



ELECTRIC AND MAGNETIC FIELDS AND YOUR HEALTH

**Information on electric and magnetic fields
associated with transmission lines,
distribution lines and electrical equipment**



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Introduction and summary

What are electric and magnetic fields?

Electric and magnetic fields are produced by any wiring or equipment carrying electric current. This includes overhead and underground power lines carrying electricity, wiring in buildings, and electrical appliances. The strengths of the fields decrease rapidly with increasing distance from the source.

Electric and magnetic fields are fundamentally different, in their physical nature and in the way they interact with the body, from true electromagnetic radiation such as radio waves and microwaves. Information on the health effects of these radiations is available in other National Radiation Laboratory publications. This booklet relates only to electric and magnetic fields around power lines, electrical wiring and appliances.

Do they present health risks?

Most research into this question has concentrated on finding out whether the magnetic fields can cause cancer or could assist the development of a cancerous condition. Other effects investigated include miscarriages, Alzheimer's disease and depression.

In spite of all the studies that have been carried out over the past thirty years there is still no persuasive evidence that the fields pose any health risks. The results obtained show that if there are any risks, they must be very small. A review published by the World Health Organization in June 2007 recommended using exposure guidelines published by the International Commission on Non-Ionizing Radiation Protection, along with low cost measures to reduce exposures where this can be readily achieved. The National Radiation Laboratory and Ministry of Health support these recommendations.

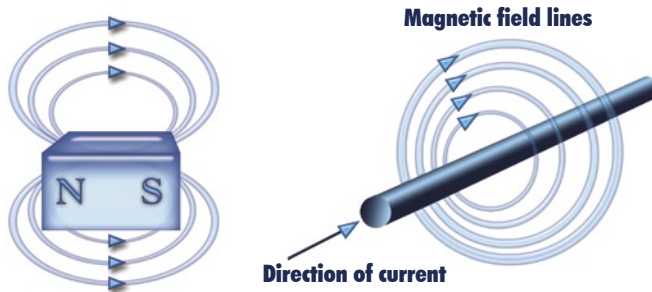
What are electric and magnetic fields?

Magnetic fields

A small piece of iron held near a magnet will move towards and attach itself to that magnet. The magnet produces a magnetic field around it, which attracts the iron. The field can be pictured by sprinkling iron filings on a sheet of paper and holding the sheet over the magnet. When the sheet is tapped gently the filings align themselves in a pattern around the magnet.

The earth is a natural magnet, which enables a compass to be used for direction finding.

Magnetic fields are also produced by an electric current. The magnetic field encircles the current-carrying wire, as illustrated in the diagram.



Magnetic field lines around a bar magnet (left) and a current-carrying wire (right)

If the current through the wire is not steady, but changes in strength and direction, these changes cause changes in the strength and direction of the magnetic field.

Mains electricity in New Zealand houses, and in almost all power lines, is an *alternating current* (AC)*. An alternating current does not flow steadily in one direction, but oscillates backwards and forwards, making 50 complete cycles every second. Therefore, the magnetic field produced by such a current also oscillates at the same rate. This frequency is commonly

expressed as 50 Hertz (Hz), and falls into a range referred to as *extremely low frequency* (ELF). The magnetic fields can be referred to as *ELF magnetic fields*.

Electric fields

The voltage on a current-carrying wire or electrically charged surface produces an electric field around it.

Like the current, the voltage on a cable or appliance carrying mains electricity is not constant but alternates 50 times every second. Therefore, the electric field also alternates and can be referred to as an *ELF electric field*.

Units of measurement

ELF magnetic fields are normally quantified in terms of the *magnetic flux density*. The international (SI) unit of measurement is the tesla (T) or microtesla (μT). 1 tesla = 1,000,000 microtesla. Some literature on the subject uses an older unit, the milligauss (mG). There is a factor of 10 difference between the microtesla and milligauss units: $1 \mu\text{T} = 10 \text{ mG}$, $0.1 \mu\text{T} = 1 \text{ mG}$, etc. In this booklet, magnetic flux densities are given in microtesla, with the equivalent value in milligauss given in brackets.

Electric field strengths are measured in units of volts per metre (V/m) or kilovolts per metre (kV/m), where $1 \text{ kV/m} = 1000 \text{ V/m}$.

* The exception is the power line linking the north and south islands. This is discussed in the section about static fields near the end of this booklet.

Sources of ELF electric and magnetic fields

Electric and magnetic fields are present around all wires carrying electricity, whether they are high voltage power lines, house wiring, or wires inside domestic appliances. The strength of the electric field depends on the voltage, while the strength of the magnetic field depends on the size of the current carried. The strengths of the fields reduce rapidly with distance from the wires.

ELF electric fields

Electricity transmission and distribution lines in New Zealand operate at voltages between 230 volts (normal household voltage) and 220,000 volts (220 kV). Lines operating at 400 kV have also been proposed. In other countries, high voltage (HV) transmission lines at voltages up to or above a million volts (1000 kV) are in use.

Under the highest voltage transmission lines currently used in New Zealand, the electric field strength can reach 3 kV/m*. Trees and buildings shield electric fields, which can reduce their strength considerably. Field strengths inside buildings may be only a small fraction of the field strength outside, and be lower than the fields around electrical appliances.

Typical ELF electric field levels in different situations are presented over the page.

ELF magnetic fields

The strength of the ELF magnetic field beneath a high voltage transmission line may reach up to around 5 microtesla (50 milligauss). The field may vary over the day and through the year as more or less current flows through the line.

* 400 kV lines are discussed in the *Frequently Asked Questions* section at the end of this booklet.

The field strength decreases quite rapidly with increasing distance from the line. Typically, within 50 to 100 metres of the line the magnetic field decreases to the levels found in many houses which are far away from any power lines.

Under low voltage (LV) distribution lines (that is, overhead street wires) the magnetic field may reach 2 microtesla (20 milligauss). Here too, the strength of the field decreases with increasing distance from the line. Magnetic fields are not shielded by trees, buildings or iron roofs. Magnetic fields around small “kiosk” transformers sited on the ground decrease to low levels within 2–3 metres.

Within a few centimetres of some electrical appliances, ELF magnetic fields may be much stronger than those under power lines. However, the fields normally decrease to much lower levels within a metre. The fields are strongest near appliances which contain an electric motor, such as hair dryers and food processors. For most people, their principal sources of exposure to ELF magnetic fields are electrical appliances and house wiring.

Typical magnetic field levels found in various locations are presented over the page.

High voltage transmission lines



Directly beneath line:

Electric fields: 0.3–3 kV/m

Magnetic fields: 0.5–5 μT (5–50 mG)

40 metres from line:

Electric fields: 0.01–0.1 kV/m

Magnetic fields: 0.1–1 μT (1–10 mG)

Generally, magnetic fields decrease to around 0.1 μT (1 mG) within 50–100 metres of the line.

Near street distribution lines



Electric fields: 0.01–0.1 kV/m

Magnetic fields: 0.05–2 μT (0.5–20 mG)

Substations



Electric fields: generally less than 0.1 kV/m except near where overhead supply lines enter or leave the station.

Magnetic fields: generally decrease to around 0.1 μT (1 mG) within 5 metres of equipment except near where supply lines enter or leave the station.

Local supply ('kiosk') transformers



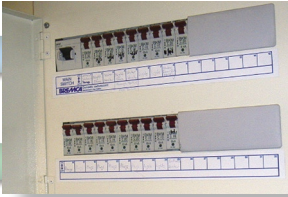
Electric fields: less than 0.1 kV/m

Magnetic fields:

300 mm from transformer: 1–10 μT (10–100 mG)

2–3 metres from transformer: around 0.1 μT (1 mG)

Near switchboard



Electric fields:

300 mm away: 20–100 V/m
1–2 metres away: 10–30 V/m

Magnetic fields:

300 mm away: 1–3 μT (10–30 mG)
1–2 metres away: 0.1 μT (1 mG)

Inside a house or office (away from transmission lines and appliances)



Electric fields: 0.003–0.03 kV/m

Magnetic fields: 0.05–0.15 μT (0.5–1.5 mG)

Near appliances

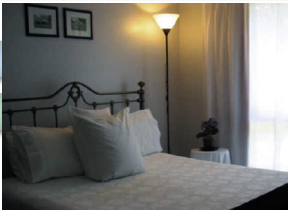


Electric fields: 0.01–0.05 kV/m

Magnetic fields:

300 mm away: 0.05–5 μT (0.5–50 mG)
1 metre away: 0.05–0.3 μT (0.5–3 mG)

Above electric blanket



Electric fields: 0.06–0.6 kV/m

Magnetic fields: 0.02–0.5 μT (0.2–5 mG)

Health effects of ELF electric and magnetic fields

The principal hazard to be avoided with electrical equipment is fatal electric shock from direct contact with conductors. Particular care should be taken by crane and yacht operators and agricultural contractors near power lines.

ELF electric fields

When a person is in an ELF electric field, an alternating electric current flows in the body. Even in fields of 50 kV/m (well above the highest fields present under AC transmission lines), the induced currents are so small they cannot be felt.

In fields of several kV/m, sensitive individuals might feel minute vibrations of skin, hair or clothing. Some people may experience small shocks when touching large ungrounded objects (eg, a large bus) in these fields. These effects are harmless but can be irritating, especially if experienced persistently. However, they can be avoided by simple means such as earthing and screening, and normally people do not feel any sensation, even under even the highest voltage lines.

Studies of people and animals who have been exposed to ELF electric fields show that, at the strengths normally encountered in the home and under power lines, ELF electric fields do not cause health problems.

ELF magnetic fields

ELF magnetic fields also induce very small electric currents in the body. The minute currents produced by fields near transmission and distribution lines and domestic appliances are far too weak to be felt, and are much lower than currents which occur naturally in the body.

Most laboratory studies have found that exposure to ELF magnetic fields has no effect on a wide range of biological processes. However, a few effects have been reported, such as changes in the flow of calcium in and out of cells, changes in hormone production and cell growth.

Although these changes are interesting to study, it is not clear whether they have any implications for health. Some of the effects reported only occurred under conditions quite different from everyday exposures, and many could not be replicated in other laboratories.

ELF magnetic fields and cancer

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 laboratory experiments with cell cultures and animals, and epidemiological studies of people who, because of where they live or work, may have higher exposures to magnetic fields than other people.

Overall, there is a wide consensus that there is a weak but relatively consistent association (correlation) between prolonged exposure to relatively strong magnetic fields and childhood leukemia. For example, a pooled analysis of the results from several studies, published in 2000, found that there was an increased incidence of childhood leukemia associated with exposure to time-averaged magnetic fields greater than $0.4 \mu\text{T}$. The fact that there is a correlation does not necessarily mean that there is a cause and effect relationship. The authors of the pooled analysis commented that “the explanation for the elevated risk estimates is unknown, but selection bias may have accounted for some of the increase.” (Selection bias is an artefact arising from the way the studies were carried out.)

The research findings have been reviewed by several panels of experts around the world*, including the World Health Organization (WHO). Overall, these groups doubt that long term exposure to magnetic fields causes cancer. Although the relationship between childhood leukemia and magnetic field exposures suggests that there may be a link, laboratory research does not indicate any effect of magnetic fields on cancer. This includes several studies on animals exposed over their lifetimes. There are also considerable doubts that ELF magnetic fields, at the levels found around power lines and electrical appliances, could produce any effect at all.

* Findings from recent reviews are summarised in the section *Summary of Conclusions from Recent Reviews*.

Other research has looked at cancer 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.

ELF magnetic fields and other health effects

There have been some studies of other health effects (such as Alzheimer's disease, suicide, depression, or altered melatonin levels) to see whether they might be related to magnetic field exposure. The findings from these studies, too, have been reviewed and found to give no persuasive evidence of any effects.

Exposure guidelines

The National Radiation Laboratory recommends the use of guidelines published by the International Commission on Non-Ionizing Radiation Protection (ICNIRP). ICNIRP is an international scientific body and is recognised by the World Health Organization (WHO) for its expertise in this area.

The ICNIRP guidelines are based on a careful examination of the research data on the health effects of exposure to ELF fields, and include margins for safety. They were first proposed in 1990, and reconfirmed in 1993 and 1998 after consideration of more recent research. ICNIRP has continued to review new research published since 1998, but has not seen any need to amend their guidelines.

ICNIRP concluded that the only effects clearly evident in the research data were those caused by currents induced in the body by ELF electric and magnetic fields. In very strong fields, these induced currents could interfere with the body's nervous system, and so should be limited to levels where no effects can occur. For electric fields, ICNIRP also wished to limit the possibility of experiencing small shocks in strong electric fields.

While acknowledging the results of studies which found a weak association between ELF magnetic field exposures and the risk of childhood leukemia, ICNIRP considered that the results were too tenuous, and lacking support from other sources, to form the basis for exposure guidelines. Other recent reviews, including the 2007 WHO review, came to the same conclusion, and found that the data currently available did not justify setting more stringent exposure limits. The 2007 WHO review supported use of the ICNIRP guidelines.

The ICNIRP guidelines set a *basic restriction* on the density of electric current induced in the body by ELF fields. As induced current density is difficult to measure in the body, the guidelines also prescribe *reference levels* in terms of the more easily measured field strengths. Compliance

with the reference levels ensures compliance with the basic restrictions, and in most applications the reference levels can effectively be regarded as “exposure limits” (although this term is not used as such). If exposures exceed the reference levels, this does not necessarily mean that the basic restriction is also exceeded. However, a more comprehensive analysis is required in order to verify compliance with the basic restrictions.

Basic restrictions and reference levels for occupational and public exposures to 50 Hz ELF electric and magnetic fields

Exposure characteristics	Basic restriction Induced current density (mA/m ²)	Reference levels		
		Electric field strength (kV/m)	Magnetic flux density	
			microtesla	milligauss
Occupational	10	10	500	5000
General public	2	5	100	1000

Note: All values are rms (root-mean-square, a kind of average)

Different limits are set for persons exposed occupationally and for the general public. The main reason for this is that people exposed occupationally are adults, exposed under controlled conditions, who should receive training to inform them of potential risks, and precautions they should be taking. They should be aware, for example, of the possibilities of receiving small shocks when touching objects in a strong electric field. Occupational exposures are limited to the duration of the working day and over the working lifetime.

The general public, on the other hand, includes individuals of all ages and in all states of health, who will not normally be aware of the exposure they are receiving. They can be exposed for twenty-four hours per day, and over a whole lifetime, and should not be expected to accept effects such as annoyance or pain due to small shocks and discharges.



The National Radiation Laboratory recommends that the occupational limits should only be applied to people like electricians or others who are aware of their exposures. In offices and most other work sites, the public limits should apply. In practice, exposures exceeding the public limits are extremely rare.

Compliance with the ICNIRP guidelines has been recommended in many countries. In countries where other recommendations are used, they generally have the same basis as ICNIRP, and recommend very similar exposure limits.

In New Zealand, a *National Policy Statement on Electricity Transmission* published in 2008 under the Resource Management Act requires that planning provisions dealing with ELF fields be based on the ICNIRP Guidelines and the 2007 WHO recommendations.

ICNIRP plans to publish revised Guidelines in 2009. While there may be changes in the detail, it is not anticipated that there will be significant changes to the basis of the Guidelines or the Reference Levels. Information on the changes will be posted on the NRL website (www.nrl.moh.govt.nz) when it is available.

Should I be worried about ELF fields affecting my health?

After some thirty years of research, there is still only weak evidence suggesting that ELF fields might be linked with childhood leukemia. The recent WHO review considered that if there were a true cause and effect relationship, there would be a “limited impact on public health”. Assuming a link does exist, worldwide the fields might be responsible for 0.2–4.9% of all childhood leukemia.

Put another way, although research may never give an absolute yes or no answer about the safety of ELF magnetic fields, we can say with some assurance that if a link is eventually proved, almost all cases of childhood leukemia would be caused by other factors. The pooled analysis of leukemia studies referred to previously included a New Zealand study, and found that none of 86 cases of childhood leukemia reported over a four year period had been exposed to strong magnetic fields (ie, average fields greater than 0.4 μ T). While this does not prove that there is no risk from magnetic fields, it does give an idea of the magnitude of any risk which may exist.

There is no persuasive evidence that magnetic fields which comply with the ICNIRP guidelines are associated with other health effects.

Prudent avoidance

Different perceptions of risks can lead to different actions. Some people conclude that the current evidence for health risks from ELF fields is so tenuous, and the possible risks so small, that no action is necessary. They feel that there are plenty of known risks in life, and that it would be more worthwhile to direct their energies towards reducing these. Others find even the slight possibility of a risk sufficiently disturbing that they would like to take precautions anyway, just in case.

The idea of *prudent avoidance* has been suggested as a means to control exposures to ELF fields if there is any doubt that they are harmless. Prudent avoidance involves limiting exposures which can be avoided with small investments of money and effort, but not doing anything drastic or expensive.

For example, ELF magnetic fields within 50 centimetres of the switchboard in the house may reach one to three microtesla (10–30 milligauss). If someone's bed is situated very close to the switchboard, they may decide to move the bed a little further away to reduce their exposure while they sleep. However, deciding to switch off electricity at the mains every night or to rewire the house would not be seen as necessary.

When buying a new house, proximity to power lines might be one of many things considered. However, even if ELF fields were eventually shown to pose a health risk, factors such as traffic patterns in nearby streets, air quality, and hazards such as open fires, pools and common household appliances are likely to be more important for the health and safety of adults and children. Moving home to get away from power lines goes beyond what would be considered prudent avoidance.

The National Radiation Laboratory and Ministry of Health encourage the use of low or no cost measures to reduce or avoid exposures, and also promote this approach for the siting of new electrical facilities. This is consistent with a recommendation in the 2007 WHO review of ELF fields to take very low cost precautionary measures to reduce exposures, which has effectively been mandated in planning provisions by the 2008 *National Policy Statement on Electricity Transmission* made under the Resource Management Act.

Cardiac pacemakers

A very small proportion of cardiac pacemakers has been found to be sensitive to 50/60 Hz electric and magnetic fields close to the ICNIRP limits for public exposure. (These same devices are also likely to be sensitive to other sources of electromagnetic interference, such as car ignition systems.) It is most likely that they will revert to a fixed pacing mode, which poses no immediate threat to the wearer. Since the field levels at which these effects occur are close to the ICNIRP limits for public exposure, the risk to members of the general public is thought to be extremely small. However, in workplaces where field strengths approaching the occupational limits are expected, precautions may need to be taken to alert or exclude pacemaker wearers.

There are no known instances of adverse effects on pacemaker users around power lines, or in other areas where exposure limits comply with the ICNIRP reference levels for the public.

FREQUENTLY ASKED QUESTIONS

Q *Do power lines and electrical appliances emit radiation?*

A The electric and magnetic fields around power lines and electrical appliances are not a form of radiation. The word “radiation” is a very broad term, but generally refers to the propagation of energy away from some source. For example, light is a form of radiation, emitted by the sun and light bulbs.

ELF fields do not travel away from their source, but are fixed in place around it. They do not propagate energy away from their source. They bear no relationship, in their physical nature or effects on the body, to true forms of radiation such as x-rays or microwaves.

Q *Are ELF fields strongest around power line pylons?*

A On flat ground, ELF fields are weaker near the pylons than between them, because the cables are at their highest point above the ground. The fields are produced by the voltage on, and electric current through, the cables supported by the pylons. The pylons are simply there to keep the cables well above the ground.

Q *Does lead shield against ELF fields?*

A Lead is very good at shielding x-rays, but has no special shielding properties for ELF fields. Like other metals, lead is a conductor and so can shield electric fields. However, it does not shield magnetic fields. Special grades of steel or alloys are required to shield magnetic fields.

Q *In the past, it was thought that things like asbestos or smoking were safe, but many years later they were found to be harmful. How do we know that some time from now ELF fields are not going to pose the same problems that, say, asbestos does today?*

A Research on ELF fields shows that if they do pose a health risk, it must be very much lower than that due to asbestos or smoking. The health risks of both asbestos and smoking showed very strongly in initial investigations, and were confirmed by subsequent studies. Similar studies on ELF fields have not shown any clear, unambiguous evidence of health risks.

Q *How do the New Zealand exposure guidelines compare with those in other countries?*

A The International Commission on Non-Ionizing Radiation Protection exposure guidelines recommended by the National Radiation Laboratory have been adopted by many overseas bodies, including the European Union. All these bodies have considered research investigating the possibility that there may be an association between exposure to weak ELF magnetic fields and some types of cancer. However, they have concluded that, taken together, the evidence does not demonstrate a cause and effect relationship, and does not form a basis from which exposure guidelines can be formulated.

In the United States, there are no national guidelines. However, some individual states have set limits on the ELF magnetic field levels at the edges of power line rights of way. These vary from 15 to 25 microtesla (150 to 250 milligauss).

Some countries, in addition to adopting the ICNIRP guidelines, have also proposed lower “precautionary” limits in what are considered “sensitive areas”. Such areas generally include places like houses, parks and schools. The levels adopted tend to be based on what is

technically achievable (based on existing levels), and apply to new installations. Switzerland, for example, has set an “installation limit value” of 1 μT (ie, the maximum field from any one installation should be less than 1 μT), and Italy has set an “attention value” of 10 μT and a “quality goal” of 3 μT . All these are time-averaged values.

The Ministry of Health and National Radiation Laboratory do not support the adoption of arbitrary limits which have no basis in the research data. On the one hand, they risk creating unnecessary alarm should exposures exceed the arbitrary level chosen. On the other, if there are genuine adverse health effects, an arbitrarily chosen exposure limit could create a false sense of security if those effects actually occur at a lower exposure level. Some research suggests that “precautionary limits” such as these can actually heighten concerns rather than alleviate them. The WHO does not support such arbitrary reductions either.

Q *Aren't exposures greater than 0.4 μT quite common?*

A While there are many places where exposures might exceed 0.4 μT (near an electric range, near many appliances, beneath low or high voltage power lines), these periods of high exposure are normally quite short. Research shows that when exposures are averaged over periods of a day or more, very few people have average exposures greater than 0.4 μT .

Q *If I am concerned about possible health effects, what simple steps can I take to reduce my exposures to ELF fields?*

A In the home, fields are elevated near operating electrical appliances and meter boards and switchboards. The strength of the fields decreases quite rapidly with increasing distance from these sources, and generally decreases to levels found elsewhere in the home

within 0.5 to 1 metre. Simple means to reduce exposures (especially prolonged exposures) include the following:

- Keep beds more than one metre away from fuse boards, meter boards and electric heaters which operate at night.
- If you have a mains-powered motor driven bedside clock (eg. an older style clock with hands), keep it at arm's length from the bed.
- Switch off electric blankets when in bed (unless the electric blanket is used to remedy health problems).
- Switch off appliances when not in use.

Q *If I live near a high voltage transmission line, am I exposed to dangerous field levels?*

A Measurements on power lines in New Zealand have shown that even directly beneath the line, the electric and magnetic fields are well below the recommended exposure limits. Typically, the field levels decrease to the background levels found in many houses (from house wiring and domestic appliances) within 50–100 metres of the line.

Q *What about the proposals for new 400 kV transmission lines in New Zealand?*

A Transpower (the owner and operator of the national high voltage electricity grid) have made a commitment to comply with the ICNIRP guidelines in all publicly accessible areas near new transmission lines. They have also stated that the conductors will be arranged so as to ensure a rapid decrease in field strengths with distance from the line (an arrangement referred to as “reverse phasing”, generally regarded as a prudent avoidance measure). Calculations of the fields based on Transpower’s design confirm that they will comply with the ICNIRP guidelines.

Q *Does a transformer on the street affect exposures in my house?*

A Magnetic field levels around small “kiosk” transformers decrease to low levels within 2–3 metres, and have no effect on field levels in nearby houses.

Q *Who is monitoring the research in New Zealand?*

A The National Radiation Laboratory, a unit of the Ministry of Health, monitors research and briefs the Minister of Health on significant developments. Research is also reviewed regularly by the *Inter-Agency Committee on the Health Effects of Non-ionising Fields*, which includes representatives from government agencies, local government, health researchers, consumer groups and industry.

Q *When will we know whether ELF fields are safe or not?*

A It is actually very hard to prove that something is safe. Experiments can prove whether there are harmful effects, and the levels at which these effects occur. However, the absence of some effect under particular exposure conditions does not necessarily prove safety for all possible exposure conditions. If there were harmful effects from exposure to ELF fields, it is not at all clear what feature of the field – average level, exposure added up over time, variations in exposure, etc – might be important.

Nevertheless, the absence of a wide range of potentially harmful effects over a variety of exposure conditions gives good grounds for believing that adverse effects are unlikely.

Static electric and magnetic fields around DC lines

For some long-distance transmission lines it is more economic to transmit electrical power as *direct current* (DC), where the current flows steadily in one direction. These lines produce static electric and magnetic fields.

The Benmore-Haywards line which links the North and South Islands via the Cook Strait cable is a High Voltage DC (HVDC) line.

Naturally occurring static fields

Magnetic and electric fields which are largely unchanging or static over time, occur naturally. The most significant magnetic field is the geomagnetic field of the earth which varies between 35 and 70 microtesla (350 to 700 milligauss) depending on location.

In fair weather the lower atmosphere contains a static electric field of approximately 0.15 kV/m. During a thunderstorm the electric field strength between the ground and clouds can reach up to a few kV/m.

Static fields and charges are also commonly created by friction through the movement of clothing. Their presence can be felt when a small shock is experienced on touching a bare metal surface, as when touching a metal object after walking on some carpets. These shocks can be unpleasant but are harmless, even though voltages of up to 20 kilovolts may be generated.

Artificial static fields

The static electric field strengths below the HVDC line in open country may reach up to about 30 kV/m. However, in built-up or wooded areas the field strengths can be much lower because of screening by trees, vegetation and buildings. The electric field is due to both the voltage on the line, and also due to the production of air ions (groups of molecules with a small electric charge) around it. The production and movement of air ions is greatly influenced by weather conditions, particularly the presence of wind and rain, so that the electric field under the line also varies.

Air ions are also produced by storms, waterfalls and flames, and as a result of air movement. The maximum ion concentration under the DC line is similar to higher levels found in some natural circumstances.

The static magnetic field beneath the HVDC line linking the North and South Islands has a strength of about half that of the earth's natural magnetic field. Similar static magnetic fields are usually present in electrified trolley buses, suburban rail systems, and much larger fields are experienced by operators in processes such as electrolytic smelting. Patients undergoing diagnostic magnetic resonance imaging examinations are exposed to even stronger fields, about 50,000 times greater than those present under DC lines.

Health effects of static fields

Large metal objects beneath the line, such as vehicles or long fence wires, may build up enough electric charge to cause small shocks when they are touched. Often, however, car tyres and fence posts conduct enough electricity to keep these effects to a minimum.

Extensive overseas studies have not produced any good evidence of adverse health effects attributable to either DC electric fields or air ions associated with HVDC lines.

The static magnetic field beneath the HVDC line is smaller than the earth's magnetic field of around 50 microtesla. No health effects are expected at this level.

Further reading

This booklet has given only a brief coverage of a complex subject. Below are some further references which provide additional information.

- ***ELF electromagnetic fields and the risk of cancer***

This report was published in 2001 by the British National Radiological Protection Board Advisory Group on Non-Ionising Radiation (v 12, no. 1 in the series *Documents of the NRPB*). It updates previous reviews by that group published between 1992 and 1994 and is quite technical, but includes simpler summaries.
- ***Exposure to electromagnetic fields (0 Hz–10 MHz)***

The Health Council of the Netherlands has set up an Electro-magnetic Fields Committee to review research on ELF fields. They published this report in March 2000 and it is available on the internet at www.gr.nl/engels/welcome/frameset.htm – follow links to publications and reports. Updates, also available at the same site, were published in 2001 and 2004.
- ***Interagency advisory committee on the health effects of electromagnetic fields: Report to Ministers. November 2004***

This report reviews the health research available through to 2004, covering both ELF and radiofrequency fields, and sets out the Ministry of Health's recommendations on protection measures. It is available at <http://www.nrl.moh.govt.nz/publications/elf-rfreporttoministers.pdf>.

- ***Guidelines for limiting exposure to time-varying electric, magnetic and electromagnetic fields (up to 300 GHz)***

This document presents the ICNIRP exposure guidelines which are recommended for use in New Zealand. It is very technical and not an easy read. Originally published in the journal Health Physics volume 74, No 4, p. 494-522, 1998. It can also be downloaded on the internet at www.icnirp.de – select “downloads”.

- ***Exposure to static and low frequency electromagnetic fields, biological effects and health consequences (0–100 kHz)***

This report was published by ICNIRP in 2003 and is a comprehensive review of laboratory and epidemiological studies of exposures to static and ELF fields.

- ***Fields from electric power. What are they? What do we know about possible health risks? What can be done?***

This is a set of three brochures prepared in 1995 by the Department of Engineering and Public Policy at Carnegie Mellon University, Pittsburgh, USA. Although not covering the most recent research, much of the discussion (on the nature and occurrence of ELF fields, possible health effects, and possible courses of action) is still relevant. They are written in non-technical language.

Publications not available on the internet may be available from local libraries. If your library does not hold them, they can be borrowed from the National Radiation Laboratory through the library interloan service.

Information is also available on the internet at:

- www.who.int/peh-emf/
This is the home page of the International EMF project, set up by the WHO in 1996 to coordinate a programme to review the scientific literature on health effects of electric and magnetic fields, encourage focused research to fill gaps in knowledge, assess possible health risks and encourage internationally acceptable, uniform exposure standards. A series of fact sheets is available.
- <http://www.microwavenews.com/www.html>
This site, operated by Microwave News, contains links to many other sites of interest.
- www.nrl.moh.govt.nz
This is the web site of the National Radiation Laboratory.
- www.emf-portal.de
This site, set up and operated by the University of Aachen, provides a database of information on studies into the effects of electromagnetic fields. It also covers the radiofrequency fields from radio transmitters.

Appendix: Summary of conclusions from recent reviews

World Health Organization (2007)

- There are established short-term effects of exposure to ELF fields, and compliance with existing international guidelines provides adequate protection.
- Epidemiological studies suggest an increased risk of childhood leukemia for chronic exposures greater than 0.3–0.4 μT . Some aspects of the methodology of these studies introduce uncertainties in the hazard assessment. Laboratory evidence and mechanistic studies do not support a causal relationship, but the evidence is sufficiently strong to remain a concern. If the relationship is causal, the global impact on public health, if any, is limited and uncertain.
- Scientific data suggesting a linkage with other diseases (other childhood and adult cancers, depression, suicide, reproductive problems, developmental and immunological disorders, and neurological disease) is much weaker, and in some cases (eg, cardiovascular disease, breast cancer) sufficient to rule out a causal relationship.
- Exposure limits such as those recommended by ICNIRP should be implemented to protect against the established acute effects of exposure to ELF fields. In view of the conclusions on childhood leukemia, the use of precautionary approaches is reasonable and warranted but exposure limits should not be reduced arbitrarily in the name of precaution.
- Precautionary approaches should not compromise the health, social and economic benefits of electric power. Given the weakness of the link between exposures to ELF fields and childhood leukemia, and the limited impact on public health if the relationship is causal, the benefits of exposure reductions are unclear, so the cost of precautionary measures should be very low.

- Very low cost measures should be implemented when constructing new facilities and designing new equipment (including appliances). When contemplating changes to existing ELF sources, ELF field reduction should be considered alongside safety, reliability and economic aspects.

The WHO report can be downloaded from http://www.who.int/peh-emf/publications/elf_ehc/en/index.html. An information sheet is available at <http://www.who.int/mediacentre/factsheets/fs322/en/index.html>.

International Agency for Research on Cancer (2001)

- There is a fairly consistent statistical association between childhood leukemia and exposure to comparatively high ELF fields. This is unlikely to have been due to chance, but may be affected by selection bias.
- There is no consistent relationship between exposures to ELF fields and the incidence of other childhood cancers, or adult cancers.
- Laboratory studies have shown no consistent enhancement of tumours in experimental animals, and other results have been generally negative.
- Overall, ELF magnetic fields fall within Class 2B (“possibly carcinogenic to humans”) of the IARC classification scheme. This puts them in the same class as car exhaust, coffee and pickled vegetables. Class 2A (probably carcinogenic) includes diesel exhaust, sun lamps and PCBs, and Class 1 (carcinogenic) includes alcoholic drinks, benzene and asbestos.

(British) National Radiological Protection Board (2004)

- Studies on the effects of ELF fields on the central nervous system provide a basis for setting quantitative exposure limits.
- Evidence on other possible effects, mostly from studies into possible effects on cancer, are insufficient to make a conclusive judgement on causality or to provide quantitative exposure limits. However, such studies taken together with people's concerns provide a basis for considering the possible need for further precautionary measures in addition to quantitative restrictions on exposures.
- The ICNIRP basic restrictions and reference levels should be used for controlling exposures.

The report can be downloaded from www.hpa.org.uk/radiation/publications/documents_of_nrp/abstracts/absd15-3.htm. Related publications produced by the NRPB (now the Radiation Protection Division of the Health Protection Agency) include *Advice on Limiting Exposure to Electromagnetic Fields (0-300 GHz)* (which was based on the review discussed above), available at http://www.hpa.org.uk/radiation/publications/documents_of_nrp/abstracts/absd15-2.htm, and *Power Frequency Electromagnetic Fields, Melatonin and the Risk of Breast Cancer*, published in 2006 and available at <http://www.hpa.org.uk/publications/PublicationDisplay.asp?PublicationID=31>.

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The National Radiation Laboratory (NRL) is a unit of the Ministry of Health. It is based in Christchurch.

Its role is to provide a regulatory function in the radiation health area, and to provide independent radiation protection advice.





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