

Powerfrequency EMFs and Health Risks

This article is separated into 11 sections, each of which can be individually downloaded. It is a 'work in progress' incorporating new information whenever time permits.

Section 1

Introduction

1. Introduction; electricity consumption; measuring meaningful exposure; static electric field from high voltage direct current transmission; precautionary recommendations; EMFs interacting with the environment or other substances; geomagnetic field (GMF) changes; a French study in 2009; residential exposure; mitigating biological effects; campaigning organisations
2. Occupational exposure; occupational research
3. Cancer; leukaemia; Sources of magnetic field exposure and cancer risk; brain cancer; breast cancer; neuroblastoma; other cancer; immune system effects; tamoxifen, doxorubicin and other drug effects; similarities to other chemical effects
4. Cellular changes and potential mechanisms; DNA breaks and changes; EEG changes; other cellular changes; potential mechanisms for interaction between exogenous EMFs and biological processes; free radical effects; effects on other cellular processes; airborne pollutant effects; other potential synergistic effects
5. MRI; contrast enhancement; individual experiences of reactions; MRI vs CT; cardiac scan; the European Physical Agents Directive; research
6. Electronic surveillance systems in shops, airports, libraries, etc.
7. Light at Night and Melatonin; circadian rhythm disruption; clock genes; plant, animal and insect effects
8. General reproductive effects; miscarriage and other effects of female exposure; powerfrequency exposure and male sperm; protective treatments
9. Other effects; ageing; amyotrophic lateral sclerosis (ALS); anxiety; asthma; autism; bacteria; behaviour changes; birth defects; effects on blood; bone changes; brain damage; cardiovascular effects; dementia; developmental effects; depression and suicide; EEG changes; energy metabolism; eye effects; gastric effects; genetic defects; hearing effects; heart; insulin and electric fields; interference problems; kidney effects; learning and memory effects; lung, spleen and liver; medical implants; mental health problems; nervous system; neurobehavioural effects; neurodegenerative effects
10. Other effects; obesity; olfactory effects; other neurological and psychological effects; pain perception; Parkinson's disease; protective effects of EMFs; skin; sleep; synergistic effects; teeth; thyroid; weight change; some experimental problems; government advisory bodies
11. References – 861 references

Powerfrequency electric and magnetic fields, together called electromagnetic fields or EMFs, are generated in the distribution and use of electricity.

Exposure to powerfrequency EMFs comes from a variety of sources.

- The distribution network of powerlines, substations and cables.
- Occupational exposure, both within the electricity industry and as a result of using electrical equipment in the working environment.
- Residential exposure due to house wiring and electric appliance use.
- Other exposure, such as transport (e.g. trains, cars), exposure to health equipment (e.g. MRI scans, physiotherapy treatments) and as a result of leisure pursuits.

Electricity consumption

From 1940 to 1992, the per capita power consumption in the United States increased 20-fold, with the accompanying population exposure estimated to have increased fivefold (Lacy-Hulbert [1998](#)). The increase gave rise to uncertainty as to whether there were any health implications in the increasing exposure caused by this relatively new source of power. Milham ([2010](#)), in the USA, charted the change in health statistics and compared them with the increase of electrification in the 1930s, 1940s and 1950s. He suggested that *“the 20th century epidemic of the so called diseases of civilization including cardiovascular disease, cancer and diabetes and suicide was caused by electrification not by lifestyle.”*

The UK electricity consumption in 2005 was 667 watts per capita, though it is unclear what that means exactly, as this will also include industrial use. Finding out what a particular individual's exposure to electric and magnetic fields is, and therefore what effect it might have, if any, on their health status, can be difficult to estimate, and varies from country to country (Li CY [2007](#)).

Measuring meaningful exposure

One of the first major studies into the potential effects of powerfrequency fields by Wertheimer & Leeper found a link between childhood leukaemia and elevated levels of magnetic fields. They used proximity to distribution cables to determine magnetic field levels in the homes of the children. Further studies have produced mixed results. There has been an ongoing debate about whether calculated (from distance to the source), or measured, fields are the most accurate measures of exposure, and what metrics you use to calculate, or when and how you take the measurements.

Li ([2008](#)) concluded that individual exposure and school exposure measurements should be taken into consideration in any analysis of data obtained from the continuous monitoring of exposure to ELF-MF, where the schools have elevated exposure to ELF-MF as a result of their close proximity to high-voltage power lines.

Studies by Deadman ([1999](#)) and Armstrong ([2001](#)) looked at the most accurate predictors of a child's exposure to magnetic fields in the home. Armstrong concluded that 24 hour stationary measurements in the child's bedroom gave one of the best estimates. Deadman came to a different conclusion, that magnetic field measurements at night provided the best surrogate for predicting total magnetic field exposure, better than 24 hour bedroom measurements. This is not a measurement that is often used in epidemiological studies.

Other confounders for exposures are city powerfrequency fields in cold countries in the winter. Straume ([2008](#)) found in Trondheim, in Norway, that even in summer 4% of street PF levels had values exceeding 0.4 microtesla (μT). In winter the number of streets with magnetic fields

exceeding 0.4 μT increased to 29% and 34% on cold or snowy days. The average levels were 0.85 μT in winter when cold and .9 μT in winter when snowy. The highest recorded level was 37 μT . High spot measurements were usually encountered above underground transformer substations. In winter electric heating of pavements also gave rise to relatively high flux densities.

About 50% of the street lengths measured in Göteborg City in Sweden had magnetic field levels of 0.2 μT or more (Lindgren [2001](#)). The authors suggested that outdoor exposures in a city environment should be considered in exposure assessments.

One study (Ilonen [2008](#)) looked at the magnetic field levels to be found in apartments in buildings which housed a transformer. The idea was to check which floor/floors should be considered 'exposed' and which 'unexposed'. They found that 63% of apartments above the transformer had 0.4 microtesla + levels as did 14% of those on the floor (first floor) above that. They considered that the first floor apartments should not be considered unexposed in epidemiological studies. A further study by Huss ([2013](#)) found lower levels of personal exposure; 0.23 μT on the floor directly above and 0.06 μT in an apartment adjacent to a transformer room. A study by Sirav ([2014](#)) looking at magnetic field levels from a transformer on the bottom floor of a three-floor building found that people living and working in the building were exposed to ELF magnetic fields higher than the threshold magnetic field value of the International Agency for Research on Cancer (IARC). Many people living in this building reported health complaints such as immunological problems of their children.

In March [2007](#), Maslanyj and others investigated residential sources of EMFs, as the large UK Childhood Cancer survey (UKCCS) concluded that there is an unexplained association between exposure to the magnetic fields arising from the supply and use of electricity, and an increase in risk of childhood leukaemia. Maslanyj's study looked at the same houses as those in the UKCCS with elevated EMFs and found that *"low-voltage (LV) sources associated with the final electricity supply accounted together for 77% of residential exposures above 0.2 microtesla (μT), and 57% of those above 0.4 μT . Most of these exposures were linked to net currents in circuits inside and/or around the home. High-voltage (HV) sources, including the HV overhead power lines that are the focus of public concern, accounted for 23% of the exposures above 0.2 μT , and 43% of those above 0.4 μT "*. This presents a problem when it comes to estimating exposure due to distance from a powerline.

Powerlines cause rotating magnetic fields, i.e. the magnetic 'direction' rotates 50 (or 60) times a second as well as the field strength varying at the same speed.

In 2010, the ICNIRP reference levels which are supposed to protect the general public from adverse health effects from EMF exposure, raised the level from 100 μT to 200 μT .

Some research makes the assumption that the higher the field, the more likely it is to find an effect if there is one (Bernard [2008](#)). This ignores the theories suggested by scientists that living systems respond in different ways to environmental stimulants and low level electromagnetic fields may 'get under the defence mechanisms' and may be more important according to when, in the lifecycle, exposure takes place (Miyakawa [2001](#)), whereas higher levels provoke self repair mechanisms, and are, therefore, less hazardous to health. Anton-Leberre ([2010](#)), reported on the absence of magnetic field effects on yeast and concluded that magnetic fields have no impact on the transcriptional machinery and on the integrity of unicellular biological systems, despite the fact that the only exposures used were 55T or 4 x 20T, which is very different to the sorts of exposure that are likely to be found in the normal environment, except possibly near an MRI, and may be well outside any effect window.

It may also be the shape of the field that is at least as significant as the strength (Jankowski [2008](#)). Carrubba, who was looking specifically at changes in EEG as a result of magnetic field exposure suggested that the reason that there have been research inconsistencies into the presence of

electromagnetic fields, is that linear methods (using time averaging) are used to analyse what are nonlinear phenomena (2007a). It has also been suggested that *changes* in exposure level may be important, as cells do not have time to adjust. This would not show in a time-averaged metric.

Many laboratory experiments do not take into account other sources of magnetic fields that may have an effect on biological changes. The Earth's (relatively static) geomagnetic field varies from about 30 microteslas to over 50 microteslas at different places on Earth – and from about 30 to 45 across the USA alone! A study by Lee (2012) found that long-term and low-dosage (0-200mT) exposure to static magnetic fields is capable of inducing an apoptosis-mediated behavioural decline in nematodes.

Laboratory equipment is often stainless steel and magnetised – so that, too, is important. Many laboratory incubators contain internal AC fan motors to circulate the air, as magnetism was never considered relevant when the incubators were designed.

Some experimental work uses human models to evaluate the effects of electromagnetic field exposure. Skarja (2009) reminds us that absorption, transmission and emission of the near electric field exposure by the organism, is quite different from its behaviour if the organism is treated as a simple dissipative conductive body. The active electrical response can be attributed at least partially to the response of the organism's own electromagnetic field.

A review by Mild & Mattson (2010) of the work done by the Bioelectromagnetics group at the Catholic University of America (CUA), concluded that *“biological effects can be found after exposure to low-level ELF and RF electromagnetic fields, and when effects are observed, applying an ELF magnetic noise field inhibits the effects.”* *“In all cases where the noise field has been applied to prevent an observed effect, it has been successful in eliminating the effect.”*

It may be the quality of the power supplied rather than the field levels. ‘Dirty’ electricity (poor power quality) was investigated in 3 schools in America (Havas & Olstad 2008), where they found high levels of dirty electricity were associated with adverse effects on teacher health and student behaviour. See the separate article on “Dirty electricity”.

When an adverse environmental factor is *proven* to have a clear health effect, governments then legislate to protect the general public. When the proof is disputed, but there is some considerable suspicion that there *may be* health implications from an environmental pollutant, then it is time for precautionary action.

A study by Calvente (2014) found that 79% of homes measured had magnetic field levels below reference levels with high variations between properties. Exposure levels were influenced by the area of residence, type and age of property, floor of the property and the season of measurement. The authors concluded *“Given the greater sensitivity to extremely low-frequency electromagnetic fields of children and following the precautionary principle, preventive measures are warranted to reduce their exposure.”*

Static electric field from high voltage direct current transmission

With the rapid development of high voltage direct current transmission, the possibility of health effects associated with static electric field (SEF) has caused wide public concern. In a study by Y Xu (2016b) the authors felt that full-body exposure to SEF might be associated with memory impairment.

Precautionary recommendations

The influential 2007 BioInitiative Report www.bioinitiative.org concluded “*a reasonable suspicion of risk exists based on clear evidence of bioeffects at environmentally relevant levels, which, with prolonged exposures may reasonably be presumed to result in health impacts. A new lower public health safety limit for habitable space adjacent to all new or upgraded powerlines and for all other new constructions should be applied. A new lower limit should also be used for existing habitable space for children and/or women who are pregnant.*” (Hardell & Sage [2008](#)).

In the 70s, 80s, and 90s, there were various studies by Marino, Battelle Pacific Northwest Labs and Rommereim that show that exposure to EMFs can have effects on health and well-being of succeeding generations. Precautions need to be taken with respect to EMF exposure as the adverse effects may not be seen immediately and, indeed, for many years to come. This may be a result of the bystander effect discussed elsewhere.

Precautionary measures always carry a cost. In 1986, at the time the electricity companies were being privatized, the Economist magazine calculated that if all the electricity generating companies were required to devote one half of one percent of their turnover to burying overhead cables, we would be able to bury 1000 miles of them every year. There are 8,000 miles of high-voltage power lines in this country, so they would all be buried by now. Denmark buries 18 percent of its high voltage cables, while Britain manages just 6 percent. (From Bill Bryson’s speech following his election to the presidency of the CPRE in July 2007). It is unlikely that the companies will pay to have this done, because of maximising profit for shareholders (Szuba [2009](#)), but if the government were to require it, it could easily be done.

In July 2007 a Cross-Party Inquiry set up to examine in detail the association between High Voltage Overhead Transmission Lines (HVOTL) and an increased risk of childhood leukaemia published its recommendations to Government. Top of their recommendations was a moratorium on the building of new homes and schools within at least 60 metres of existing HVOTL of 275 kV and 400 kV and on the building of new HVOTL within 60 metres of existing homes and schools, and the same within 30 metres from 132 kV, 110 kV and 66 kV lines. The Inquiry also recommended that the Government consider the case for extending this distance to 200 metres for the highest voltage lines and pro-rata to lower voltages. The government chose not to act on these recommendations.

In **Sweden**, a discretionary policy has been established based on a magnetic field strength of 0.2 microtesla, which has not been made law. In **Italy**, new installations are limited to 0.2 microtesla in Toscana, Emilia-Romagna and Veneto. There are also distance limits for Toscana of 80 metres for 150kV and 120 metres for lines with voltages higher than that and an electric field limit of 0.5kVm^{-1} . In general, the regulations apply to new installations near nurseries, schools, hospitals, houses and places where people spend more than 4 hours per day. In a study by Qin ([2011](#)), the team concluded “*The electromagnetic radiation intensity near high-voltage (110kV) lines may be mitigated or intensified by the manner in which the high-voltage lines are set up, and it merits attention for the potential impact on human health.*”

It seems that the evidence is becoming more convincing that ill health is associated with living near powerlines and that it is the government’s responsibility to protect the general public from being exposed to the increased risk. Henshaw ([2002](#)) looked at the different illnesses that have been associated with powerfrequency radiation exposure. He concluded “*Within 150m of powerlines, magnetic field exposures above 0.1 microT are postulated to result in 9000 excess cases of depression in adults and 60 cases of suicide. Electric field effects can mediate increased exposure to air pollution. Within 400m of powerlines, this may result annually in 200-400 excess cases of lung cancer,*

2000-3000 cases of other illnesses associated with air pollution and 2-6 cases of childhood leukaemia. Seventeen cases of non-melanoma skin cancer might occur by exposure directly under powerlines”.

A review by Santini (2009) on the cellular effects of ELF EMFs concludes “The myriad of effects that ELF fields have on biological systems should not be ignored when evaluating risk to humans from these fields and, consequently, in passing appropriate legislation to safeguard both the general public and professionally-exposed workers.”

A further review by Carpenter (2013) states that “excessive exposure to magnetic fields from power lines and other sources of electric current increases the risk of development of some cancers and neurodegenerative diseases.”

A study by Migliore (2017) of the potential effects on cognitive functions from the electric fields generated at power line frequency concluded that, although EF effects on cognitive processes may not often occur in everyday life, their consequences deserve some consideration, especially when they are constantly present in living environments.

EMFs interacting with the environment or other substances

As well as the magnetic fields generated by the flow of current along the power cables, there has been research done by Fews (1999a, 1999b) and the team at Bristol University, which show that the electric fields from the powerlines act as a magnet to airborne aerosols, which are then deposited nearby. This may increase the risk of skin and lung cancer if you live near power lines in areas where there are toxic pollutants such as motorways, cement factories, etc. The Harvard School of Public Health (reported by the BBC in May 2008) found that breathing in air pollution from traffic fumes can raise the risk of deep vein thrombosis, a potentially lethal effect. Most of these conditions have not been investigated near overhead power lines.

Juutilainen summarised a number of studies (2008) concluding “The majority of *in vitro* studies have reported positive findings, which supports the conclusion that magnetic fields of 100 microtesla or higher interact with other chemical and physical agents. Further studies should address biophysical mechanisms and dose-response relationship below 100 microtesla. Animal studies designed according to the classical initiation-promotion concept may not be sufficient for studying the cocarcinogenic effects of magnetic fields, and further studies using novel study designs would be useful. Epidemiological data on the interaction between magnetic fields and other environmental agents are scant and inconclusive, and any further studies may be difficult because of the scarcity of subjects with suitable combined exposures.”

Scassellati Sforzolini and colleagues (2004) concluded as a result of an *in vitro* study that 50 Hz magnetic fields had genotoxic and co-genotoxic capabilities. They concluded “The possibility that ELF-MF might interfere with the genotoxic activity of xenobiotics has important implications, since human populations are likely to be exposed to a variety of genotoxic agents concomitantly with exposure to this type of physical agent.” Maes (2000), Koyama (2005) and Jian (2009) also found that EMF altered the spectrum of mutations that resulted from X-ray irradiation. Jian concluded not only that it was synergistic, but also cumulative.

Navas-Acién reported (2002) that EMFs enhanced the effect of specific chemicals (solvents, lead and pesticides/herbicides) in the causation of gliomas, but not meningiomas.

The combination of atrazine (a herbicide) and electromagnetic fields caused degranulation in mast cells which did not occur with EMF exposure alone (Rajkovic 2010).

McNamee (2009) has suggested that as a result of the work on geomagnetic fields (GMF) and health effects (see section below), GMF parameters should be recorded in all laboratory ELF studies.

Geomagnetic field (GMF) changes

Simulated sudden geomagnetic storms, which change the earth's magnetic field exposures, were found by Persinger (2005) to cause sudden death in epileptic rats. Earlier, Schnabel (2000) had not found such a link with human epileptics.

A review by Zhadin (2001) reported an apparent increase in the number of complaints of adverse cardiovascular symptoms on days with high GMF disturbances. Gmitrov & Ohkubo (2002) and Dimitrova (2004) found increases in arterial pressure in relation to changes in GMF disturbances. It has been suggested that GMF activity may play a role in modulating other forms of artificial magnetic field exposure (Chibisov 2004). Gmitrov (2007) reported that static magnetic field (SMF) exposure altered microcirculation on days of low GMF activity, but not at other times.

Lipnicki (2009) suggested that there is an association between geomagnetic activity (GMA) and dream bizarreness. It was suggested that this may be a result of GMA on the secretion of melatonin.

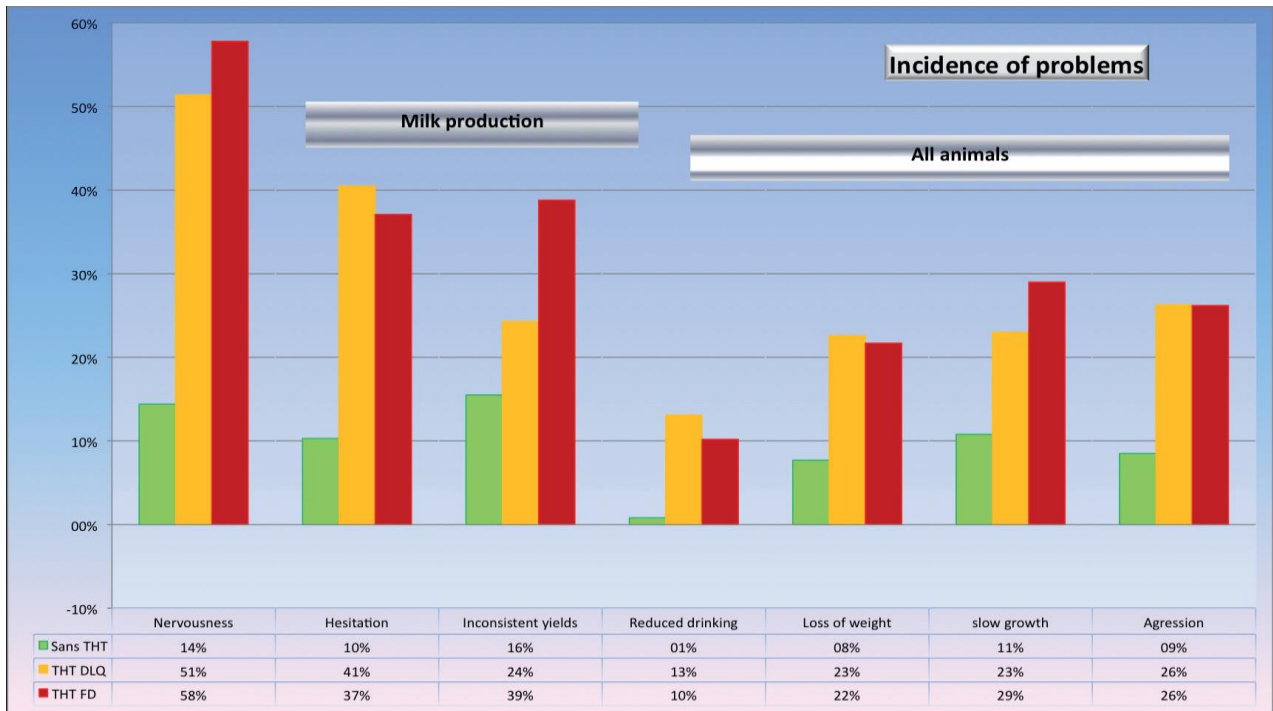
Dupont (2005) had found that litter size was reduced in rats exposed for 48 hours to a simulated high level of geomagnetic activity before giving birth. They were looking for a potential cause of sudden infant deaths.

Many creatures (including birds, salmon and bats) use the earth's magnetic field to help with aspects of their natural behaviour. Dr S Begall from the University of Duisburg-Essen in Germany, told the BBC in 2008 that cattle and wild deer tend to align their bodies in a North-South direction (Begall 2008). She suggested that it may be the Earth's magnetic field influencing this behaviour. In Africa and South America, cattle tend to align themselves in a North east-South west direction; the Earth's magnetic field is much weaker in those areas. Professor John Phillips, at the Virginia Tech University, USA, commented that this 6th magnetic sense might be "*virtually ubiquitous in the animal kingdom*". It is clear that if this is so, humans will be affected by anything which distorts this field, even though we may not know the cause of the effect.

Further research by Burda (2009) found that ELF EMFs generated by high voltage power lines disrupt alignment of cattle and roe deer with the geomagnetic field. The disturbing effect diminished with distance from the powerlines. The reaction to weak ELF EMFs implies effects at the cellular and molecular levels.

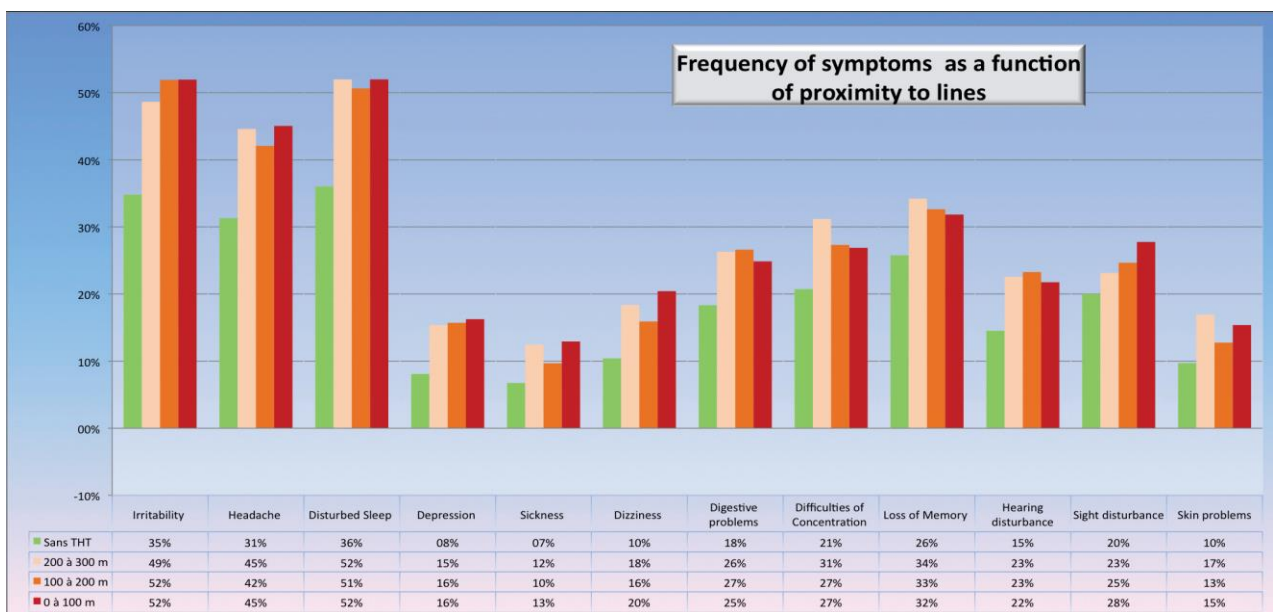
A French study in 2009

This extensive study looked at both human health and cattle behaviour (to eliminate the placebo effect), near to 2 high-voltage power-lines carrying different loads.



The green bar shows the behaviour of cattle in the unexposed areas, the yellow and red bars are near each of the two power-lines.

The graph below shows symptoms reported by people living within 300 metres of the 2 power-lines, compared with those who were unexposed (green bars).



For more information, see:-

http://www.stop-tht.org/IMG/pdf/090219_living_with_a_very_high_voltage_power_line.pdf

Residential exposure

What is the evidence for health effects arising from exposure to EMFs? The results have been mixed as explained in the earlier sections, with respect to occupational exposure. However, there has been sufficient concern expressed by some of the research, such that investigations are ongoing.

The first important study of residential exposure that raised general concern was by Wertheimer & Leiper, who, in 1979 found an association between electricity distribution cables (and the magnetic field levels associated with them) near houses, and an increased risk of children developing leukaemia.

In December 2005, a small, unpublished study in Stoke on Trent UK, looked at the health of people living within 50 metres of a 400 kV powerline (with field levels of over 0.4 microtesla), compared with a control group living 150 metres or more away from a powerline. There were 12 people with cancers in the study group and none in the control group (4 with breast cancer, see Tamoxifen below); twice as many people with depression, 18 of whom had medical treatment, whereas none of the control group did; 3 times as many people with gastric problems; and a staggering 18 miscarriages compared with one in the control group. Many more people living near the pylon line had had medical, including hospital, treatment than those living further away.

Shamsi Mahmoudabadi ([2013](#)) found that low frequency electromagnetic fields exposure is probably related to early spontaneous abortions.

A study by Wartenberg ([2010](#)) found, to the authors' surprise, that people living within 2000 feet from high-voltage transmission lines were more likely to be exposed to magnetic fields, were white, of higher income, more educated and home owners, than those living further away. The possible explanations, they felt, could include the desire for open space created by the rights-of-way, the preference for new homes that are often located near HVTL, and moving closer to the lines before EMFs were considered a risk. It could also be that such properties were discounted due to their proximity to HVTL and were considered a better investment.

Meanwhile, despite the evidence for health effects from living near powerlines mounting, building underneath these structures still continues. In St Marcel les Valence in France, a residential estate was built under a 400kV line. From the picture below, it is clear that the line predated the house-building.



June 2008

January 2011

A team (Al-Bassam [2016](#)) looked at a new housing development in Kuwait, and especially the schools within the development. They measured the field levels from the HV powerlines nearby and concluded “The EMF associated with high tension transmission lines that surrounded the proposed site has to be below $0.2 \mu\text{T}$ (Italian EMF regulations are the most suitable regulations for the establishment of schools in Kuwait). The safety clearance distance from the existing 300-kV high-tension power line has been assigned as 200 m and from other existing 132-kV high-tension power line was 50 m.”

A team in California used a different approach to evaluating whether there were health effects from EMFs. They considered various illnesses and first decided whether they thought there was an association with electromagnetic fields. Then they read the research that either found or did not find a link, and re-considered their position as to whether they thought there was a link or not. Sometimes there was a difference of opinion, but the report suggested there was a link if the majority felt there was a greater than 50% likelihood that there was a connection between EMF exposure and the illness in question. The report was released in 2002, with an excellent summary and commentary by Professor Denis Henshaw of Bristol University. It concluded that there was a likely link between power-frequency magnetic fields and childhood leukaemia, adult leukaemia, adult brain cancer, female breast cancer, and a possible link to childhood brain cancer, male breast cancer and heart disease.

Professor Henshaw, and statistician Professor Mike O'Carroll, produced a [report](#) demonstrating succinctly that despite the fact that powerlines are being shown to increase the risk of developing childhood leukaemia, it is simply the tip of the iceberg. It appears there are far stronger statistical associations showing that powerlines are substantially increasing a number of other conditions such as depression, other cancers, and even miscarriage and suicide.

Tomitsch ([2010](#)) found that the highest low frequency electric fields in homes were due to lamps beside the bed (up to 166 V/m) and the highest magnetic fields were because of device transformers ($1.0 \mu\text{T}$) or powerlines ($0.38 \mu\text{T}$). Earthed lamps, such as those supplied by EMFields, would reduce the electric field exposure dramatically <http://emfields.org/lighting/led-lamps.asp>.

The current development in electronics technology (for example computer use) may lead to increased EMF exposure at younger ages. It has been reported that the number of synapses in the human brain peaks at 2 years of age, and decreases by 40% in adulthood as experience is acquired and redundant connections are lost (Kheifets [2005](#)). This age-dependent pattern of synaptic evolution begs the question as to whether or not EMF exposures in childhood could lead to adverse health effects that are manifested only later in life.

Mitigating biological effects

Litovitz ([1997](#)) showed that biological changes which occurred as a result of exposure to ELF's could be prevented by a simultaneous imposition of ELF 'noise.'

Campaigning organisations

REVOLT www.revolt.co.uk - Revolt opposes unnecessary, excessive and intrusive powerline development. The site has frequent newsletters on related issues, a FAQ section and a links page with (at May 2011) 14 links for EMF research and information, 6 for EMR and masts campaign groups, 40 for powerline campaign groups in 8 national groupings across the world, and 6 miscellaneous links.