J. Aust. Coll. Nutr. & Env. Med. Vol. 25 No.2 (August 2006) pages 3-6 & 9

Briefing Report on Electromagnetic Fields: Health Effects, Public Policy and Site Planning

CL Sage, MA **and SA Sage,** BS
Sage Associates, Santa Barbara, California, USA

There is renewed interest in EMF since the State of California Department of Health Services, the World Health Organization and the National Institutes of Environmental Health Sciences have recently concluded that EMF exposure may be a human carcinogen

Abstract

Recent decisions by national and international public health agencies have categorized extremely-low frequency electromagnetic fields (ELF-EMF) as a Group 2B (possible) Carcinogen under the World Health Organization International Agency for Cancer Research (IARC) standardized criteria for evaluation of carcinogens.

This is a briefing report that provides overview of the major issues and evolving public policies regarding exposure to electromagnetic fields (extremely-low frequency or ELF-EMF 60-hertz electric power frequency electric and magnetic fields). The actions of six (6) agencies are summarized to characterize new 'milestones' in response to the growing body of evidence linking ELF-EMF to health effects.

Key scientific studies on adult and childhood cancers are summarized that report increased risk of cancer with exposure levels of ELF-EMF.

Average residential and occupational exposures based on national studies are provided for comparative purposes (0.5 – 0.9 mG for residential; 1 – 2 mG for typical office).

Building construction can routinely achieve 0.1 – 0.2 mG ambient ELF-EMF exposures where attention is given to correct wiring, grounding and bonding of electrical wiring, and distancing from electrical subpanels and other sources is observed.

Background

In the last decade, EMF has been intensively studied and determined by both California State and international health agencies to be a concern for public health. EMF has been considered an environmental planning constraint that should be taken into account in land planning and site design since at least 1982. Many references are available that document concerns about power line impacts, including property value loss, visual impairment, noise and electromagnetic field issues (both the perception of risk and evidence that EMF is a possible carcinogen). Land owners, developers, merchant builders, school officials, utility planners and land planners all take EMF issues into account in various ways, to reduce the potential for adverse impacts and liability. Some utilities now disclose the "presence of EMF or hazardous substances" in the sale of properties with transmission lines (CPUC, 2005).

Previous Actions

The California Department of Education mandated in 1989 that new school construction observe setbacks from power lines and these requirements were codified in Title 5. This was done as a precautionary measure to reduce electromagnetic fields (EMF) exposure to school children, faculty and staff at California schools, while study continued on potential health and safety risks associated with EMF.

The California Public Utilities Commission issued a ruling in 1993 that required California investor-owned utilities to develop transmission, distribution and substation siting guidelines that incorporate planning for no- and low-cost EMF reduction. These documents show how the EMF impacts from transmission lines, for example, can be reduced or eliminated by changes in construction and operation of power lines.

New Milestones for EMF in Land Planning

There is renewed interest in EMF since the State of California Department of Health Services, the World Health Organization and the National Institutes of Environmental Health Sciences have recently concluded that EMF exposure may be a human carcinogen (Group 2B or possible carcinogen). These relatively new findings have taken a decade of study to confirm. Today, there are six important milestones that have occurred to make EMF again a 'front-burner' issue. These are summarized below:

1) On June 24, 1998, the National Institute for Environmental Health Sciences (NIEHS) Working Group voted to classify extremely low frequency (ELF) EMF such as those from power lines to be classified a Group 2B carcinogen (possible carcinogen) under stringent standards established by World Health Organization International Agency for Cancer Research (IARC). Other possible carcinogens classified within the Group 2B designation are DDT and lead, for which there is sufficient evidence to implement avoidance measures for children and adults.

The Working Group Report specified that: "classification of ELF EMF as a possible carcinogen is a conservative, public health decision based on limited evidence for an increased occurrence of childhood leukemia and

an increased occurrence of chronic lymphocytic leukemia in occupational settings".

The magnetic field levels which were identified in numerous scientific articles reporting increased risk of leukemia, and which were relied upon by the NIEHS Working Group are in the 2-5 mG range. Therefore, prudence would establish firm EMF limits below 2 mG by some reasonable margin of safety.

The NIEHS Report to Congress based on the Working Group Report stated that the power industry should continue the practice of siting power lines to reduce exposures and continue to explore ways to reduce the creation of magnetic fields around transmission and distribution lines without creating new hazards (for linemen). The recommendations also included direction for the National Institute of Occupational Safety and Health, and OSHA to review whether current EMF standards are adequate for workers.

2) The National Institutes of Environmental Health Sciences (NIEHS) issued a report to Congress in 1999 that urged utilities to continue to distance new power lines from where people live, work and go to school. This was based on the NIEHS Working Group Report (prepared by nearly one hundred research scientists), which concluded that EMF is classifiable as a Category 2B carcinogen (about 300+ substances are on the Category 2B – possible Carcinogen list). The NIEHS Report stated that "although the exposure metrics used as surrogates for exposure to magnetic fields are of varying precision, it is difficult to find an explanation other than exposure to magnetic fields for the consistency of the reported excess of childhood leukemia in studies conducted in different countries under different conditions, with different study designs." (Portier and Wolfe, 1998).

3) The International Agency for Cancer Research (IARC) of the World Health Organization concluded that EMF is a Category 2 B carcinogen (2001).

4) The California Department of Health Services initiated a major seven-year $7 million study of EMF at the direction of the CPUC to specifically address health risks from EMF and to identify issues at California schools. The DHS EMF Program Report was issued in Fall 2002. It contains findings that EMF exposure is a risk factor for childhood leukemia (and other diseases). It is classifiable as a 2 B Carcinogen (Possible Carcinogen) depending on the type of cancer and the risk assessment criteria used. It is expected that new interest will be generated in the EMF health risk issue, particularly at California schools. Public interest in the EMF issue was strong in the early 1990s, and waned with a decade of 'studies in progress.'

5) The National Radiation Protection Board (United Kingdom) has determined from a review of the available scientific research on cancer and EMF, that there is limited evidence that residential exposure to ELF magnetic fields (EMF) is carcinogenic in children (NRPB, 2001). This review is significant because prior to this review, the NRPB had taken a position that EMF is not harmful to health in humans.

6) The World Health Organization and the European Environmental Agency (2002) have issued a joint report on Children's Health and Environment: A Review of Evidence. Chapter 13 of the report titled Electromagnetic Fields states that:

"The classification of power-frequency electromagnetic fields (EMF) as a possible human carcinogen is partially based on studies of childhood leukemia."

EMF Studies Relevant to School Site Selection and Buildings

Childhood and adult cancer studies that report increased risk of some cancers, primarily leukemia, and adult miscarriage risk are discussed below. There is a significant body of scientific evidence available beyond this summary which reports increased risk of childhood and adult cancers, ALS, and miscarriage with EMF exposure (Sage, 1996; Sage et al., 2004). Exposure ranges that are associated with increased risk of cancer and miscarriage are in the 2-5 mG (TWA) and to 16 mG range (intermittent), respectively. Health studies begin to show elevated risk for childhood leukemia at 1.4 mG and above (Green, 1999).

Children, EMF and Cancer Studies

In 1993, Dr Maria Feychting reported that children living in residences near high voltage power lines had increased risk of cancers, particularly of leukemia. The distance within 325 meters (about 1000 feet) from 220 kV to 400 kV power lines was investigated. For EMF exposures of 4 mG and above, the risk for cancer was 5.6 (560% increase). For EMF exposures less than 2 mG the risk of leukemia was 2.0 (200% increase), and for 2 mG and above the risk was reported to be 2.7 (270% increase). For EMF exposures of 3 mG and above the risk of leukemia increased to 3.8 (380% increase).

In 1993, Dr Daniel Wartenberg published a report that looked at childhood cancers including leukemia in relation to EMF exposure level. Childhood cancer risk was 1.4 (40% increase) or EMF exposure at 2 mG and above but for EMF exposure at 3 mG and above, the risk increased to 2.3 (230% increase). For childhood leukemias, a cutpoint of 2 mG and above resulted in a risk of 1.9 (90% increase), but for a cutpoint of 3 mG and above the risk was 3.7 (370% increase). For ALL, a type of childhood leukemia a cutpoint of 2 mG and above resulted in increased risk of 1.6 (60% increase) but a cutpoint of 3 mG and above resulted in an increased risk of 5.3 (530% increase). These findings suggest that risk exists at 2 mG and above, but dramatically increases when EMF exposures of 3 mG and above are examined. Thus, the choice of EMF exposure level (whether one looks at 1, 2 or 3 mG and above) will have a major influence on what level of risk is identified.

Olsen (1993) reported that Danish residences near high voltage power lines had more cancers in children under age 14. At 4 mG and above, the risk of all major cancers was 5.6 (560% increase), and at greater than 1 mG, the risk of malignant lymphoma was 5.0 (500% increase). Washburn (1994) reported that childhood leukemia risk was 1.49 (a 49% increased risk) when considering 13 epidemiological studies in a meta-analysis conducted. Taking all thirteen studies on childhood leukemia into account, there was a statistically significant increase in risk and a dose relationship where higher exposures resulted in increased risk.

The Scandinavian researchers who originally published the Swedish studies on childhood leukemia and power lines later reported that taking into account both the Swedish and Danish childhood cancer data in a meta-analysis. The results were reported to show that taken together, there was a 2-fold (or doubling) of risk of childhood leukemia for calculated magnetic field levels greater than 2 mG and above. At 5 mG and above the risk increased to 5.1 RR, or a 510% increase. The results support an association between magnetic field exposure and childhood leukemia (Feychting, 1995).

In 1995, Dr Joseph Bowman reported that exposure to both elevated AC fields and geomagnetic (or DC static) fields at reasonance points for potassium and calcium resulted in an increase in risk for childhood leukemia of 9.2 (a 920% increase). The discussion points to the possibility that certain geographic areas of the earth that have a geomagnetic (natural) field that, when combined with elevated AC magnetic fields (from power lines or other sources of electricity) may result in increased risk for disease. In this case the homes of children at DC reasonance frequencies for potassium and calcium that also had elevated AC magnetic fields showed a much higher risk for leukemia.

Feychting (1997) reported that subjects who lived within 300 meters of transmission lines for at least one year, those with EMF exposures above 2 mG had a doubling of risk for some leukemias. Those who worked in fields at or above 2 mG also showed a doubling of risk. But for those who both worked and lived in fields at or above 2 mG, there was a 6-fold (600%) increase in risk for AML and CML. Cumulative exposure to EMF may therefore be an important factor if individuals are exposed at both home and work, or home and school.

Michaelis (1997) reported a 230% increased risk (OR 2.3) for childhood leukemia at EMF exposures at 2 mG and above; and a 710% increased risk (OR 7.1) for children less than four years old who slept in bedrooms with EMF levels over 2 mG.

Wartenberg (1998) reported in a meta-

analysis of 11 childhood leukemia studies for the National Academy of Sciences that "the studies provide relatively strong and consistent support for a somewhat weak, elevated risk of leukemia for children living in proximity to power lines." The data cannot be explained on the basis of random fluctuations alone. The overwhelming majority of studies show an increase in risk. He found statistically significant risk nine times more often than would be expected by chance. There would have to be at least a dozen unpublished negative studies to be due to publication bias (not publishing studies showing no result). Therefore, the conclusion was strongly supportive of a link between EMF and childhood leukemia.

Linet (1998) reported that childhood leukemia rates were increased with exposures at 2 mG and above (53% increase in cancer), at 3 mG and above (72% increase in cancer), and between 4 mG and 5 mG (641% increase in cancer). There were fewer or no exposed children above these levels. The Linet study used a control level of 0.65 mG and below, which is a relatively high 'non-exposed' comparison, so the rise in childhood leukemia would be under-estimated in comparison to a truly unexposed control group, or a control group with lower exposures. Note that, in comparison to the Green study (above), young children with average exposure of only 1.4 mG showed a five-fold risk of cancer.

In 1999, Dr Lois Green of the University of Toronto found the leukemia risk of children in the highest exposure group was 4.5 times higher (450% higher), after adjusting for possible confounders, than that of children in the least-exposed group. This was a statistically significant difference. Further, the study reported a difference in risk between younger and older children. For children less than six years old at the time of diagnosis and with average exposures over 1.4 mG, the risk was 5.7 times higher (a 570% higher risk) than for those with exposures of less than 0.3 mG, and this difference was also statistically significant. The corresponding risk ratio among older children is 1.6 but non-significant.

Ahlbom (2000) reported a doubling of risk for childhood leukemia in a meta-analysis of nine childhood leukemia studies for exposures equal to or above 4 mG as compared to exposures less than 1 mG, using a geometric mean for exposure.

Greenland (2000) reported a 68% increased risk for exposures greater than 3 mG as compared to exposures of less than 1 mG, using a time-weighted average for exposure.

Schuz (2001) reported an odds ratio of 5.9 (590% risk) for childhood leukemia for children based on residential EMF exposures in Germany.

Wartenberg (2001) reported in a meta-analysis of childhood leukemia studies and EMF that "Overall, I see largely positive results with small to moderate size effects."

"These studies are unlikely to be changed by additional studies unless those studies are extremely large and produce markedly different results. If one chooses to use these summary estimates for interpretation, given the widespread exposure to magnetic fields they suggest perhaps as much as a 15-25% increase in the childhood leukemia rate, which is a large and important public health impact."

Kheifets (2005) reported that "consistent epidemiological evidence demonstrates a small risk of extremely low frequency (ELF) electromagnetic fields (EMF) on childhood leukemia, thus leading to an International Agency for Research on Cancer (IARC) classification of ELF as a 'possible' or 2B carcinogen in 2002." Further, "(P)ooled analyses points to the occurrence of an effect of ELF on leukemia at high levels of exposure, described as greater than 0.3 or 0.4 μT."

Children with leukemia who are recovering in high ELF environments defined as 0.3 μT and greater are reported to be 4.5 times as likely to die than children with leukemia at ELF exposures less than 1 μT (Foliart, 2006).

Adult Exposures, EMF and Leukemia / Miscarriage

Dr Sam Milham published a report in 1982 showing an increase in leukemia incidence among men who were exposed to EMF at work. Exposure led to an increased risk factor for all types of leukemia by 1.39 (39% increase) and an increase risk factor for acute leukemia of 1.63 (63% increase).

In 1982 William E. Wright published a study that also found an increase risk for men who were exposed to EMF in the workplace. The risk for all leukemia is 1.28 (28% increase), 1.72 (72% increase) for acute leukemia, and 2.07 (207% increase) for acute myeloid leukemia.

In 1983 Michael Coleman investigated the relationship of mortality of electrical workers and exposure to EMF. The null hypothesis was that the incidence of leukemia would be equal among all occupations. The results showed an increase risk for leukemia in all electrical occupations by 17%, and an increase risk of up to 146% based on specific electrical occupations.

In 1985 Dr Priscilla Gilman published a study linking leukemia risk with male coal miners who had prolonged EMF exposure. A statistically significant risk for all leukemia was found to be 2.53 (253% increase), for chronic leukemia 8.22 (822% increase), 4.74 (474% increase) for myelogenous leukemia, and 6.33 (633% increase) for chronic lymphocytic leukemia.

In 1986 Dr Ulf Flodin reported that an association between electrical workers and their incidence of acute myeloid leukemia was statistically significant with a risk of 3.8 (380% increase). In 1990 Dr Flodin again published findings from his new study which showed a risk of 2.1 (210% increase) for electrical workers exposed to EMF and their likelihood of contracting acute myeloid leukemia.

In 1986 Frank B. Stern found a significantly elevated risk for electricians and welders of developing leukemia from their occupational exposure to EMF. Stern found an electrician's risk for leukemia to be 3.00 (300% increase) and a 6.00 (600% increase) risk for lymphatic leukemia. A welder's risk for leukemia was found to be 2.25 (225% increase) and 3.83 (383% increase) for lymphatic leukemia.

In 1988 J. Juutilainen from the University of Kuopio, Finland reported an increase risk of leukemia for electrical workers in Finland. Linemen and cable jointers had the highestrisk of 3.13 (313% increase) and all electrical occupations combined have an increased risk of 1.23 (23% increase).

In 1989 Neil Pearce found an increase in risk of leukemia for electrical workers in New Zealand. An increased risk for leukemia was found to be 1.62 (62% increase). Certain categories of electrical workers had a much higher risk of leukemia. Radio and television repairers had a risk of 7.86 (786% increase), electricians had a risk of 1.68 (68% increase), electric lineman had a risk of 2.35 (235% increase), and power station operators had a risk of 3.89 (389% increase).

In 1990, Dr Bastuji-Garin investigated the link between acute leukemia occurrence and occupational exposure to EMF. Workers exposed to EMF were found to have a significantly higher risk of contracting acute leukemia of 4.04 (404% increase) after adjustments were made for possible confounding exposures.

Dr Siv Tornqvist from the National Institute of Occupational Health in Sweden reported in 1991 an increase in incidence of leukemia in some electrical occupations where EMF exposure was prevalent. An increase risk for leukemia was found among electrical engineers and technicians of 1.3 (30% increase). An increase risk for leukemia was also seen among workers in the telephone and machine industries of 2.1 (210% increase) and 2.6 (260% increase) respectively. Risk for chronic lymphoid leukemia was also increased for electrical engineers and technicians to 1.7 (70% increase) as well as for workers in the machine industry to 4.8 (480% increase). Linesman and power linesman also were found to have an increased risk for chronic lymphoid leukemia of 2.0 (200% increase) and 2.8 (280% increase). Risk for acute myeloid leukemia for miners was elevated to 2.2 (220% increase) and for iron/ore miners to 5.7 (570% increase).

In 1991 Dr Youngson studied the relationship between adult haematological cancers and adults living near overhead power-lines. Adults living within 50m of an overhead powerline had a risk for haematological cancer of 1.29 (29% increase). Exposure of less than 0.1mG of EMF showed a risk of 1.03 (3% increase) and exposure greater than 3mG showed a risk of 1.87 (87% increase).

Dr Cynthia F. Robinson published a study in 1991 regarding EMF exposure and leukemia mortality. Workers in all fields studied, except

welders, had an increase risk for mortality from leukemias by a risk factors varying between 1.09 (9% increase) to 2.10 (210% increase). Mortality from acute myelogenous leukemia had a higher risk factor, which varied from 1.22 (22% increase) to 4.99 (499% increase).

In 1992 Dr S. Richardson published a study showing a significant risk factor for acute leukemia is occupational EMF exposure. The risk factor for those exposed to EMF in the workplace, calculated through logistic regression analysis is 3.19 (319% increase).

Conditional logistic regression analysis showed a risk of 3.99 (399% increase).

In 1993 Dr Genevieve Matanoski reported that the instance of leukemia increased with an increase in EMF exposure for telephone linemen. Workers with median exposure levels greater than the general public have a risk of 2.5 (250% increase). Workers with median peak exposure levels greater than the general public have a risk of 2.4 (240% increase). When a latency period of 10 to 15 years is factored in, workers have a risk of 6.6 (660% increase).

In 1993 Dr Birgetta Floderus published a study comparing occupational EMF exposure between 250 leukemia patients and a 1,121-person control group. Risk for contracting leukemia was found through consecutive exposure levels with a risk factor of 1.1 (10% increase), 2.2 (220% increase), and 3.0 (300% increase) as exposure increased. The risk of leukemia increased as EMF exposure increased.

Chronic lymphocytic leukemia in occupational settings has been reported to be an increased risk for adults. The scientific literature reporting increased leukemia shows that it is the 2-5 mG range of exposure that is suspected to be linked to increased risk (Floderus, 1993, Floderus 1998, Feychting,1997).

In 1994 Birgitta Floderus published a study that investigated the incidence of cancer in Swedish railway workers who had been exposed to extremely high levels of EMF (5.5-40.3 mG). An increase risk for chronic lymphocytic leukemia was found to be 1.9 (90% increase) and a risk of 1.4 (40% increase) for acute myeloid leukemia.

In 1994 Maria Feychting published a study investigating the link between leukemia and adults living near high-voltage power lines. Adults exposed to EMF levels greater than 1.9 mG had a risk of 1.7 (70% increase) for acute myeloid leukemia and for chronic myeloid leukemia. Based on cumulative exposure for the 15 years before diagnosis, risk for acute myeloid leukemia was 2.3 (230% increase) and 2.1 (210% increase) for chronic myeloid leukemia.

In 2001 Peter Bethwaite published a study that found an increase risk of leukemia for electrical workers in New Zealand. A risk of 1.9 (90% increase) for leukemia was found for adults who had ever worked in an electrical occupation. Risk was significantly increased for welders to 2.8 (280% increase) and for telephone line workers to 5.81(581% increase). A dose response was also noted in this study.

Li (2002) conducted a study on miscarriage in a population-based prospective cohortstudy of personal magnetic field exposures during pregnancy. The studies included 969 women with a positive pregnancy test at less than 10 weeks of gestation. Intermittent magnetic field exposures over 16 mG were statistically significantly associated with spontaneous abortion when compared to those women with less than 16 mG exposures. These exposures did not have to be continuous, but simply intermittent. The increased risk was 80% for spontaneous abortion (RR = 1.8). The risk was highest for women at less than 10 weeks (more than double the risk or RR = 2.2)); and for women with prior fetal losses or with fertility problems (more than triple the risk or RR = 3.1).

Lee (2002) conducted a nested case-control study of residential and personal magnetic field exposures and spontaneous abortion. She reported that "women in the second through fourth quartiles of EMF exposure had a 50% increased risk of spontaneous abortion (RR = 1.5).

Implementation Strategies for Precautionary Action

The design and construction of homes, schools and office buildings can achieve EMF levels that test at no more than 0.1 mG or 0.2 mG when fully loaded and operational (all electricity is on and working). With the exception of measurements directly adjacent to electrical appliances, a properly designed and built structure should measure at or under 0.5 mG. Health studies begin to show elevated risk for childhood leukemia at 1.4 mG and above (Green, 1999), so that there is little margin of safety in observing only a 1 mG planning target limit.

Further Reading for Childhood Cancer Studies

Ahlbom A, Day N, Feychting M, Roman E, Skinner J, Dockerty J, Linet M, McBride M, Michaelis J, Olsen J, Tynes T, Verkasalo P. A pooled analysis of magnetic fields and childhood leukemia. 2000. Brit J Cancer 83 (5) 692-698.

Bowman J Thomas DC London SJ Peters JM. 1995. Hypothesis: the risk of childhood leukemia is related to combinations of power frequency and static magnetic fields. Bioelectromagnetics 16:48-59.

Green L. 1999. Childhood Leukemia and EMF. Cancer Causes and Control (10) 233-243.

Greenland S, Sheppard A, Kaune W, Poole C, Kelsh M. A pooled analysis of magnetic fields, wire codes and childhood leukemia. Epidemiology 2000, Vol 11, No. 6, 624-634.

Feychting M Ahlbom A. 1993. Magnetic Fields and Cancer in Children Living near Swedish High-Voltage Power Lines. Am J Epidemiology. 138: 467-481

Feychting M Schulgen G Olsen JH and Ahlbom A. 1995. Magnetic fields and Childhood Cancer-A Pooled Analysis of Two Scandinavian Studies. European Jornal of Cancer. Vol. 31A, No. 12:1035-2039.

Foliart DE Pollock BH Mezei G Iriye R Silva JM Ebi KL Kheifets L Link M Kavet R. 2006, Magnetic field exposure and long-term survival among children with leukaemia. British Journal of Cancer 94, 161-164.

Kheifets L Shimkhada R. 2005a. Childhood Leukemia and EMF: Review of the Epidemiological Evidence. Bioelectromagnetics Supplement #7, 1-7.

Linet M, et al. 1998. Residential Exposure to Magnetic Fields and Acute Lymphoblastic Leukemia in Children. New England Journal of Medicine. Vol. 337, No. 1: 1-7.

Michaelis J, Schuz J, Meinert R, Zemann E. Combined risk estimate for two German population based case-control studies on residential magnetic fields and childhood acute leukemia. Epidemiology 1997. Vol 9, No. 1. 92-94.

Milham, S: Mortality from leukemia in workers exposed to electrical and magnetic fields. N Engl J Med 1982;307:249.

National Institute for Environmental Health Sciences. 1998. Assesment of Health Effects from Exposure to Power-Line Frequency Electric and Magnetic Fields. NIEHS EMF Working Group Report. National Institutes of Health.

National Institutes of Health. 1999. NIEHS Report on Health Effects from Exposure to Power-Line Frequency Electric and Magnetic Fields No.99-4493. Transmitted to the US Congress as required in response to the 1992 Energy Policy Act (PL 102-486, Section 2118).

Olsen JH Nielson A Schulgen G. 1993. Resisdence near High-Voltage Facilites and Risk of Cancer in Children. BMJ 307: 891-895.

Schuz J Grigat J Brinkmann K Michaelis J. 2001. Residential magnetic fields as a risk factor for childhood acute leukemia: Results from a German population-based case-control study. Int J Cancer 91:728-735.

Wartenburg D Savitz D. 1993. Evaluating Exposure Cutpoint Bias in Epidemiologic Studies of Electric and Magnetic Fields. Bioelectromagnetics 14: 237-245.

Wartenburg D. 1998. Residential Magnetic Fields and Childhood Leukemia: A Meta-analysis. American Journal of Public Health 12:1787-1794.

Wartenburg D. 2001. Residential EMF Exposure and Childhood Leukemia: Meta-analysis and Population Attributable Risk. Biolectromagnetics Supplement 5: S69-104.

Washburn EP, et al. 1994. Residential Proximity to Electricity Transmission and Distribution and Risk of Childhood Leukemia, Childhood Lymphoma, and Childhood Nervous System Tumors; Systematic Review, Evaluation, and Meta-analysis. Cancer Causes and Control. Vol. 5, 299-308.

Further Reading for Adult Cancers and Miscarriage

Bastuji-Garin S, Richardson S, Zittoun R: Acute leukemia in workers exposed to electromagnetic fields. Eur J Cancer 1990;26:1119-1120.

Bethwaite P, Cook A, Kennedy J, Pearce N: Acute leukemia in electrical workers: A New Zealand casecontrol study. Cancer Causes and Control 2001; 12: 683-689

Coleman M, Bell J, Skeet R: Leukemia incidence in electrical workers. Lancet 1983;1:982-983.

Briefing Report on Electromagnetic Fields
... Reading for Adult Cancers and Miscarriage cont'd

Feychting M, Ahlbom A: Magnetic fields, leukemia and central nervous system tumors in Swedish adults residing near high-voltage power lines. Epidemiology 1994;5:501-509.

Flodin U, Frederikson M, Axelson O, Persson T, Hardell L: Background radiation, electrical work, and some other exposures associated with acute myeloid leukemia in a case-referent study. Arch Env Health 1986;41:77-84.

Floderus B, Persson T, Stenlund C, Wennberg A, et al: Occupational exposure to electromagnetic fields in relation to leukemia and brain tumors: a case-control study in Sweden, Cancer Causes and Control, 1993; :189-194.

Floderus B, Törnqvist S, Stenlund C: Incidence of selected cancers in Swedish railway workers, 1961-1979. Cancer Causes and Control 1994;5:189-194.

Gilman PA, Ames RG, McCawley MA: Leukemia among United States white male coal miners. J Occup Med 1985;27:669-671.

Juutilainen J, Pukkala E, Läärä E: Results of epidemiological cancer study among electrical workers in Finland. J Bioelectricity 1988; 7:119-121.

Lee et al, 2002. A nested case-control study of residentiala nd personal magnetic field measurements and miscarriages. Epidemiology Vol. 13, No 1.

Li et al, 2002. A population-based prospective cohory study of personal exposure to magnetic fields during pregnancy and the risk of miscarriage. Epidemiology Vol 13 No.1

Pearce N, Reif J, Fraser J: Case-control studies of cancer in New Zealand electrical workers. Int J Epidemiol 1989;18:55-59.

Richardson S, Zittoun R, Bastuji-Garin S, et al: Occupational risk factors for acute leukaemia: A case-control study. Int J Epidemiol 1992;21:1063-1073

Robinson CF, Lalich NR, Burnett CA, Sestito JP, et al: Electromagnetic field exposure and leukemia mortality in the United States. J Occ Med 1991;33:160-162.

Stern RM, Waxweiler RA, Beaumont JJ, Lee ST, et al: Cancer incidence among welders: possible effects of exposure to extremely low frequency electromagnetic radiation (ELF) and to welding fumes. Am J Epidemiol 1986;123:980-992.

Törnqvist S, Knave B, Ahlbom A, Persson T: Incidence of leukemia and brain tumors in some electrical occupations. Br J Ind Med 1991;48:597-603.

Wright WE, Peters JM, Mack TM: Leukemia in workers exposed to electric and magnetic fields. Lancet 1982;2:1160-1164.

Reprinted with the permission of Sage Associates, Santa Barbara, California, USA.