# Electric Magnetic Fields and Health Effects

John R. Contreras, PhD, MSPH
Epidemiologist
Utah Department of Health

# Electric Magnetic Fields

- Help you see the entire (most) of the picture.
  - Epidemiology
  - Roles: Risk, Biostatistics, and Causation
  - Background: Electric and Magnetic Fields.
  - Health Concerns and Effects
  - Animal Data
  - Limitations of Studies
  - Conclusions
  - Recommendations

# Epidemiology (Environmental)

- Environmental epidemiology may be defined as the study of environmental factors that influence the distribution and determinants of disease in human populations.
  - Communicable Diseases
  - Chronic Disease
  - Clinical Trials
  - Behavioral

Source: Environmental Epidemiology and Risk Assessment, 1993

# Epidemiology Cont'd

- We try to find out who gets the disease and why.
- For example, is the disease more frequent in men or women, young or old, rich or poor, among blacks or whites?
- Is it due to a genetic trait or occupational exposure, or lifestyle (such as smoking)?
- Is it geographical?

# Variations in Health Outcomes

- Variation from person to person is ubiquitous, so this makes it difficult to identify the effect of a given factor to one's health.
- For example, a habitual smoker may live to be 90, while someone who never smoked may die at age 30.
- Epidemiology attempts to sort out such seeming contradictions by studying properly chosen groups of people (samples).
- Variation: Part of all observational studies.

# Epidemiology (cont'd)

- Two basic approaches:
  - To identify a disease or injury, characterize the exposure and population and attempt to establish a causal chain by reasoning from effect (disease) back to exposure.
  - To identify the exposure and the population affected, and search for a likely health endpoint.
  - Compare and Contrast (2 groups)

# “Confounding”

- This is a term that is used in epidemiological (sort of a “third wheel” concept). A variable that distorts the results of a study.
- Example: Air Pollution (particulate matter) and Lung Cancer. If you have smokers in your study, that becomes a problem in evaluating the results.
- The role of smokers distorts the results of the study. This is part of the sorting.

# Epidemiology Environmental (Cont'd)

- Epidemiological Reasoning; Generally 3 step process:
  - Determination of an association between the exposure and an endpoint (disease).
  - Formulate a biological inference (hypothesis) about the relationship or association.
  - **Gather Data &Test It.**

Source: Environmental Epidemiology and Risk Assessment, 1993

# Testing Tools
# “Biostatistics”

- Biostatistics are applications of statistical techniques for testing scientific research in health-related fields:
  - Medicine
  - Biology
  - Public Health (& Environment)

# Risk

- This is the main measure used by epidemiologist to assess an association between the health outcome and the exposure or event on the basis of the comparison group's experience.
- It is often expressed as a ratio/relative risk (RR), or a *rate*.
  - Ratio or RR – 1.25 or .89
  - Rate – 136.8 per 100,000 population

# Risk (cont'd)

- Risk may imply either an adverse or beneficial relationship, or no relationship.

- Heart disease (HD) near a freeway (as an example)
  - Observed # of cases with HD / expected # of cases
    - (Example: 41/36 = 1.14 or 36/41 = 0.88)

    - 1.0 suggests no risk
    - More than 1.0 = Suggests more HD than expected
    - Less than 1.0 = Suggests less HD than expected

# Statistical Significance

- Statistical Significance is a statistical term that tells how sure you are that a difference or relationship exists (95% confidence).
- To say that a significant difference or relationship exists only tells part of the story.
  - Is it a strong, moderate, or weak relationship?
  - Significant differences can be large or small. It just depends on your sample size.

# Causal Association

- Causal Associations or Evidence
  - Temporal Relationship
  - Biological Plausibility
  - Strength of Association (a true diff. of the magnitude)
    - Statistical Power (Small Sample Size <Power)
  - Dose Response
  - Replication of study

Source: Epidemiology: Beyond the Basics, Hill's Guidelines, 2006 (page 382)

# Electric and Magnetic Fields (EMF) What are they?

- EMFs are invisible waves of electric and magnetic energy that are produced by any wiring or equipment carrying electric current. This includes:
  - Overhead and underground power lines
  - Wiring in buildings & Electrical appliances.

- Electric Fields are produced by electric charges with cycle frequencies of greater than 3 Hertz (Hz) and less that 3000 Hz; this is generally referred to as extremely low frequency (ELF).

- Magnetic Fields are produced by the flow of current through wires or electrical devices and increase in strength as the current increases.

- Both rapidly become weaker with distance from the source.

Source: Environmental Protection Agency, http://epa.gov/radtown/power-lines.html (accessed 08/18/09); National Institute of Environmental Health Sciences, National Institutes of Health sponsored by the NIEHS/DOE EMF RAPID Program (2002)

# Electric and Magnetic Fields (EMF) Background

- In the United States, electricity is usually delivered as 60 Hertz (measure of units - Hz) alternating current 50 to 60 Hz cycles are generally referred to as the power-line frequency of alternating current electricity.

- In addition to magnetic fields associated with electricity, the earth also has a static magnetic field that varies by location.

Source: National Institute of Environmental Health Sciences (NIEHS), NIH Publication No. 99-4493 (1999); http://www.niehs.nih.gov/health/docs/niehs-report.pdf; National Institute of Environmental Health Sciences (NIEHS), Q&A, 2002 - http://www.niehs.nih.gov/health/docs/emf-02.pdf (accessed August 10, 2009)

# What happens when one is exposed to EMFs

- **Electric fields**

  A person standing directly under a high-voltage transmission line may feel a mild shock when touching something that conducts electricity. These sensations are caused by the strong electric fields from the high-voltage electricity in the lines. They occur only at close range because the electric fields rapidly become weaker as the distance from the line increases. Electric fields may be shielded and further weakened by buildings, trees, and other objects that conduct electricity.

- **Magnetic fields**

  Alternating magnetic fields produced by (Alternating Current –AC) electricity and can induce the flow of weak electric currents in the body. However, such currents are estimated to be smaller than the measured electric currents produced naturally by the brain, nerves, and heart.

Source: National Institute of Environmental Health Sciences (NIEHS), NIH Publication No. 99-4493 (1999)- http://www.niehs.nih.gov/health/docs/niehs-report.pdf; National Institute of Environmental Health Sciences (NIEHS), Q&A, 2002 - http://www.niehs.nih.gov/health/docs/emf-02.pdf (accessed August 10, 2009)

# Electric and Magnetic Fields (EMF) Background

- **Non-ionizing Radiation**

  Non-ionizing radiation has lower energy and longer wavelength than ionizing radiation. It is not strong enough to change the structure of atoms it contacts but may be strong enough to heat tissue. Examples include radio waves, microwaves, visible light, and infrared.

Source: Centers for Disease Control and Prevention, http://www.cdc.gov/nceh/radiation/factsheets/cellphone_facts.pdf - March 2005 (accessed August 15, 2008)

# EMFs
## Background Information (cont'd)

- EMFs should not be confused with ionizing radiation, such as x-rays or gamma rays.

- EMFs - This type of radiation has lower energy and therefore cannot cause ionization (potentially resulting in chemical changes) in the body. This type of energy fields are non-ionizing radiation. (Debate about DNA damage)

Source: Centers for Disease Control and Prevention, http://www.cdc.gov/nceh/radiation/factsheets/cellphone_facts.pdf - March 2005 (accessed August 15, 2008)

# Health Concerns and EMF

- Most research into this question has concentrated on finding out whether the magnetic fields can cause cancer (brain, leukemia, skin, and breast) or could assist the development of a cancerous condition. Other effects investigated include:

- Spontaneous Abortion
  - End of a pregnancy at a stage where the embryo or fetus is incapable of surviving

- Reproductive Outcomes (Birth Concerns)
  - Low Birth Weight
  - Intrauterine Growth Retardation (baby not growing normally)
  - Pre-Term Birth (early births)
  - Congenital Anomalies (health defects at birth)

Source: National Institute of Environmental Health Sciences (NIEHS), NIH Publication No. 99-4493 (1999); http://www.niehs.nih.gov/health/docs/niehs-report.pdf; National Institute of Environmental Health Sciences (NIEHS), Q&A, 2002 - http://www.niehs.nih.gov/health/docs/emf-02.pdf (accessed August 10, 2009)

# Health Concerns and EMF (Cont'd)

- Suicide and Depression
- Alzheimer's & Amyotrophic Lateral Sclerosis (neurological disease)
- Adverse Cardiovascular Outcomes (affects the heart)
- Melatonin Suppression & Immune System

Source: National Institute of Environmental Health Sciences (NIEHS), NIH Publication No. 99-4493 (1999); http://www.niehs.nih.gov/health/docs/niehs-report.pdf; National Institute of Environmental Health Sciences (NIEHS), Q&A, 2002 - http://www.niehs.nih.gov/health/docs/emf-02.pdf (accessed August 10, 2009)

# Spontaneous Abortion

- Studies of pregnancy outcomes in women working with visual/video display units and exposure to the accompanying electric and magnetic fields have provided no consistent evidence for adverse effects on reproduction.
- Meta-analyses (combined studies) have found no excess risk of spontaneous abortion or malformations.
- However, studies evaluating effects of residential exposure to EMF have demonstrated conflicting results; some studies have suggested a slight increase or early pregnancy loss.

Sources: *Am. J. Ind. Med*. 32:403-407, 1997. © 1997 Wiley-Liss, Inc.; World Health Organization; *New England Journal of Public Health* Volume 324:727-733, no 11, March 14, 1991; National Institute of Environmental Health Sciences (NIEHS), NIH Publication No. 99-4493 (1999); http://www.niehs.nih.gov/health/docs/niehs-report.pdf; National Institute of Environmental Health Sciences (NIEHS), Q&A, 2002 - http://www.niehs.nih.gov/health/docs/emf-02.pdf (accessed August 10, 2009)

# Reproductive Outcomes

- Low birth weight, intrauterine growth retardation, preterm birth, and congenital anomalies were not found as significantly associated with occupational exposures to EMF. Evidence is lacking for a strong association.

- No association was observed for heated waterbeds, and inconsistent results were reported for electric blanket use.

Sources: *Epidemiology* 6:263-270(1995); *American Journal of Industrial Medicine* 32:681-688(1997); *Journal of Occupational and Environmental Medicine* 40:111-117(1998); Bioelectromagnetics 7:13-22(1986); *American Journal of Epidemiology* 135:1000-1011(1992); Bioelectromagnetics. 2001;Suppl 5:S5-18 and *Epidemiology* 6:485-489(1995); Source: National Institute of Environmental Health Sciences (NIEHS), NIH Publication No. 99-4493 (1999); http://www.niehs.nih.gov/health/docs/niehs-report.pdf; National Institute of Environmental Health Sciences (NIEHS), Q&A, 2002 - http://www.niehs.nih.gov/health/docs/emf-02.pdf (accessed August 10, 2009)

# Suicide and Depression (Headaches)

- Findings are based on residential and occupational epidemiological studies:
  - No association observed – EMF exposure is unlikely to be either a necessary or sufficient cause of depression or suicide, and its role relative to other predictive factors is likely to be small.
  - The literature on depressive symptoms and EMF is difficult to interpret because the findings are not consistent.
  - The studies found to show an association were based on small numbers.

Source: National Institute of Environmental Health Sciences (NIEHS), NIH Publication No. 99-4493 (1999); http://www.niehs.nih.gov/health/docs/niehs-report.pdf; National Institute of Environmental Health Sciences (NIEHS), Q&A, 2002 - http://www.niehs.nih.gov/health/docs/emf-02.pdf (accessed August 10, 2009); *West J Med.* 2000 August 173(2): 100–101; *American Journal of Epidemiology* 148:362-368(1998); *American Journal of Industrial Medicine* 25:165-176(1994); and *Occupational and Environmental Medicine* 53:17-24(1996).

# Alzheimer's

- There are several studies that have reported an increase in Alzheimer's disease in specific worker groups that are submitted to high exposure levels. However, the results likely pertain to the general population. No clear significant differences have been established.
- Some of the data was inadequate for interpreting a possibility for an association and confounding issues.
- Studies of occupational exposure to EMFs do not provide strong evidence of associations with neurodegenerative diseases.
- Further research / follow-up is needed in this area.

Sources: *BMC Neurol.* 2007; 7: 13; World Health Organization; Source: National Institute of Environmental Health Sciences (NIEHS), NIH Publication No. 99-4493 (1999); http://www.niehs.nih.gov/health/docs/niehs-report.pdf; National Institute of Environmental Health Sciences (NIEHS), Q&A, 2002 - http://www.niehs.nih.gov/health/docs/emf-02.pdf (accessed August 10, 2009)

# Amyotrophic Lateral Sclerosis (ALS)

- ALS, sometimes called Lou Gehrig's disease, is a rapidly progressive, invariably fatal neurological disease that attacks the nerve cells *(neurons)* responsible for controlling voluntary muscles. The cause of ALS is not known, and scientists do not yet know why ALS strikes some people and not others.

- Researchers have also studied environmental factors such as **EMF**, and exposure to toxic or infectious agents. Other research has examined the possible role of dietary deficiency or trauma.

- Studies of occupational exposure to EMFs do not provide strong evidence of associations with neurodegenerative diseases (Alzheimer's and ALS). More research needed.

Source: National Institute of Neurological Disorders and Stroke, National Institutes of Health, http://www.ninds.nih.gov/disorders/amyotrophiclateralsclerosis/detail_amyotrophiclateralsclerosis.htm 9/2008 (accessed 8/15/09); Epidemiology 9:398-404(1998); and American Journal of Epidemiology 148:362-368(1998).

# Adverse Cardiovascular Outcomes

- Several studies have reported (under precise circumstances) EMF can influence the cardiovascular system by slightly decreasing or increasing the heart rate (3-5 beats per minute).
- No obvious acute or long-term cardiovascular-related hazards have been demonstrated at levels below current exposure levels.
- However, even though decreased heart-rate variability is associated with increased risk of cardiovascular death, it is not clear that transiently induced changes in healthy individuals will carry any risk.
- Clinical studies: Effects have not been observed consistently in repeated experiments.
- Basically, findings are inconsistent or inconclusive.

Sources: World Health Organization 2008, Source: National Institute of Environmental Health Sciences (NIEHS), NIH Publication No. 99-4493 (1999); http://www.niehs.nih.gov/health/docs/niehs-report.pdf; National Institute of Environmental Health Sciences (NIEHS), Q&A, 2002 - http://www.niehs.nih.gov/health/docs/emf-02.pdf (accessed August 10, 2009)

# Adverse Cardiovascular Outcomes (cont'd)

- Which raises the question about pacemakers or other medical devices…
  - According to the U.S. Food and Drug Administration, interference from EMF can affect various medical devices including cardiac pacemakers and implantable defibrillators. Most current research in this area focuses on higher frequency sources such as cellular phones, citizens band radios, wireless computer links, microwave signals, radio and television transmitters, and paging transmitters.
  - Sources such as welding equipment, power lines at electric generating plants, and rail transportation equipment can produce lower frequency EMF strong enough to interfere with some models of pacemakers and defibrillators.
  - Consult Manufacturer.

Sources: National Institute of Environmental Health Sciences, National Institutes of Health, 2002; National Radiation Laboratory, Ministry of Health, New Zealand, 2008.

# Melatonin Suppression & Immune System

- Melatonin is a hormone produced in the brain by the pineal gland. The release of melatonin are stimulated by darkness and suppressed by light. Melatonin possesses antioxidant activity (prevents cell damage), and many of its proposed therapeutic or preventive uses are based on this property.

- When all studies combined are evaluated they provide little support that exposure to ELF-EMF is altering melatonin levels in humans.

- A number of other hormones were also studied such as testosterone, thyroid hormones and several stress hormones; no effects of EMF exposure on these levels were observed.

Sources: National Institute of Environmental Health Sciences (NIEHS), NIH Publication No. 99-4493 (1999); Medline http://www.nlm.nih.gov/medlineplus/druginfo/natural/patient-melatonin.html (accessed 08/16/09)

# Melatonin Suppression & Immune System (cont')

- There are conflicting conclusions on EMF and the immune system with studies.
- Some human and animal studies report large immunological changes upon exposure to environmental levels of modern, human-made EMFs. Cell phones appear to achieve significant outcomes more often.
- Appears to affect females more than males.
- These conflicts could be due to unmeasured confounding.
- Further research / follow-up is needed in this area.

Sources: National Institute of Environmental Health Sciences (NIEHS), NIH Publication No. 99-4493 (1999); Pathophysiology (2009), doi:10.1016/j.pathophys.2009.03.004; Int J Immunopathol Pharmacol. 2006 Oct-Dec;19(4 Suppl):37-42.

# Cancer

- Cancer is term that encompasses a complex group of more than 100 different types of cancerous diseases. Cancer can affect just about every organ in the human body.

- Each type of cancer is unique with its own causes, symptoms, and methods of treatment. Like with all groups of disease, some types of cancer are more common than others

- The American Cancer Society estimates that 1 in 2 men and 1 in 3 women will have cancer in his or her lifetime.

Source: American Cancer Society, 2006

# Cancer
## (cont'd.)

- Lifestyle Concerns:
  - Tobacco
  - Diet
  - Lack of Exercise
  - Obesity

  Each year, about 550,000 Americans die of cancer; fully one-third of these deaths are linked to life style concerns.

- If you throw in tobacco use - account for approximately 80% of cancers.

Source: National Cancer Institute, 2006; American Cancer Society, http://www.cancer.org/docroot/PED/content/PED_3_1x_Link_Between_Lifestyle_and_CancerMarch03.asp 10/2006 (accessed 8/24/09)

# Childhood Cancer

- Approximately 10,730 new cases of pediatric cancer were expected to be diagnosed in children 0–14 years of age in 2008.
- Among the major types of childhood cancers, leukemias (blood cell cancers) and brain and other central nervous system (CNS) tumors account for more than half of new cases.
- White children are more likely than children from any other ethnic group to develop cancer.

Source: National Cancer Institute, 2008 (http://www.cancer.gov/aboutnci/servingpeople/pediatric-snapshot.pdf

# Cancer & EMF

- Over the past 30 years, a lot of research has been carried out to determine whether ELF magnetic fields might be a potential cause of cancer. This work has involved:
  - Epidemiological studies of people who, because of where they live or work, may have higher exposures to magnetic fields than other people.
  - Laboratory experiments with cell cultures and animals.

# EMF
# Childhood Cancer

- Earlier studies have suggested an association with EMF and several forms of childhood cancer; those initial findings have not been confirmed (poor reproduction) by other studies. Consensus is there is no association (correlation).
- Childhood Leukemia: Overall, there is a weak but relatively consistent correlation between prolonged exposure to relatively strong magnetic fields and childhood leukemia.

- Note: Correlation does not necessarily mean that there is a cause and effect relationship.

Source: Source: National Institute of Environmental Health Sciences (NIEHS), NIH Publication No. 99-4493 (1999); http://www.niehs.nih.gov/health/docs/niehs-report.pdf; National Institute of Environmental Health Sciences (NIEHS), Q&A, 2002 - http://www.niehs.nih.gov/health/docs/emf-02.pdf (accessed August 10, 2009)

# Cancer and EMF
# Adult Cancer

- The studies that have been conducted to address EMF and adult cancer do not provide strong evidence for an association between (residential) EMF exposure and adult cancers, including:
  - Leukemia, Brain, and Breast.

- Studies that have shown significant elevations have not been consistent with poor reproducibility.

Source: Source: National Institute of Environmental Health Sciences (NIEHS), NIH Publication No. 99-4493 (1999); http://www.niehs.nih.gov/health/docs/niehs-report.pdf; National Institute of Environmental Health Sciences (NIEHS), Q&A, 2002 - http://www.niehs.nih.gov/health/docs/emf-02.pdf (accessed August 10, 2009)

# Cancer & EMF
# Electrical Occupations

- Detailed studies of the health of workers, especially electric utility workers, have been conducted in the United States, Canada, France, England, and several Northern European countries.
- Some studies have found evidence that suggests a link between EMF exposure and both leukemia and brain cancer, whereas other studies of similar size and quality have not found such associations.
- The reproducibility of these effects is usually poor, with no clear physiological or pathogenic mechanism (so far) to explain the alleged effects.

Source: Source: National Institute of Environmental Health Sciences (NIEHS), NIH Publication No. 99-4493 (1999); http://www.niehs.nih.gov/health/docs/niehs-report.pdf; National Institute of Environmental Health Sciences (NIEHS), Q&A, 2002 - http://www.niehs.nih.gov/health/docs/emf-02.pdf (accessed August 10, 2009)

# Other Cancer Research & EMF

- Other research has looked at cancer (other) in adults who may be exposed to relatively high levels of ELF magnetic fields at home or in the course of their work. The review groups have concluded that there is no consistent evidence of a relationship between adult exposure and cancer risk.
- Studies that used distance from power-lines, without taking account of other variables such as load, or between calculated RF-EMF and measured RF-EMF resulted in exposure misclassification rendering the findings un-interpretable or inconclusive.

Sources: Med Pr. 2008;59(5):421-8; Bioelectromagnetics, 2009 Apr;30(3):183-8; Bioelectromagnetics. 2009 Feb;30(2):81-91; National Radiation Laboratory, Ministry of Health, New Zealand, 2008

# International Agency for Research Cancer Classification

- Overall, ELF magnetic fields fall within Class 2B ("possibly carcinogenic to humans") of the International Agency for Research on Cancer (2001) classification scheme.
- This classification was based on a NIEHS Working Group Report (1998) of 30 scientists who conducted a complete review of EMF studies, including those sponsored by the EMF RAPID Program and others.
- The working group also reported that animal and cellular studies neither confirm nor deny the epidemiological studies' suggestion of a disease risk.

Source: International Agency for Research on Cancer (2001), National Radiation Laboratory; National Institute of Environmental Health Sciences (NIEHS), NIH Publication (June 2002)

# EMF & Cancer Challenges

- The major challenge in EMF epidemiology is to identify the small number of highly exposed cases and assess the exposure retrospectively.
- Only studies designed to minimize bias and methodological weaknesses while maximizing our ability to detect an significantly strong association (should one exist), would have a potential to contribute to our understanding.
- The reproducibility of effects has to be consistent and clearly explain the physiological or pathogenic mechanisms. In other words…the effects it has on our bodies (i.e., heart rate, tooth decay, liver) and how or what is causing these effects.

# Animal Studies

- Cancers: Leukemia, Skin, Breast, Liver, and Brain.
- Laboratory studies have shown no consistent effects of EMF exposures and the development of tumors in experimental animals, and other results have been generally negative or inconsistent.

Source: International Agency for Research on Cancer (2001), National Institute of Environmental Health Sciences (NIEHS), NIH Publication (June 2002)

# Limitations of Studies
# "No such thing as a perfect study"

- Recall Bias
- Selection Bias
- Migration (Residential Tenure)
- Familial History (Genetics)
- Exposure History and Misclassification
- Methodological Weaknesses

.....

# Conclusions

## Concern

- There remains a wide consensus that there is a weak but relatively consistent association (correlation) between prolonged exposure to relatively strong magnetic fields and childhood leukemia.
- From a public health perspective, this evidence cannot and should not be ignored.

# Conclusion (cont'd)

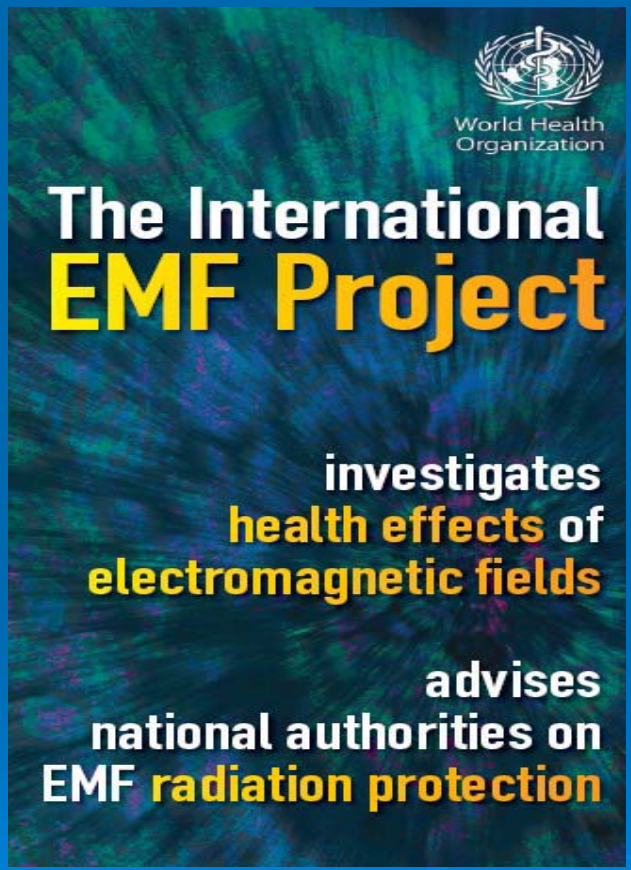
- Despite the large number of studies evaluating cancer and non-cancerous diseases, further research is still necessary in order to make a complete assessment of health effects of exposure to electric and magnetic fields.

- The inconsistencies within studies need to be resolved and reported effects must be replicated with consistency. The better we understand whether possible risks exists (biological explanation) the better we can provide exposure guidelines to provide adequate protection to communities and workplaces. (Need consistent laboratory evidence).

- Overall the research does not indicate that there is a significant health hazard with exposures to electric and magnetic fields and it is unclear what aspect of the exposure, if any, may be the active component of the field resulting in the increased cancer risk or other diseases.

- National and international committee's, work groups, etc support the conclusions.

# Electric Magnetic Fields




- World Health Organization: No significant public health risks have emerged from several decades of EMF research.

# Recommendations

- Educate yourself – minimize exposures
- Set standards for transmission-line electric fields.
- Use caution with all electrical lines and fields.