programme on EMF and Health
- National Institute of Environmental Health Sciences/ National Institutes of Health, Review Committee, Neurotoxicology, Superfund Hazardous Substances Basic Research and Training Program, 2004
- National Institute of Environmental Health Sciences, Review Committee Role of Air Pollutants in Cardiovascular Disease, 2004
- Working Group on Non-Ionizing Radiation, Static and Extremely Low-Frequency Electromagnetic Fields, International Agency for Research on Cancer, 2000–2002
- Working Group, EMF Risk Perception and Communication, World Health Organization, 1998–2005
- Member, International Committee on Electromagnetic Safety, Subcommittee 3 - Safety Levels with Respect to Human Exposure to Fields (0 to 3 kHz) and Subcommitee 4 - Safety Levels with Respect to Human Exposure (3kHz to 3GHz) Institute of Electrical and Electronics Engineers (IEEE), 1996–present
- Invited participant, National Institute of Environmental Health Sciences EMF Science Review Symposium: Clinical and In Vivo Laboratory Findings, 1998
- Working Group, EMF Risk Perception and Communication, International Commission on Non-Ionizing Radiation Protection, 1997
- U.S. Department of Energy, RAPID EMF Engineering Review, 1997
- Oak Ridge National Laboratory, 1996
- American Arbitration Association International Center for Dispute Resolution, 1995–1996
- U.S. Department of Energy, 1995
- National Institute for Occupational Safety and Health, 1994–1995
- Federal Rail Administration, 1993–1996
- U.S. Forest Service, 1993
- New York State Department of Environmental Conservation, 1993
- National Science Foundation
- National Institutes of Health, Special Study Section—Electromagnetics, 1991–1993
- Maryland Public Service Commission and Maryland Department of Natural Resources, Scientific Advisor on health issues pertaining to HVAC Transmission Lines, 1988–1989
- Scientific advisor on biological aspects of electromagnetic fields, Electric Power Research Institute, Palo Alto, CA, 1985–1989
- U.S. Public Health Service, NIMH: Psychopharmacology and Neuropsychology Review Committee, 1984
- Consultant on biochemical analysis, Colgan Institute of Nutritional Science, Carlsbad, CA, 1982–1983
- Behavioral Medicine Abstracts, Editor, animal behavior and physiology, 1981–1983

- Consultant on biological and behavioral effects of high-voltage DC transmission lines, Vermont Department of Public Service, Montpelier, VT, 1981–1982
- Scientific advisory committee on health and safety effects of a high-voltage DC transmission line, Minnesota Environmental Quality Board, St. Paul, MN, 1981–1982
- Consultant on biochemical diagnostics, Biokinetix Corp., Stamford, CT, 1978–1980

Professional Affiliations

- The Health Physics Society (Affiliate of the International Radiation Protection Society)
- Society for Risk Analysis
- International Society of Exposure Analysis
- New York Academy of Sciences
- American Association for the Advancement of Science
- Air and Waste Management Association
- Society for Neuroscience/International Brain Research Organization
- Bioelectromagnetics Society
- The Institute of Electrical and Electronics Engineers/Engineering in Medicine and Biology Society