
Electromagnetic radiation and health

Electromagnetic radiation can be classified into ionizing radiation and non-ionizing radiation, based on whether it is capable of ionizing atoms and breaking chemical bonds. Ultraviolet and higher frequencies, such as X-rays or gamma rays are ionizing. These pose their own special hazards: see *radiation* and *radiation poisoning*.

Non-ionizing radiation, discussed here, is associated with two major potential hazards: electrical and biological. Additionally, induced electric current caused by radiation can generate sparks and create a fire or explosive hazard.

Types of hazards

Electrical hazards

Strong radiation can induce current capable of delivering an electric shock to persons or animals. It can also overload and destroy electrical equipment. The induction of currents by oscillating magnetic fields is also the way in which solar storms disrupt the operation of electrical and electronic systems, causing damage to and even the explosion of power distribution transformers,^[1] blackouts (as in 1989), and interference with electromagnetic signals (*e.g.* radio, TV, and telephone signals).^[2]

Fire hazards

Extremely high power electromagnetic radiation can cause electric currents strong enough to create sparks (electrical arcs) when an induced voltage exceeds the breakdown voltage of the surrounding medium (*e.g.* air). These sparks can then ignite flammable materials or gases, possibly leading to an explosion.

This can be a particular hazard in the vicinity of explosives or pyrotechnics, since an electrical overload might ignite them. This risk is commonly referred to as HERO (Hazards of Electromagnetic Radiation to Ordnance). MIL-STD-464A mandates assessment of HERO in a system, but Navy document OD 30393 provides design principles and practices for controlling electromagnetic hazards to ordnance.

On the other hand, the risk related to fueling is known as HERF (Hazards of Electromagnetic Radiation to Fuel). NAVSEA OP 3565 Vol. 1 could be used to evaluate HERF, which states a maximum power density of 0.09 W/m² for frequencies under 225 MHz (*i.e.* 4.2 meters for a 40 W emitter).

Biological hazards

The best understood biological effect of electromagnetic fields is to cause dielectric heating. For example, touching or standing around an antenna while a high-power transmitter is in operation can cause severe burns. These are exactly the kind of burns that would be caused inside a microwave oven.

This heating effect varies with the power and the frequency of the electromagnetic energy. A measure of the heating effect is the specific absorption rate or SAR, which has units of watts per kilogram (W/kg). The IEEE^[3] and many national governments have established safety limits for exposure to various frequencies of electromagnetic energy based on SAR, mainly based on ICNIRP^[4] Guidelines,^[5] which guard against thermal damage.

There are publications which support the existence of complex biological effects of weaker *non-thermal* electromagnetic fields (see Bioelectromagnetics), including weak ELF magnetic fields,^{[6] [7]} and modulated RF and microwave fields.^[8] Fundamental mechanisms of the interaction between biological material and electromagnetic fields at non-thermal levels are not fully understood.^[9]

DNA fragmentation. A 2009 study at the University of Basel in Switzerland found that intermittent (but not continuous) exposure of human cells to a 50 Hz electromagnetic field at a flux density of 1 mT (or 10 G) induced a slight but significant increase of DNA fragmentation in the Comet assay.^[10] However that level of exposure is already above current established safety exposure limits.

Positions of governments and scientific bodies

World Health Organization

"The Task Group concluded that there are no substantive health issues related to ELF *electric* fields at levels generally encountered by members of the public.... [O]n balance, the evidence [about *magnetic* fields being] related to childhood leukaemia is not strong enough to be considered causal.... A number of other adverse health effects have been studied for possible association with ELF magnetic field exposure. These include other childhood cancers, cancers in adults, depression, suicide, cardiovascular disorders, reproductive dysfunction, developmental disorders, immunological modifications, neurobehavioural effects and neurodegenerative disease. The WHO Task Group concluded that scientific evidence supporting an association between ELF magnetic field exposure and all of these health effects is much weaker than for childhood leukaemia. In some instances (i.e. for cardiovascular disease or breast cancer) the evidence suggests that these fields do not cause them."^[11]

Health Canada

"There is no *conclusive evidence* of any harm caused by exposures [to electric and magnetic fields] at levels found in Canadian homes and schools, including those located just outside the boundaries of power line corridors."^[12]

U.S. military definition

In Federal Standard 1037C, the United States government adopts the following definition:

Electromagnetic radiation hazards (RADHAZ or EMR hazards): Hazards caused by a transmitter/antenna installation that generates electromagnetic radiation in the vicinity of ordnance, personnel, or fueling operations in excess of established safe levels or increases the existing levels to a hazardous level; or a personnel, fueling, or ordnance installation located in an area that is illuminated by electromagnetic radiation at a level that is hazardous to the planned operations or occupancy. These hazards will exist when an electromagnetic field of sufficient intensity is generated to: (a) induce or otherwise couple currents and/or voltages of magnitudes large enough to initiate electroexplosive devices or other sensitive explosive components of weapon systems, ordnance, or explosive devices; (b) cause harmful or injurious effects to humans and wildlife; (c) create sparks having sufficient magnitude to ignite flammable mixtures of materials that must be handled in the affected area. —Department of Defense Dictionary of Military and Associated Terms

Electric power transmission

The preponderance of evidence suggests that the low-power, low-frequency, electromagnetic radiation associated with household current does not constitute a short or long term health hazard, and whilst some biophysical mechanisms for the promotion of cancer have been proposed (such as the electric fields around power lines attracting aerosol pollutants^{[13] [14]}), none have been substantiated.^{[11] [15] [16] [17] [18] [19]} Nevertheless, some research has implicated exposure in a number of adverse health effects. These include, but are not limited to, childhood leukemia,^[11] adult leukemia,^[20] neurodegenerative diseases (such as amyotrophic lateral sclerosis),^{[21] [22] [23]} miscarriage,^{[24] [25] [26]} and clinical depression.

Mitigation

One response to the potential dangers of overhead power lines is to place them underground. The earth and enclosures surrounding underground cables prevent the electric field from radiating significantly beyond the power lines, and greatly reduce the magnetic field strength radiating from the power lines, into the surrounding area.^[27] However, the cost of burying and maintaining cables at transmission voltages is several times greater than overhead power lines.^[28]

Leukemia and cancer

Suggesting no significant link

In 1997 the National Cancer Institute (NCI) released a report published in the *New England Journal of Medicine*, the result of a seven-year epidemiological investigation. The study investigated 638 children with acute lymphoblastic leukemia (ALL) and 620 controls and concluded that their study provided "little evidence that living in homes characterized by high measured time-weighted average magnetic-field levels or by the highest wire-code category increases the risk of ALL in children."^[29] Following the report, the US Department of Energy disbanded the EMF Research and Public Information Dissemination (RAPID) Program, saying that its services were no longer needed.^[30]

In 2005, the Canadian Federal-Provincial-Territorial Radiation Protection Committee said, "The outcome of a recently conducted pooled analysis of several epidemiological studies shows a two-fold increase in the risk of leukemia in children living in homes, where the average magnetic field levels are greater than 0.4 microtesla (4 milligauss). [However,] it is the opinion of [this committee] that the epidemiological evidence to date is not strong enough to justify a conclusion that EMFs in Canadian homes, regardless of locations from power lines, cause leukemia in children."^[31]

The World Health Organization issued a fact sheet, No. 322, in June, 2007 based on the findings of a WHO work group (2007), the IARC (2002) and the ICNIRP (2003), which reviewed research conducted since the earlier publication. The fact sheet says "that there are no substantive health issues related to ELF electric fields at levels generally encountered by members of the public." For ELF magnetic fields, the fact sheet says, "the evidence related to childhood leukaemia is not strong enough to be considered causal", and "[as regards] other childhood cancers, cancers in adults, ... The WHO Task Group concluded that scientific evidence supporting an association between ELF magnetic field exposure and all of these health effects is much weaker than for childhood leukaemia. In some instances (i.e., for ... breast cancer) the evidence suggests that these fields do not cause them."^[11]

According to Dr. Lakshmikumar at the National Physical Laboratory, India, a direct, causal, link between RF radiation and cancer (including leukemia) would require one to be "willing to discard Planck's Law... and the entire body of quantum physics."^[32]

In 2010, Maslanyj *et al.*, applying the Bradford-Hill criteria to available evidence, considered the application of low-cost exposure reduction measures as appropriate precautionary responses to "small and uncertain public health risks". Even after pooling all the data, they found it fell short of establishing "strength of association, dose-response relationship, biological plausibility and coherence, and analogy". They recognised that controversy would continue so long as other interpretations of the data were possible.^[33]

Suggesting a significant link

In 2001, Ahlbom *et al.* conducted a review into EMFs and Health, and found that there was a doubling in childhood leukemia for magnetic fields of over 0.4 μT , but said that "This is difficult to interpret in the absence of a known mechanism or reproducible experimental support".^[34]

In 2002 a study by Michelozzi *et al.* found a relationship between leukemia and proximity to the Vatican Radio station transmitters.^[35]

In 2005 Draper *et al.* found a 70% increase in childhood leukemia for those living within 200 metres (656 ft) of an overhead transmission line, and a 23% increase for those living between 200 and 600 metres (656 and 1969 ft). Both of these results were statistically significant.^[36] The authors considered it unlikely that the increase from 200 m to 600 m is related to magnetic fields as they are well below 0.4 μT at this distance. Bristol University (UK) has published work on a theory that could account for this increase, and would also provide a potential mechanism, being that the electric fields around power lines attract aerosol pollutants.^[14]

Other findings

The World Health Organisation issued Factsheet No. 263 in October 2001 on ELF (Extremely low frequency) EMFs and cancer. It said that they were "possibly carcinogenic", based primarily on IARC's similar evaluation with respect to childhood leukemia. It also said that there was "insufficient" data to draw any conclusions on other cancers.^[37]

In 2007, the UK Health Protection Agency produced a paper showing that 43% of homes with magnetic fields of over 0.4 μT are associated with overground or underground circuits of 132 kV and above.^[38]

UK SAGE report

The UK Department of Health set up the Stakeholder Advisory Group on ELF EMFs (SAGE) to explore the implications and to make recommendations for a precautionary approach to power frequency electric and magnetic fields in light of any evidence of a link between EMF and childhood leukemia. The first interim assessment of this group was released in April 2007^[39], and found that the link between proximity to power lines and childhood leukemia was sufficient to warrant a precautionary recommendation, including an option to lay new power lines underground where possible and to prevent the building of new residential buildings within 60 m (197 ft) of existing power lines. The latter of these options was not an official recommendation to government as the cost-benefit analysis based on the increased risk for childhood leukemia alone was considered insufficient to warrant it. The option was considered necessary for inclusion as, if found to be real, the weaker association with other health effects would make it worth implementing.^[40]

Mobile telephones

Mobile phone radiation and health concerns have been raised, especially following the enormous increase in the use of wireless mobile telephony throughout the world (as of August 2005, there were more than 2 billion users worldwide). Mobile phones use electromagnetic radiation in the microwave range, and some^[41] believe this may be harmful to human health. These concerns have induced a large body of research (both epidemiological and experimental, in non-human animals as well as in humans). Concerns about effects on health have also been raised regarding other digital wireless systems, such as data communication networks.

The World Health Organization, based upon the consensus view of the scientific and medical communities, states that health effects (*e.g.* headaches or promotion of cancer) are unlikely to be caused by cellular phones or their base stations,^[42] ^[43] and expects to make recommendations about mobile phones in the third quarter of 2010 at the earliest, or the first quarter of 2011 at the latest.^[44]

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External links

- Information page (<http://www.who.int/peh-emf/en/>) on electromagnetic fields at the World Health Organization web site
- Biological Effects of Power Frequency Electric and Magnetic Fields (May 1989) (<http://www.princeton.edu/~ota/disk1/1989/8905/8905.PDF>) (over 100 pages)

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