Electric and Magnetic Fields and Your Health

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

2013 edition

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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 Ministry of Health 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 30 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 very low-cost measures to reduce exposures where this can be readily achieved. The Ministry of Health supports these recommendations, which more recent research indicates are still valid.

What are electric and magnetic fields?

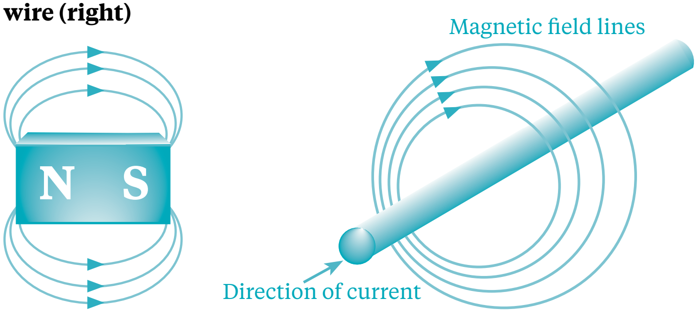
Magnetic fields

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 Figure 1.

Figure 1: 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 μT = 10 mG, 0.1 μT = 1 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 kV/m = 1000 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). A line capable of operating at up to 400 kV was put into service in 2012, but will only operate at 220 kV until about 2035. 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 on pages 6 and 7.

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

ELF magnetic fields

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

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 µT (20 mG). 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 on pages 6 and 7.

Examples of electric and magnetic field levels

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: 0.1–0.7 µT (1–10 mG)

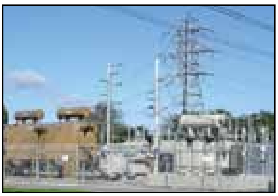
Generally, magnetic fields decrease to around 0.1 µT (1 mG) within 50–100 metres of the line.

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: 0.02–0.1 kV/m
1–2 metres away: 0.01–0.03 kV/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, very weak electric fields are induced in the body. At the levels encountered in everyday life, these are too small to have any effects.

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 weak electric fields in the body. The electric fields induced near transmission and distribution lines and domestic appliances are far too weak to produce any effects in the body. At exposure levels very much higher than found in everyday life, the first effect noticed is the induction of phosphenes through electrical interactions with the retina of the eye. This would be perceived visually as faint flickering lights and disappear with no lasting effect as field levels reduce.

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 µT (4 mG). Studies published since then do not change this assessment. 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). 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. For this reason the expert groups conclude that the evidence is not strong enough to indicate a causal relationship. On the other hand, in view of the positive findings, they consider that it is worth taking simple measures to reduce exposures, if these can be achieved at very low cost and without compromising electrical safety and reliability.

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, reproductive effects and effects on the immune system) 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.

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

Exposure guidelines

The Ministry of Health 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. The basis for the guidelines has remained unchanged for over twenty years, but subsequent reviews have refined the numerical limits. The most recent revision was published in 2010. ICNIRP continues to review research in the area, and has stated that the guidelines will be changed should new data suggest that this is necessary.

ICNIRP concluded that the only effects clearly evident in the research data were those caused by electric fields induced in the body by external ELF electric and magnetic fields. In very strong external fields, these induced fields could interfere with the body's nervous system, and so should be limited to levels where no effects can occur. ICNIRP also wished to limit the possibility of experiencing small shocks in strong external 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 there is no compelling evidence of a causal relationship, and referred to the risk management advice contained in the 2007 WHO review (which supported use of the ICNIRP guidelines).

The ICNIRP guidelines set a **basic restriction** on the internal electric fields induced in the body by external ELF fields. As internal electric fields are difficult to measure in the body, the guidelines also prescribe

reference levels in terms of the more easily measured external 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.

Table 1: Basic restrictions and reference levels for occupational and public exposures to 50 Hz ELF electric and magnetic fields

	Occupational exposures	General public exposures
Basic restrictions:		
CNS tissues of head	0.1 V/m	0.02 V/m
All tissues of head and body	0.8 V/m	0.4 V/m
Reference levels:		
Electric fields	10 kV/m	5 kV/m
Magnetic fields	1000 µT (10,000 mG)	200 µT (2,000 mG)
Contact currents	1 mA	0.5 mA

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 24 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 Ministry of Health 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. Occupational settings in which exposures may approach the occupational limits include areas close to cables carrying very high currents (thousands of amps), or close to large transformers in high voltage electrical switchyards.

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 1991 requires that planning provisions dealing with ELF fields be based on the ICNIRP Guidelines and the 2007 WHO recommendations.

The National Environmental Standards (NES) for Electricity Transmission Activities that came into effect on 14 January 2010 include limits for ELF fields based on the ICNIRP Guidelines.

The NES applies to existing high voltage electricity transmission only. It does not apply to the construction of new transmission lines, nor to substations. The NES does not apply to electricity distribution lines – these are the lines carrying electricity from regional substations to electricity users.

Should I be worried about ELF fields affecting my health?

After more than 30 years of research, there is still only weak evidence suggesting that ELF fields might be linked with childhood leukemia. The 2007 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 leukaemia would be caused by other factors. The pooled analysis of leukaemia studies referred to previously included a New Zealand study. None of the 86 cases of childhood leukaemia reported here over a four year period had been exposed to strong magnetic fields (ie, average fields greater than 0.4 μT (4 mG)). 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 1 to 3 µT (10 to 30 mG). 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 Ministry of Health encourages the use of low or no cost measures to reduce or avoid exposures, and also support 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 1991.

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

Do power lines and electrical appliances emit radiation?

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.

Are ELF fields strongest around power line pylons?

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 and are electrically insulated from the cables.

Does lead shield against ELF fields?

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.

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?

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.

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

The International Commission on Non-Ionizing Radiation Protection exposure guidelines recommended by the Ministry of Health 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 μT (150 to 250 mG).

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 (10 mG) (ie, the maximum field from any one installation should be less than 1 µT (10 mG)), and Italy has set an 'attention value' of 10 µT (100 mG) and a 'quality goal' of 3 µT (30 mG). All these are time-averaged values.

The Ministry of Health does 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.

Aren't exposures greater than 0.4 µT (4 mG) quite common?

While there are many places where exposures might exceed 0.4 µT (4 mG) (near an electric range, near many appliances, beneath low or high voltage power lines), these periods of high exposure are normally quite short. When exposures are averaged over periods of a day or more, very few people have average exposures greater than 0.4 µT (4 mG).

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

In the home, fields are elevated near operating electrical appliances, 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.

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

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.

What about the 400 kV transmission line in New Zealand?

The 400 kV capable line, which became operational in 2012, will be operated at 220 kV until about 2035. According to information presented by Transpower at the Board of Inquiry which granted consent for the line, the fields in public areas around it will at all times comply with the ICNIRP Guidelines.

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

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.

Who is monitoring the research in New Zealand?

Research is reviewed regularly by the Inter Agency Committee on the Health Effects of Non-ionising Fields, which is convened by the Ministry of Health and includes representatives from government agencies, local government, health researchers, consumer groups and industry. The Ministry of Health also participates in the WHO's EMF project and calls on other specialist advice as needed.

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

In principle, it is impossible 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.

Is any research still going on in this area?

While research continues it is at lower levels than seen previously, as there are no clear leads to follow. Most research is focused on trying to provide a firm answer to the question of whether long term exposures increase the risk of leukaemia in children. As it is recognised that population-based studies are unlikely to provide new information, most of this work is being carried out in laboratories.

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 µT (350 and 700 mG) 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 (MRI) 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 µT (500 mG). No health effects are expected at this level. ICNIRP recommends a public exposure limit of 400 mT (400,000 µT/4,000,000 mG).

Further reading

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

Guidelines for limiting exposure to time-varying electric and magnetic fields (1 Hz to 100 kHz)
This document presents the 2010 ICNIRP exposure guidelines which are recommended for use in New Zealand. Originally published in the journal *Health Physics* volume 99, No 6, p. 818–838, 2010, it can also be downloaded from **www.icnirp.org** – select 'downloads'. A factsheet on the Guidelines can also be downloaded from the ICNIRP site.

Guidelines on limits of exposure to static magnetic fields
This document presents the 2009 ICNIRP exposure guidelines for static magnetic fields. Originally published in the journal *Health Physics* volume 96, No 4, p. 504–514, 2009, it can also be downloaded from **www.icnirp.org** – select 'downloads'. A factsheet on the Guidelines can also be downloaded from the ICNIRP site.

Environmental Health Criteria 232. Static fields
This is a comprehensive review of the health research on static electric and magnetic fields, published by the WHO in 2007. It can be downloaded from **www.who.int/peh-emf/publications/reports/ehcstatic/en/index.html**. A Factsheet based on this publication can also be downloaded from the WHO site: **www.who.int/mediacentre/factsheets/fs299/en/index.html**

Information is also available from:

www.who.int/peh-emf/
This International EMF project website, 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.

www.health.govt.nz
This is the website of the Ministry of Health.

www.emf-portal.de
This website, run 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.

www.sagedialogue.org.uk
SAGE is the Stakeholder Advisory Group on Extremely Low Frequency Electric and Magnetic Fields. It is a UK group set up in 2004 to consider possible precautionary measures in relation to EMFs. The Group has prepared two assessments: one covering transmission lines, and wiring and electrical equipment in homes, and the second covering low and intermediate voltage distribution systems.

http://arimmora-fp7.eu/
ARIMMORA (Advanced Research on Interaction Mechanisms of electromagnetic exposures with Organisms for Risk Assessment) is a European research programme investigating ways in which ELF fields interact with organisms, with a particular interest in whether there is a mechanism which could explain the correlation between exposure to weak ELF magnetic fields and an increased risk of leukemia in children.

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
www.who.int/peh-emf/ publications/elf_ehc/en/index.html

An information sheet is available at
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 PCBs and fumes from hot frying, and Class 1 (carcinogenic) includes alcoholic drinks, diesel exhaust and asbestos.

(European) Scientific Committee for Emerging and Newly Identified Health Risks (2009)

- ELF magnetic fields are a possible carcinogen, based chiefly on childhood leukaemia results. Cellular studies do not suggest a mechanism which could explain these findings.
- There is no consistent relationship between exposure to ELF fields and self-reported symptoms ('electrical hypersensitivity').
- Recent epidemiological studies suggest an increase in Alzheimer's disease arising from exposure to ELF fields. Further epidemiological and laboratory investigations of this observation are needed.
- The report (which also covers radiofrequency fields) and a 2007 report by the same group can be downloaded from **http://ec.europa.eu/health/scientific_committees/policy/opinions_plain_language/index_en.htm**. This page contains links to summaries of the two reports (Electromagnetic fields 2007, and Electromagnetic fields 2009). The summary pages provide links to the full reports.

European Health Risk Assessment Network on Electromagnetic Fields Exposure (2012)

- There is limited evidence for an association between ELF magnetic fields and leukemia in children. Epidemiology studies show an association with some degree of consistency, but there is no known mechanism which could explain any effect, no supporting evidence from laboratory studies, and it is acknowledged that other factors could have produced a spurious association.
- For cardiovascular disease, breast cancer and electrical hypersensitivity the evidence suggests that ELF magnetic fields have no effects.

- For other outcomes the evidence is insufficient to draw firm conclusions. This may be because study results are inconsistent, or because few studies have been carried out, or both.
- The report (which also covers radiofrequency fields) can be downloaded from http://efhran.polimi.it/docs/D2_Finalversion_oct2012.pdf