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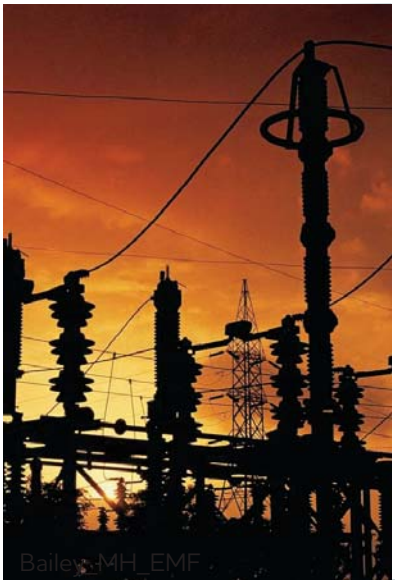


EMF Science Update: Manitoba-Minnesota Transmission Line EIS

William H. Bailey, Ph.D.

Manitoba Clean Environment Commission
Winnipeg MB, Canada
May 15, 2017

Highlights on EIS Topics

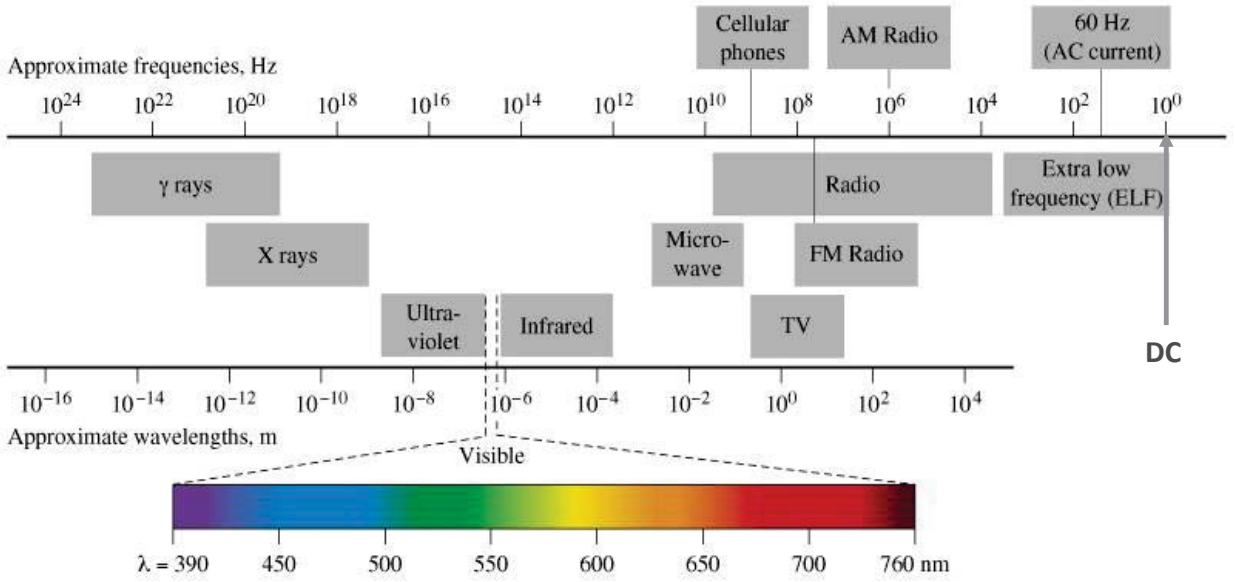
- What are EMFs?
- Magnetic field sources and levels
- Research on magnetic fields
- Agency reviews of EMF research
- Recent international developments
- EMF exposure guidelines
- Livestock, wildlife, and crops
- Electronic devices
- MMTP assessment

What are EMFs?

Four Fundamental Forces of Nature

- Gravity
- **Electromagnetic Fields**
- Nuclear – Strong
- Nuclear – Weak

Electromagnetic Fields Frequency Spectrum



Electric Fields

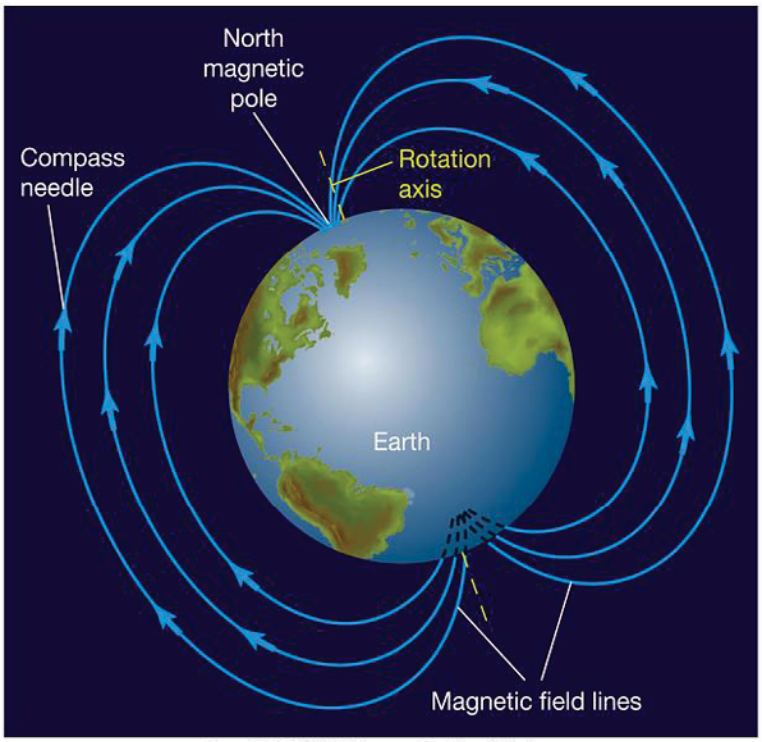
- Electric fields result from electric charges
- Measured in units of volts per meter (V/m) or kilovolts per meter (kV/m)
  - 1,000 V = 1 kV
- Strength diminishes as you move away from the source
- Shielded by common objects such as trees, shrubs, or walls

Magnetic Fields

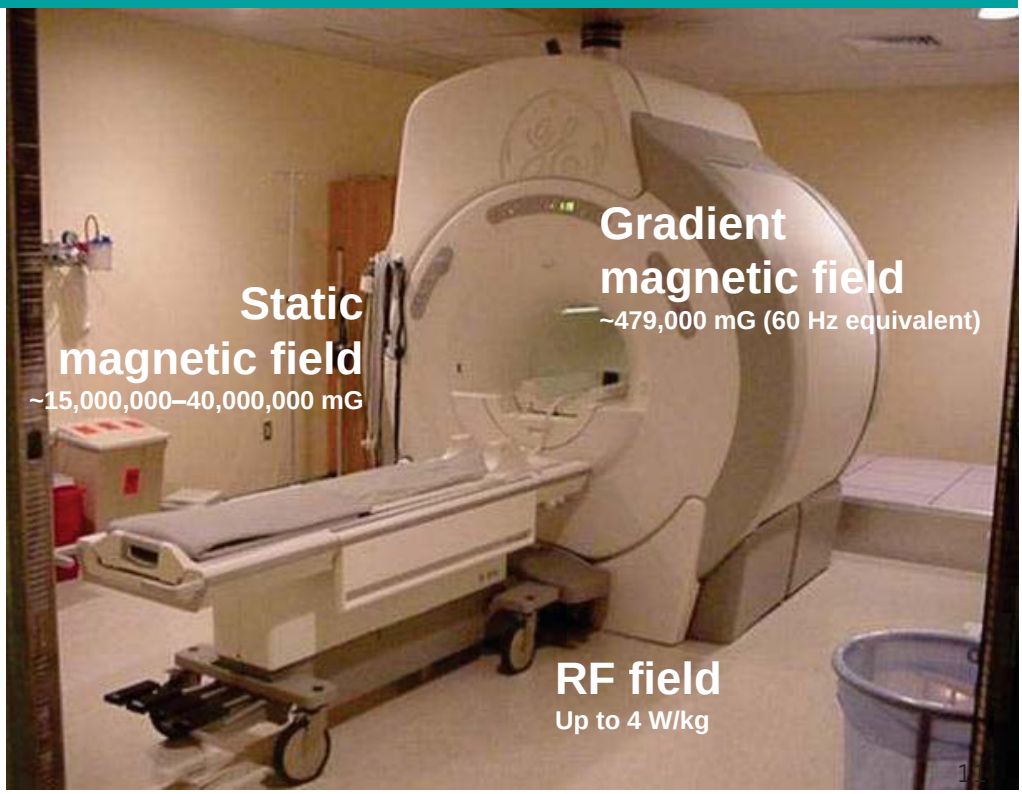
- Magnetic fields result from current flow
- Measured in gauss (G) or milligauss (mG)
  - 1,000 mG = 1G
- Strength diminishes as you move away from the source
- Not shielded by common objects such as trees, shrubs, or walls

Magnetic Field Sources and Levels

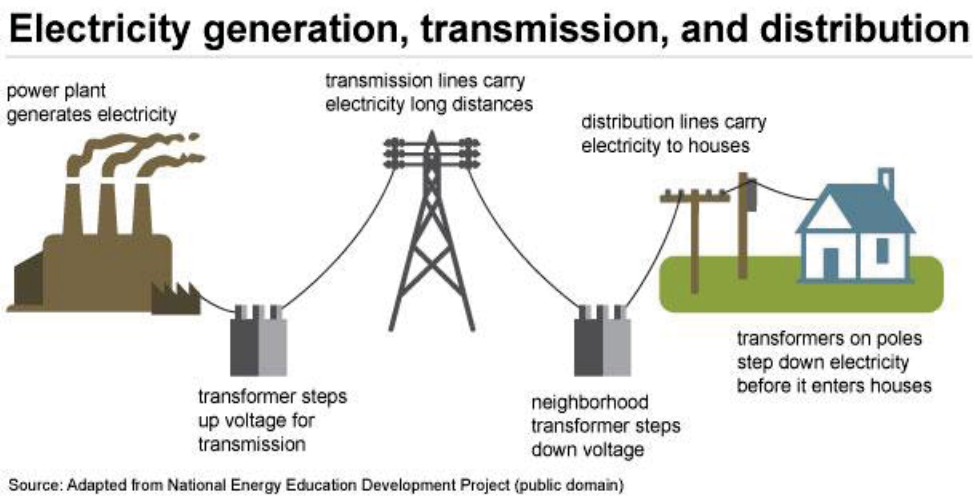
Earth's Static Magnetic Field ~ 300–700 mG

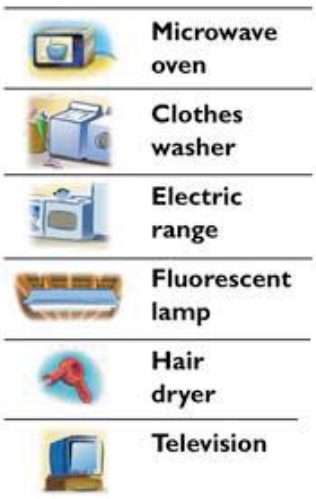


Magnetic Resonance Imaging (MRI)

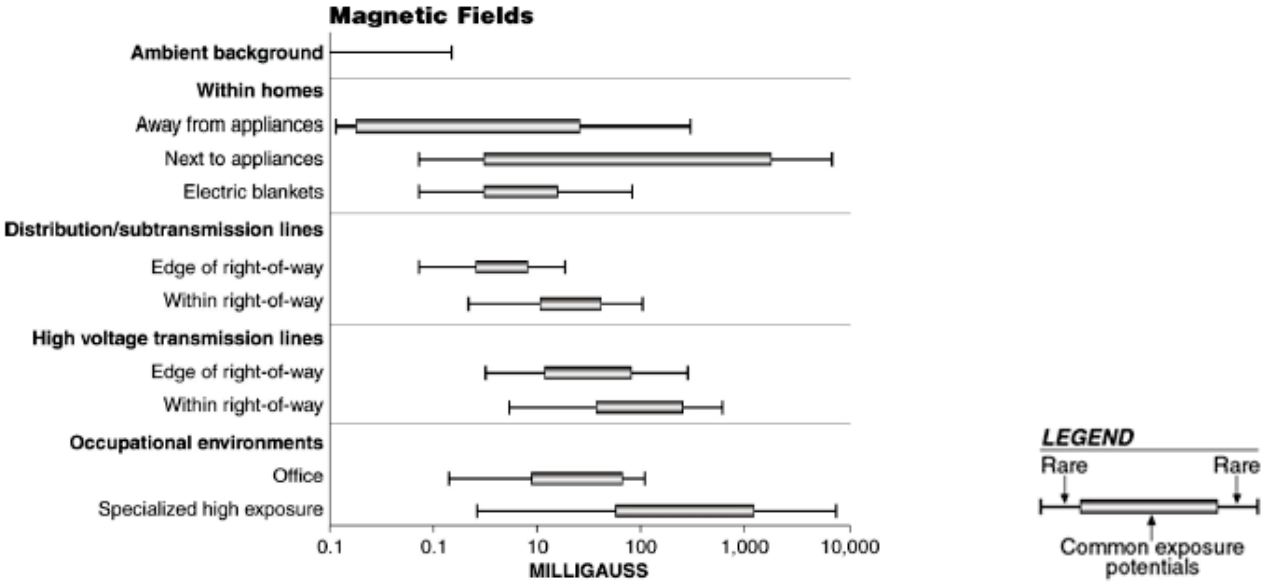


Power System Sources of Magnetic Fields

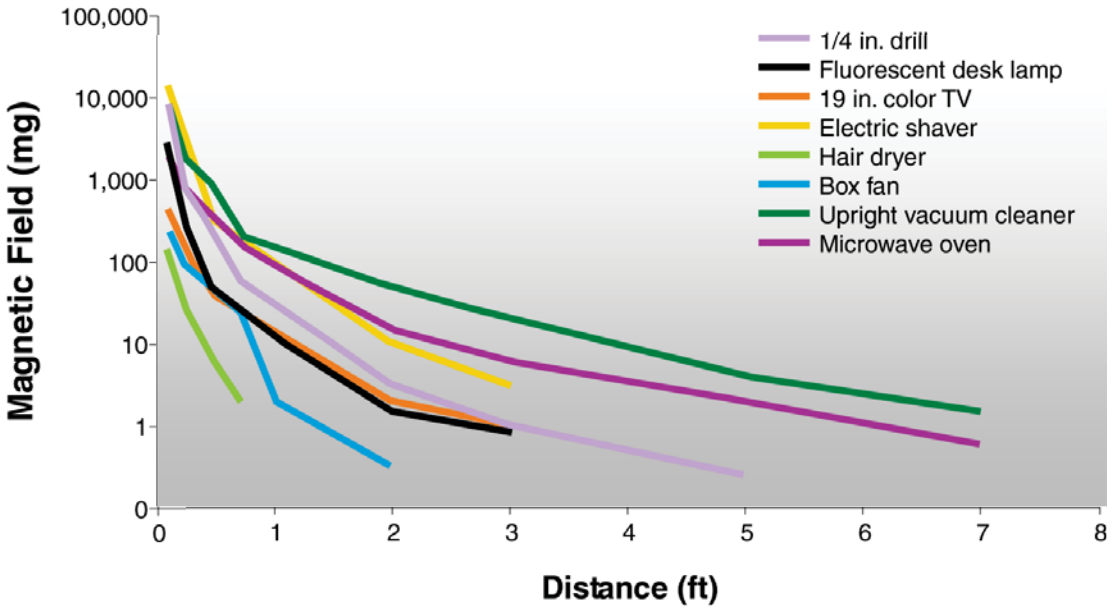




Levels of 60-Hz Magnetic Fields: Various Sources (Savitz et al., 1989)



Magnetic Fields from Home Appliances



Agency Reviews of EMF Research

Role of Science in Public Health

- Investigation
  - Research (primary)
  - Analysis of existing studies
- Interpretation
  - Weight of evidence
  - Characterization of potential risk
- Limitations
  - Cannot guarantee safety
  - Cannot prove that something does not exist

Essential Components of a Weight-of-Evidence Review

- Epidemiology studies – people
- Laboratory studies – animals
- Studies in cells – cells and tissues

A systematic evaluation of the entire body of scientific evidence

Science Basic: Take-Home Messages About Epidemiology

- One epidemiology study is not enough
- All epidemiology studies are not created equal
- Association does not equal causation

Scientific Reviews of EMF Research by National/ International Organizations

- Large panels, balanced composition
- Experts in multiple disciplines
- Defined methodology
- Conclusions represent a consensus

Some Reviews of EMF and Health Research by Scientific Organizations

1998 National Institute for Environmental Health Sciences (NIEHS)

2002 International Agency for Research on Cancer (IARC)

2003 International Commission on Non-Ionizing Radiation Protection (ICNIRP)

2004 National Radiological Protection Board (NRPB)

2005 Federal-Provincial-Territorial Radiation Protection Committee (FPTRPC)

2007 International EMF Project, World Health Organization (WHO)

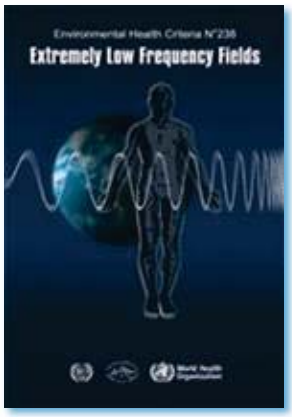
FPTRPC: Canada (2005)

- Established to support government radiation protection agencies in Canada
- Review of epidemiology and laboratory research regarding 60-Hz EMF
- Conclusion
  - "Adverse health effects from exposure to power-frequency EMFs, at levels normally encountered in homes, schools and offices, have not been established."
  - "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."

Major Reviews of EMF and Health Research by Health Agencies after WHO report

- International Commission on Non-ionizing Radiation Protection (ICNIRP, 2010)
- Swedish Radiation Safety Authority (SSM, 2010, 2013, 2014, 2015, 2016)
- Scientific Committee of European Commission (SCENIHR, 2015)

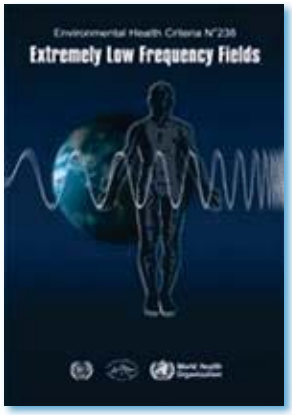
World Health Organization (2007)



Source: World Health Organization (WHO). Environmental Health Criteria 238: Extremely Low Frequency (ELF) Fields. WHO, Geneva, Switzerland, ISBN 978-92-4-157238-5, 2007. Pg. 355-356.

"Consistent epidemiological evidence suggests that chronic low-intensity ELF [extremely low-frequency] magnetic field exposure is associated with an increased risk of childhood leukemia. However, the evidence for a causal relationship is limited, therefore exposure limits based upon epidemiological evidence are not recommended, but some precautionary measures are warranted."

World Health Organization (2007) Precautionary Recommendations



Source: World Health Organization (WHO). Environmental Health Criteria 238: Extremely Low Frequency (ELF) Fields. WHO, Geneva, Switzerland, ISBN 978-92-4-157238-5, 2007. Pg. 372-373.

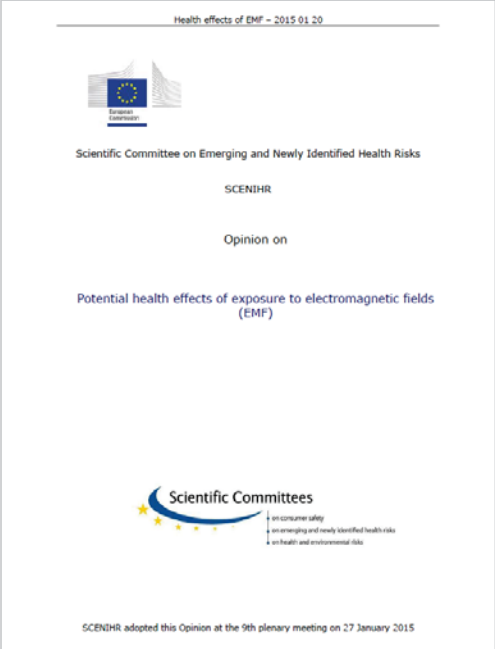
"Provided that the health, social and economic benefits of electric power are not compromised, implementing very low-cost precautionary procedures to reduce exposures is reasonable and warranted."

"Changes to engineering practice to reduce ELF exposure from equipment or devices should be considered, provided that they yield other additional benefits, such as greater safety, or involve little or no cost."

"Government and industry should promote research programmes to reduce the uncertainty of the scientific evidence on the health effects of ELF field exposure."

Scientific Committee on Emerging and Newly Identified Health Risks (2015)

- Exposure to EMF
- Health effects
  - THz, RF, IF
  - ELF
  - Static magnetic fields
  - Combined EMF
  - Co-exposure of EMF and other stressors
- Research recommendations


Health effects of EMF – 2015 01 20

Scientific Committee on Emerging and Newly Identified Health Risks

SCENIHR

Opinion on

Potential health effects of exposure to electromagnetic fields (EMF)

Scientific Committees

SCENIHR adopted this Opinion at the 9th plenary meeting on 27 January 2015

"Only studies that are considered relevant for the task are commented upon in the opinion."

SCENIHR Conclusions on ELF-EMF

- "The new **epidemiological** studies are consistent with earlier findings of an increased risk of childhood leukemia with estimated daily average exposure above 0.3 to 0.4 μT."
- "…**no mechanisms** have been identified…"
- "…no support …from **experimental studies**" & "shortcomings of the **epidemiological studies** prevent a causal interpretation".
- "Overall, existing studies do not provide convincing evidence for a causal relationship between ELF MF exposure and self-reported **symptoms**."
- "Epidemiological studies do not provide convincing evidence of an increased risk of **neurodegenerative diseases**."
- "Recent results do not show an effect… on **reproductive** function in humans."

What are the Views of Scientific Review Groups?

- They agree that there is little evidence suggesting that EMF is associated with adverse health effects
- They believe that there is some epidemiologic evidence for a statistical association of magnetic fields at high average levels with childhood leukemia
- They agree that the laboratory data does not support a link between EMF and any adverse health effect, including leukemia
- They have not concluded that EMF is known to cause any disease

Recent International Developments

- Epidemiology of childhood leukemia
- Epidemiology of neurodegenerative diseases

Epidemiology of Childhood Leukemia

Flurry of Power Line Studies

BJC

FULL PAPER

British Journal of Cancer (2013) 108, 1899 – 1906 | doi: 10.1038/bjc.2013.128

Keywords: childhood leukaemia; epidemiology; incidence; case-control; high-voltage overhead power lines

Childhood leukaemia close to high-voltage power lines – the Geocap study, 2002–2007

C Sermage-Faure[1,2], C Demoury[1,2], J Rudant[1,2,3], S Goujon-Bellec[1,2,3], A Guyot-Goubin[1,2,3], F Deschamps[4], D Hemon[1,2] and J Clavel[1,2,3]

[1]Inserm, Centre for Research in Epidemiology and Population Health (CESP), U1018, Environmental Epidemiology of Cancer Team, Villejuif F-94807, France; [2]Univ Paris-Sud, UMRS 1018, Villejuif F-94807, France; [3]French National Registry of Childhood Hematological Malignancies (NRCH), Villejuif, France and [4]Réseau de Transport d'Electricité (RTE), Coeur Défense, 110 esplanade du Général de Gaulle, La Défense 92932, France

Background: High-voltage overhead power lines (HVOLs) are a source of extremely low-frequency magnetic fields (ELF-MFs), which are classified as possible risk factors for childhood acute leukaemia (AL). The study was carried out to test the hypothesis of an increased AL incidence in children living close to HVOL of 225–400 kV (HVS–HVOL) and 63–150 kV (HV–HVOL).

Methods: The nationwide Geocap study included all the 2779 cases of childhood AL diagnosed in France over 2002–2007 and 30000 contemporaneous population controls. The addresses at the time of inclusion were geocoded and precisely located around the whole HVOL network.

Results: Increased odds ratios (ORs) were observed for AL occurrence and living within 50 m of a VHV-HVOL (OR = 1.7 [0.9–3.6]). In contrast, there was no association with living beyond that distance from a VHV-HVOL or within 50 m of a HV-HVOL.

Conclusion: The present study, free from any participation bias, supports the previous international findings of an increase in AL incidence close to VHV-HVOL. In order to investigate for a potential role of ELF-MF in the results, ELF-MF at the residences close to HVOL are to be estimated, using models based on the annual current loads and local characteristics of the lines.

High-voltage overhead power lines (HVOLs) are one of the major sources of extremely low-frequency magnetic fields (ELF-MFs), considered a possible risk factor for childhood leukaemia. In the absence of any underlying biological hypothesis, the International Agency for Research on Cancer (IARC) classified ELF-MF as possible carcinogens (group 2B), based on epidemiological observations over more than two decades (IARC, 2002). The first meta-analysis concluded that exposure to ELF-MF levels of at least 0.3 μT was significantly associated with an increased incidence of childhood acute leukaemia (AL) (odds ratio (OR) = 1.7 (1.2–2.5) for exposures ⩾0.3 μT (Greenland et al, 2000) and OR = 2.0 (1.3–3.3) for exposures ⩾0.4 μT (Ahlbom et al, 2000)). A recent meta-analysis of the studies published after 2000 (Kheifets et al, 2010) generated consistent but weaker results (OR = 1.4 (0.9–2.1) for exposures ⩾0.3 μT). The large British study by Draper et al (2005) focused on the proximity of VHV-HVOL and showed an association between AL and residence at birth <200 m from a VHV-HVOL (OR = 1.7 (1.1–2.5)) and, to a lesser extent, between 200 and 600 m from a VHV-HVOL (OR = 1.2 (1.0–1.5)). With the same data, the relative risk was not significantly increased for estimates of ELF-MF ⩾0.4 μT (Kroll et al, 2010). High-voltage overhead power lines account for only a fraction of ELF-MF exposure, but, in their near vicinity, constitute the main source of background exposure (Schüz et al, 2000; Mezei et al, 2007).

The aim of the present study was to test whether the risk of AL was increased in the vicinity of HVOL, where children were expected to encounter higher residential exposure to ELF-MF. We followed a two-step approach. The present one aims at investigating the relationship between AL and distance to HVOL. The second step will rely on calculated residential exposure to ELF-EMF based on characteristics of the neighbouring HVOL. The study, the first in France, was based on the geolocation of the lat

childhood
in Denmark

(ORs) were 0.76 [95 % confidence
35] for children who lived 0–199 m
r line and 0.92 (95 % CI 0.67–1.25)
00–599 m away when compared with
>600 m away. When restricting the
00 kV overhead power lines, the OR
200–599 m from a power line was
77) compared to children who lived
er, chance is a likely explanation for
lt was not significant, numbers were
no indications of an higher risk closer
ases were observed within 200 m of

and no higher risk of leukaemia for
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power line is likely to be a chance

d leukaemia · Power lines ·
· Case-control study

J Looper in 1979 [1] found an asso-
ciated exposure to ELF-MF and
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childhood leukemia associated with
above 0.3/0.4 μT. In 2001, a working
nal Agency for Research on Cancer
xposure to ELF-MF as "possibly

Springer

BJC

FULL PAPER

British Journal of Cancer (2014), 1–7 | doi: 10.1038/bjc.2014.15

Keywords: powerline; risk; childhood leukaemia; magnetic field; residential distance at birth

Residential distance at birth from overhead high-voltage powerlines: childhood cancer risk in Britain 1962–2008

K J Bunch*[,1], T J Keegan[2], J Swanson[3], T J Vincent[3] and M F G Murphy[1]

[1]Childhood Cancer Research Group, University of Oxford, Nuw Richards Building, Old Road Campus, Headington, Oxford OX3 7LG, UK; [2]Leicester Medical School, Leicester University, Fulvens Building, Leicester LE1 4PA, UK and [3]National Grid, 1-3 Strand, London WC2N 5EH, UK

Background: We extend our previous study of childhood leukaemia and proximity to high-voltage powerlines by including more recent data and cases and controls from Scotland, by considering 132 kV powerlines as well as 275 and 400 kV and by looking at greater distances from the powerlines.

Methods: Case–control study using 32 515 children from the National Registry of Childhood Tumours 1962–2008, matched controls, and calculated distances of mother's address at child's birth to powerlines at 132, 275, and 400 kV in England, Wales and Scotland.

Results: Our previous finding of an excess risk for leukaemia at distances out to 4[illegible]m declines over time. Relative risk and 99% confidence interval for leukaemia, 0–199 m compared with >1000 m, all voltages: 1965–4.50 (0.97–20.83), 2006–0.71 (0.49–1.03), aggregate over whole period 1.12 (0.90–1.38). Increased risk, albeit less strong, may also be present for 132 kV lines. Increased risk does not extend beyond 600 m for lines of any voltage.

Conclusions: A risk declining over time is unlikely to arise from any physical effect of the powerlines and is more likely to be the result of changing population characteristics among those living near powerlines.

Exposure to power-frequency electric and magnetic fields (EMFs) and associated risks of various diseases have been studied for >30 years. Laboratory evidence has been largely negative (IARC Working Group on the Evaluation of Carcinogenic Risks to Humans, 2002; World Health Organization, 2007), and no plausible biological mechanisms have been identified (Swanson and Kheifets, 2006), though candidates remain, for example, free radicals' (Athlen, 1976; Bruckbauer and Mclauchlan, 1990). Epidemiological studies have provided inconsistent support for a link between EMFs and various diseases (IARC Working Group on the Evaluation of Carcinogenic Risks to Humans, 2002; World Health Organization, 2007; Kheifets et al, 2010; Elliott et al, 2011), but a relatively consistent association has been found for magnetic fields and childhood leukaemia (Ahlbom et al, 2000; Greenland et al, 2000; Kheifets et al, 2010a).

The epidemiological evidence for effects on health from exposure to power-frequency electric fields is largely negative (World Health Organization, 2007; Kheifets et al, 2010a). The remaining concern is principally with power-frequency magnetic fields, which are classified as 'possibly carcinogenic' (IARC Working Group on the Evaluation of Carcinogenic Risks to Humans, 2002; World Health Organization, 2007), and with residential proximity to high-voltage powerlines, which are one source of such fields.

In 2005, we reported a relationship of childhood leukaemia risk 1962–95 in England and Wales (E&W) with distance of mother's usual residence at the time of birth of the child from the National Grid pylon (NGP) overhead powerlines [at 400/275 kV powerlines in E&W plus a small fraction of 132 kV lines] (Draper et al, 2005). Leukaemia risk was increased within 600 m of the lines, compared

to transmission
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between childhood cancer risk and
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ethods of case ascertainment, control
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er lines up to 2000 m and included
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to achieve high specificity, which is

mber 2013 doi:10.1038/bjc.2013.68
hood cancer power lines;

than 600 m from a high-voltage line
ved within 200 m had a relative risk of
those who lived between 200 and 600 m
3 (95% CI, 1.02–1.48).[10] As the MF are
beyond 30 m,[11] the apparent risk
greater than would be expected if
age lines were a causal agent. There-
did not appear to be fully compatible
are on ELF MF and childhood leukaemia.
dations of note was the dependence
e selected control subjects rather than
thermometers, suggesting the potential
in the study.[12] The study by Draper et al,
ciation between residential distance
lhood cancers of the central nervous

ents a detailed description of the study
certainment, control selection, exposure
ysis plan of a study that attempts to
study of Draper et al,[10] In a different
in the study by Draper, and unlike many
in the address at diagnosis, we focus

Leukaemia, UCA Fielding School of Public Health,
School of Public Health, Los Angeles, California, USA;
ondon Working, University of Southern California,
espondence to: Dr Lesley Rodney, Department of
ER 1TU, UK.

French Power Line Study

- Sermage-Faure et al., BJC 2013
  - 2,779 cases of acute leukemia (< 15 years), 2002–2007
  - 30,000 controls randomly selected (5000 per study year)
  - Geocoded address information
    - Time of diagnosis/inclusion
    - 70% and 77% with exact address
  - Geocoded proximity to nearest transmission line
    - Voltages of 400 kV, 225 kV, 150 kV, 90 kV, 63 kV

Danish Power Line Study

- Pedersen et al., Cancer Causes Control 2014
  - 1,698 cases of leukemia (< 15 years), 1968–2006
  - 3,396 controls randomly selected (individually matched)
  - Geocoded address information
    - Time of birth
  - Geocoded proximity to nearest transmission line
    - Voltages of 132 kV to 400 kV
    - Sub-analysis for 220-400 kV lines

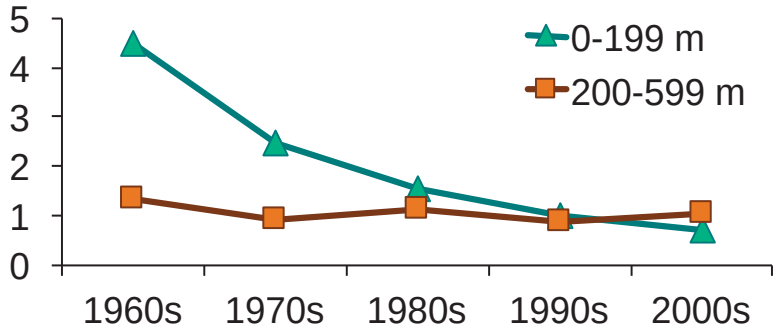
UK Power Line Study

- Bunch et al., BJC 2014
  - Extension and update to Draper et al 2005
    - Additional 13 years
    - Inclusion of lower voltage lines (132 kV)
    - Inclusion of Scotland
  - 53,515 cases of cancer (< 15 years), 1962–2008
  - 66,204 controls randomly selected (individually matched)
  - Address at birth
  - Distance to overhead transmission lines
    - Voltages of 132 kV, 275 kV and 400 kV

UK Power Line Study

Results

Childhood leukemia OR by decade

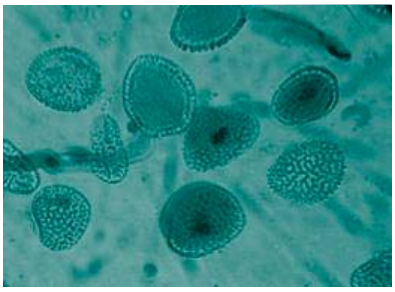


California Power Line Study

- Crespi et al., BJC 2016
  - Replication of Draper et al 2005 in California
  - 5788 leukemia and 3308 CNS cancer cases (< 15 years), 1988–2008
  - Controls randomly selected (individually matched)
    - Additional controls for methodological comparisons
  - Address at birth
  - Distance to overhead transmission lines
    - Voltages of 100-500 kV (some 60-69 kV)

Large-Scale, Life-Time Laboratory Animal Studies

- Chronic Magnetic Field Carcinogenicity Bioassays
  - Yasui et al., 1997
    - Rats exposed to 50 Hz fields up to 5 mT
  - Mandeville et al., 1997
    - Rats exposed to 60 Hz fields up to 2 mT
  - Boorman et al., 1999
    - Rats exposed to 60 Hz fields up to 1 mT
  - McCormick et al., 1999
    - Mice exposed to 60 Hz fields up to 1 mT
- Overall, no consistent increase in any type of cancer



Epidemiology of Alzheimer's Disease

Power Lines and Alzheimer's Disease in Switzerland

American Journal of Epidemiology Advance Access published November 5, 2008

DOI:10.1093/aje/kwn297

Original Contribution

Residence Near
Longitudinal Stu

Anke Huss, Adrian

Initially submitted May

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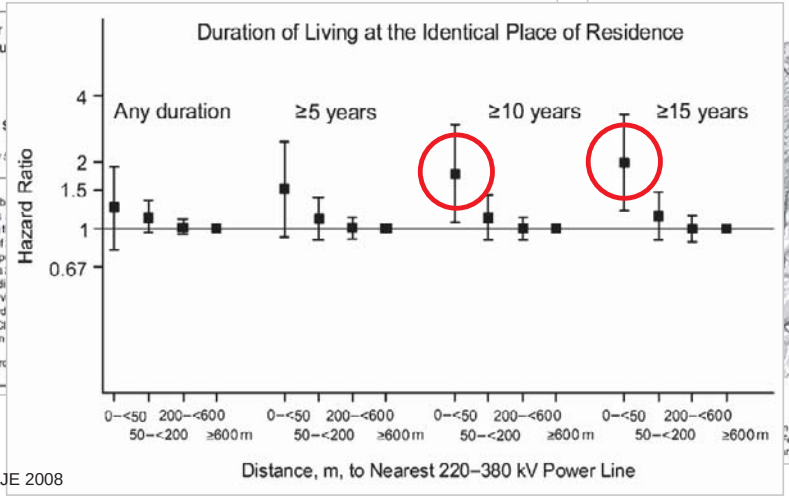
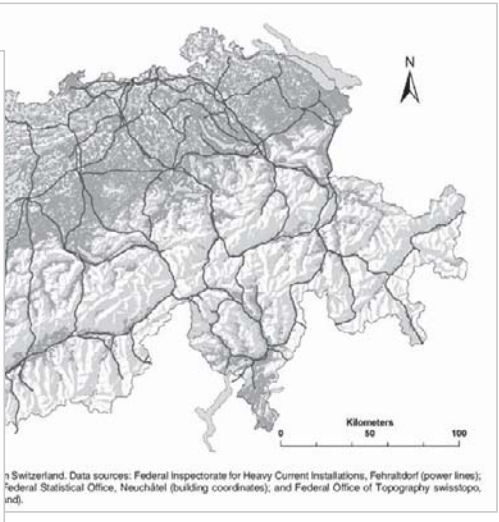




n Switzerland. Data sources: Federal Inspectorate for Heavy Current Installations, Fehraltdorf (power lines); Federal Statistical Office, Neuchâtel (building coordinates); and Federal Office of Topography swisstopo, nd).

Source: Huss et al., AJE 2008

Replication of Swiss Study in Denmark

- Danish registry (1994–2010)
  - Identification of *new* cases
  - *Geocoded* address histories
- Danish power companies
  - GIS location data on power lines
  - Current and historical load data
  - Power line configurations
- Results
  - No consistent association between Alzheimer's disease (or other NDD) and residential distance to power lines

Original Contribution

Residential Distance to High-voltage Power Lines and Risk of Neurodegenerative Diseases: a Danish Population-based Case-Control Study

Patrizia Frei, Aslak Harbo Poulsen*, Gabor Mezei, Camilla Pedersen, Lise Cronberg Salem, Christoffer Johansen, Martin Röösli, and Joachim Schüz

* Correspondence to Aslak Harbo Poulsen, Danish Cancer Society Research Center, Danish Cancer Society, Strandboulevarden, 2100 Copenhagen Ø, Denmark (e-mail: aslak@cancer.dk).

Initially submitted March 22, 2012; accepted for publication July 23, 2012.

The aim of this study was to investigate the possible association between residential distance to high-voltage power lines and neurodegenerative diseases, especially Alzheimer's disease. A Swiss study previously found increased risk of Alzheimer's disease for people living within 50 m of a power line. A register-based case-control study including all patients diagnosed with neurodegenerative diseases during the years 1994–2010 was conducted among the entire adult population of Denmark. Using conditional logistic regression models, hazard ratios for ever living close to a power line in the time period 5–20 years before diagnosis were computed. The risks for developing dementia, Parkinson's disease, multiple sclerosis, and motor neuron disease were not increased in persons living within close vicinity of a power line. The risk of Alzheimer's disease was not increased for ever living within 50 m of a power line (hazard ratio = 1.04, 95% confidence interval: 0.69, 1.56). No dose-response according to number of years of living within 50 m of a power line was observed, but there were weak indications of an increased risk for persons diagnosed by the age of 75 years. Overall, there was little support for an association between neurodegenerative disease and living close to power lines.

dementia; environmental exposure; magnetic fields; neurodegenerative diseases

Abbreviations: CI, confidence interval; CPR, Central Population Register; ELF-MF, extremely low frequency magnetic field(s); HR, hazard ratio; ICD-10, *International Classification of Diseases, Tenth Revision*.

Transmission of electric power is a prerequisite of modern life and gives rise to extremely low frequency (ELF) electric and magnetic fields (MF) in the vicinity of power lines. ELF-MF have been classified as "possibly carcinogenic" by the International Agency for Research on Cancer because of limited evidence in humans in relation to childhood leukemia and inadequate evidence in experimental animal studies, as well as a lack of a known biological mechanism (1, 2). For noncancer endpoints, a 3- to 4-fold risk increase for Alzheimer's disease related to occupational exposure to ELF-MF was suggested in an initial report by Sobel et al. (3). Subsequent studies summarized in reviews and meta-analyses on occupational ELF-MF exposure (4–6) found less consistent results, but indications of an increased risk of Alzheimer's disease remained, with reported risks on the order of 1.5–2 for exposure levels of >0.1 μT to >0.5 μT (4). A Swedish study suggested that the increased risk might be restricted to cases with disease onset by age 75 years (7), which was confirmed in 7 subsequent studies (8, 9), and the risk was found to be higher in men than in women (8). For other neurodegenerative diseases, amyotrophic lateral sclerosis, the most frequent motor neuron disease, has been quite consistently linked with electrical occupations (3, 6). Even if an association were found in workers, extrapolation to the general public would remain difficult—for example, due to occupational coexposure to other potential risk factors, particularly electric shocks (6).

Recently, the first study analyzing a possible association between residential ELF-MF exposure and neurodegenerative diseases was conducted in Switzerland (10). An increased risk of Alzheimer's disease was observed for people living within 50 m of a high-voltage power line compared with people living at a distance of ≥600 m, and risks were highest for people who had lived within 50 m of a

970 Am J Epidemiol. 2013;177(9):970–978

Source: Frei et al., AJE 2013

Danish Results: Alzheimer's Disease

Distances to power line, 132–400kV (m)	Number of Cases	Number of Controls	Hazard Ratio	95% Confidence Interval
0-<50	28	165	1.04	0.69, 1.56
50-<200	184	1,178	0.95	0.81, 1.12
200-<600	907	5,181	1.05	0.98, 1.13
200-<600	19,456	106,693	1	Referent

~1

Cumulative time within 50m of a power line, 132–400kV	Number of Cases	Number of Controls	Hazard Ratio	95% Confidence Interval
≥10 years	11	95	0.71	0.38, 1.33
5-9 years	10	31	1.79	0.87, 3.68
< 5 years	7	39	1.08	0.48, 2.45
Always ≥ 600m	19,456	106,693	1	Referent

~1

Research Summary

- No conclusion that EMF causes disease
- No consistent statistical association between magnetic fields and any disease
  - Except for observation of higher average magnetic fields (>3–4 mG) among children with leukemia in some studies
  - Weaker or no association in more recent studies
- Short and long-term animal studies as a whole do not show adverse effects
- Laboratory studies of cells and tissues have not confirmed any mechanism for harm

Overall Conclusion of National and International Agencies

- The NIEHS, WHO, ICNIRP and SCENIHR did not conclude that EMF is the cause of any disease.

  "Based on recent in-depth review of the scientific literature, the WHO concluded that current evidence does not confirm the existence of any health consequences from exposure to low level electromagnetic fields."

- World Health Organization "What are electromagnetic fields?"

Livestock, Wildlife, Plants

Research Studies of Livestock, Wildlife, and Crops

- Farm and observational studies of cattle near high-voltage transmission lines
- Experimental studies of cattle, sheep, swine
- Migration, grazing patterns of elk and reindeer
- Field studies of corn, soybeans, etc.
- Experimental studies of > 70 plant species

Overall, no effect of 400kV, 500kV, 765 kV transmission lines or EMF exposures

Electronic Devices

Interference with Implanted Medical Devices

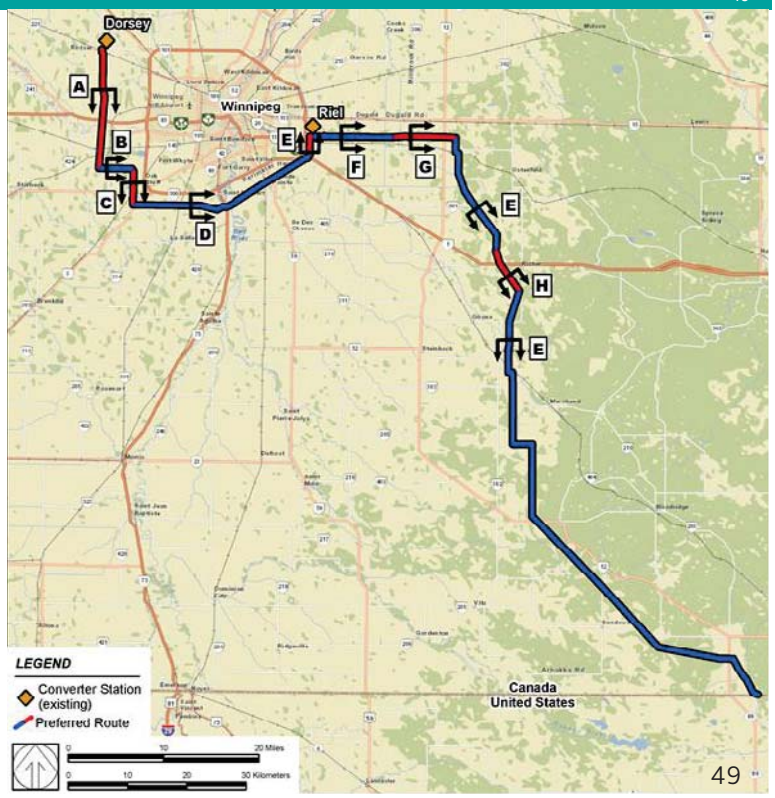
- Modern devices include design features that make devices more immune to outside electric signals
  - Shielding by metallic cases
  - Built-in filters, switches
  - Programmable settings of sensitivity
- Potential for interference exist with EMF sources (e.g., cell phones, anti-theft devices, MRI)
  - Power lines are not known to result in medically confirmed and documented interference events

MMTP Assessment

Manitoba: Minnesota Transmission Project

- Project components
  - Dorsey-Iron Range 500kV line (D604I)
    - Routed on existing ROW except sections E1, E2
  - Equipment at Dorsey, Riel & Glenboro South stations

Preferred Route of MMTP Line



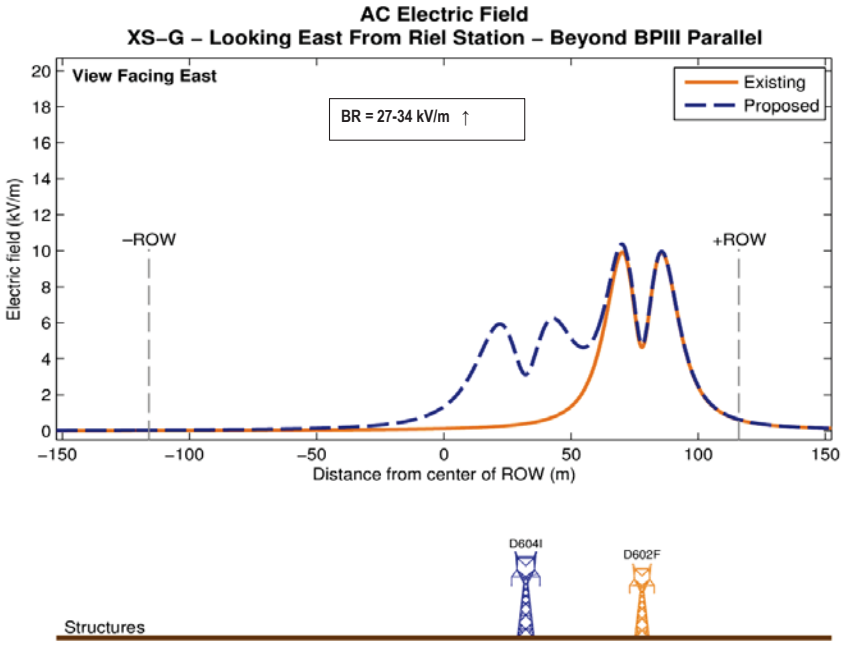
Exposures Evaluated in EIS

- Electric field (including induction on large farm combine)
- Magnetic field
- Audible noise
- Radio noise

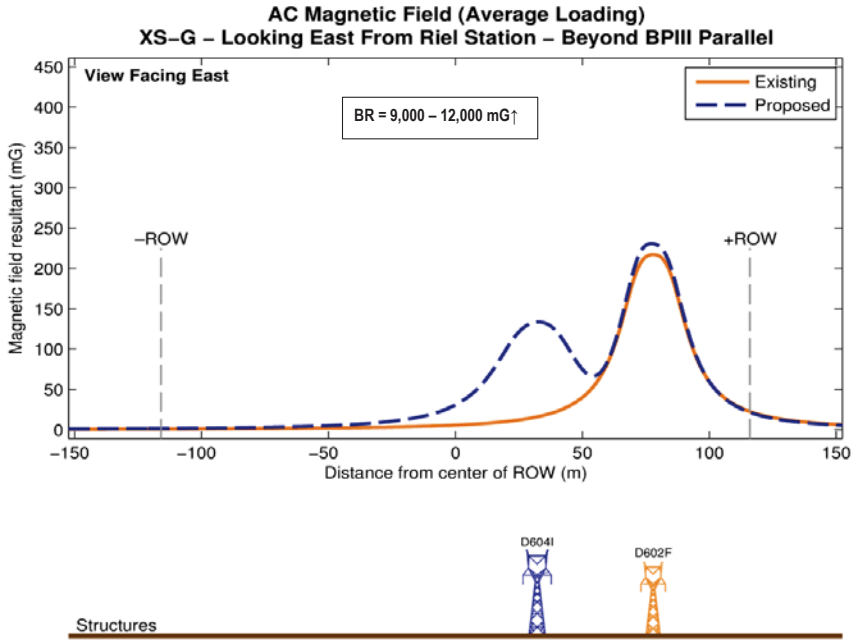
Configuration of MMTP Line D604I in Route Section G

- One of the route sections with the highest EMF levels at edge of ROW

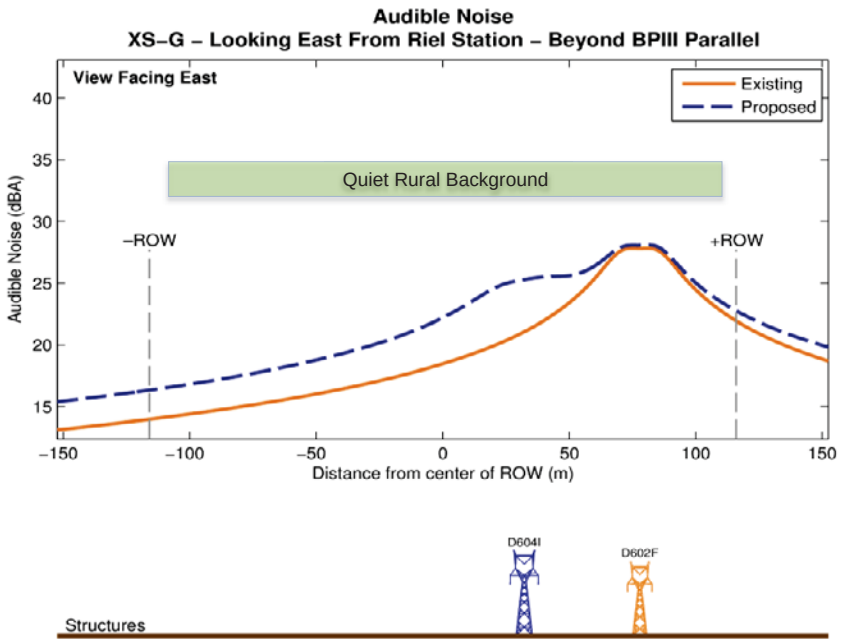
Calculated Electric Field—Route Section G



Calculated Magnetic Field—Route section G



Calculated Audible Noise—Route Section G



EMF Exposure Guidelines

EMF Standards and Guidelines Published by Scientific Advisory Organizations

- International Commission on Non-Ionizing Radiation Protection (ICNIRP, 2010)
- IEEE International Committee on Electromagnetic Safety (ICES, 2002/2007)

Comparison of EMF Guidelines

	ICNIRP (2010)	ICES (2002/2007)
Controlled		
Magnetic Field	10,000 mG	27,100 mG
Electric Field	8.30 kV/m	20.00 kV/m
General Public		
Magnetic Field	2,000 mG	9,040 mG
Electric Field	4.2 kV/m	5.00 kV/m[1]

Induced Currents on Vehicles

- Large vehicles parked under transmission lines can collect charge if not well grounded
- Assessment made of currents induced on largest expected vehicle (a large farm combine)
- CSA (2015) limits the short-circuit level to 5 milliamperes (mA)
  - Excluding Sections F and G, the maximum induced current value for farmland increases from 1.7 mA (Sections A and B) under existing configurations to 3.3 mA (Sections B, C, D, and E2) under proposed configurations.
  - In Sections F and G the induced current does not change as a result of the project (existing sources dominate and result in current of 5.6 mA)

Induced Currents on Vehicles

- In the RVTC the induction is just above the CSA limit of 5 mA
- RVTC is owned 100% by Manitoba, but some land is being used for farming activities.
- To mitigate potential issues Manitoba Hydro will reinforce standard electrical safety messages and educate farmers in the RVTC about appropriate safety measures associated with induced currents.
- Induced voltage depends on
  - Vehicle size
  - Electric field level
  - Isolation of person touching vehicle to ground
  - Conservative calculations in RVTC: 5.6 mA
- Mitigated by
  - Drag chain
  - Insulating boots/gloves

Summaries from EIS reports

- ". . . MMTP will increase EMF, AN, and RN on the transmission line right-of-way (ROW), but will result in only a small change in these parameters at the edge of the ROW and beyond. All [MTTP] transmission line EMF, AN, RN, and induced current levels are calculated to comply with standards and guidelines applied as health and environmental assessment criteria."
- "The current consensus among the numerous national and international scientific agencies that have reviewed this extensive body of research . . . is that there are no known adverse health consequences of exposure to ELF EMF at the levels generally found in residential and occupational environments, including proximity to electric transmission and distribution facilities. Results from recent scientific research do not provide evidence to alter this conclusion."

Questions and Answers