A Review of Recent Investigations into the Possible Health Effects of Exposure to Electromagnetic Fields (EMF) from Power Lines

1 Introduction

Power lines which transport large amounts of electrical power over long distances have been the subject of much investigation for more than three decades with regard to the possible impact they may have on human health. Studies have been carried out in many countries and the results of the research is generally available in scientific literature and in reports issued by academic bodies, governmental agencies and the media. There has been a steady improvement in the methods of measurement and analysis used by investigators over the years, employing both epidemiological and experimental approaches.

In 2007 the Department of Communications, Marine and Natural Resources published a comprehensive report on Health Effects of Electromagnetic Fields which had been prepared by an international panel of experts[1]. The present paper focuses on the possible health effects of electromagnetic fields produced by power lines, and is motivated by the prospect of a new cycle of construction of high voltage transmission lines.

This extensive array of international research, reviews and reports shows a wide degree of consensus, although in some areas the interpretation of investigations of potential health risks is still somewhat controversial. There still exists a range of opinions within the scientific community and elsewhere. The bulk of the research has focussed on determining whether there is any link between exposure to power line electro-magnetic fields (EMF) and the occurrence of cancer. An association with childhood leukaemia was first suggested in 1979[2], although power frequency fields have too little energy by a factor of many millions to break the weakest chemical bond. Adverse links have, from time to time, been reported also to adult cancer, Alzheimer's disease, depression, miscarriage, suicide and cardiovascular diseases. However, more recent and more thorough investigations have failed to confirm these results.

2 Electric and Magnetic Fields Associated with Power Lines

The transport of large amounts of electrical power over long distances is done with high voltage transmission lines. Low voltage is avoided because of higher line losses. Alternating (AC) high voltage can then be reduced without additional losses by using step-down transformers and be supplied to homes in Ireland at 230 volts. The alternating current oscillation frequency is 50 cycles per second (50 HZ) and the high voltage transmission values range from 400kV to 38kV.

Electric and magnetic fields (EMF) are produced whenever electricity passes through a conductor. They consist of a region in space through which energy passes that has been created by electrically charged particles. As an example, electric and magnetic fields exist in the vicinity of home wiring, electrical appliances and power lines. Both types of field lessen in intensity with distance from the source. The strength of the electric field depends on the voltage involved and magnetic field strength depends on the amount of current being carried. Shielding against electric fields is not difficult and a typical house shields most of the electric fields that are generated outside it. It is more difficult to shield against magnetic fields. The vast majority of reports on EMF and health effects deal with **magnetic fields**. The investigation of human exposure to **electric fields** has not been considered with the same interest, in the absence of any evidence of significant impact to date. However, indirect effects have been reported due to the increased deposition of charged airborne particles in the respiratory system caused by the presence of large AC electric fields in the vicinity of power lines. A detailed study of the proposed mechanism has been carried out and the suggestion has been rejected (see section 5).

3 Magnetic Field Strength in the Immediate Vicinity of Power Lines.

The unit of magnetic field is the Tesla, or for practical purposes, the microtesla (μT), one millionth of a Tesla. Figure 1 shows the magnetic field associated with power line transmission voltages of 400 kV and 220kV as a function of distance in metres from the centre line. It can be seen that the field strength falls off rapidly with distance. For example, for 400kV (the highest voltage used in Ireland) it can be seen that the maximum magnetic field strength (~11.2 μT) falls to less than ten per cent of its maximum value (~1μT) at a distance of 40 metres from the centre line.

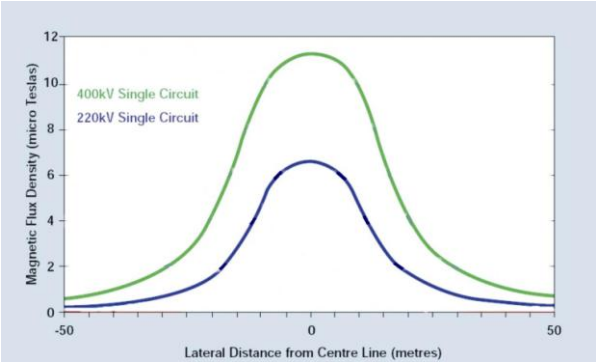

Figure 1 Magnetic field strength as a function of distance from centre line
(Based on Figure 4 in reference 3)

To put this in perspective, Table 1 shows the magnetic field associated with a range of common domestic equipment at ~1m distance. In the average Irish kitchen the magnetic field at the centre of the room rarely exceeds 0.2 μT on average[1].

Table 1 Average Magnetic Field Values for Some Domestic Equipment

Some Domestic Sources of EMF	Range of Average Measurements (μT) at ~1m
Television	0.02 - 0.2
Refrigerator	0.2 - 0.5
Kettle	0.2 - 1.0
Electric Cooker	0.2 - 3.0
Microwave Oven	0.25 - 0.6
Coffee Machine	0.05 - 0.3
Electric Blanket (adjacent)	0.02 - 0.5

4. Investigations of the Occurrence of Childhood Leukaemia and Other Health Effects

Following the first report alleging a link between childhood leukaemia and EMFs produced by power lines, numerous epidemiological and experimental investigations were conducted internationally. Many of the studies conducted during the 1980s and 1990s involved small sample sizes of low statistical significance and they produced a range of conflicting results. The fact that there was no biological explanation for the alleged phenomenon added extra interest and gave rise to further efforts to study the problem. Improved instrumentation and methods of analysis have resulted in new investigations and several specialist reviews including references 4 and 5.

(a) In 1999 the National Institute of Environmental Health Sciences (NIEHS) in the United States published a report[6] which focussed on laboratory studies of the problem and concluded that the evidence suggesting that EMF exposures pose a health risk is weak .The strongest evidence for health effects comes from epidemiological studies which demonstrate a nearly consistent pattern of small increased risk with increasing exposure for childhood leukaemia. No such increase was found in mechanistic studies or in experimental animal studies. The report concluded *"that EMF exposure cannot be recognised as entirely safe because of weak scientific evidence that exposure may pose a leukaemia hazard."*

(b) By combining the results of several studies completed up to the late nineties, Ahlbom et al[7] created larger, statistically significant samples. They found a consistent tendency towards a very small increased risk for childhood leukaemia in areas close to power lines for time-weighted average exposures of more than 0.4 μT. Such exposures are rarely encountered by the general public and the results if confirmed, would correspond to, for instance, an additional 2 cases of childhood leukaemia per year in the UK, compared to an annual total of 500 cases.

However, studies in North America, the UK, Germany, New Zealand, and Scandinavia failed to confirm these findings. Nevertheless, the UK Advisory Group on Non-Ionising Radiation (AGNIR)[8] stated that *"the possibility remains that high and prolonged time-weighted average exposure to power frequency magnetic fields can increase the risk of leukaemia in children"*.

(c) A study[9] of childhood cancer in relation to distance from high voltage power lines in England and Wales reported a similar trend for children living within 200 metres of overhead transmission lines.

(d) The Californian Department of Health issued a report in 2002[10] dealing with the health effects of electric and magnetic fields from transmission lines and other sources, and concluded that EMFs were responsible for an increase in childhood leukaemia, adult brain cancer, and miscarriage. This differed significantly from the conclusions of most other international authorities apart from their agreement that some association with childhood leukaemia existed.

The Californian studies were based mainly on epidemiological methods which are generally observational rather than experimental in nature and researchers cannot influence who does or does not receive an exposure. Consequently, these investigations may be affected by bias or a confounding factor. It is therefore difficult to

infer causal relationships based on epidemiological studies alone, although in combination with information from other sources, they can be important.

(e) Recent World Health Organisation (WHO) investigations[11] based on the results of a WHO work group and the International Agency for Research on Cancer (IARC) and the International Commission on Non-Ionising Radiation Protection (ICNIRP) reviews between 2000 and 2007 found that there is no substantive health issues related to magnetic fields at levels encountered by the general public and conclude that the evidence related to childhood leukaemia is not strong enough to be considered causal. As regards other cancers, it concluded that scientific evidence is much weaker than for childhood leukaemia. WHO also state that evidence does not support an association between EMF exposure and cardiovascular disease. The evidence for breast cancer was also considered to be effectively negative, while for other diseases it was judged to be inadequate.

(f) Members of the public exposed occupationally to low frequency EMFs should exhibit enhanced levels of any health effects associated with power lines and similar sources, because they generally receive much higher exposures than the general public. Several studies were undertaken over the last decade and most were based on very large samples and provide excellent data. These investigations have, generally, not shown raised risks of leukaemia or brain cancer.

5. Search for Explanation for Alleged Effects

(a) Sources of Corona Ions

The presence of high voltage systems which give rise to strong electric fields can cause electrical breakdown of the surrounding air (corona discharges) if they are close to conductors such as water droplets. As a consequence, high voltage AC power lines can produce clouds of negative and positive ions that are readily blown downwind. These clouds can deposit electrical charges on pollutants that pass through them and can increase their deposition in the lung[12].

The main health hazards of airborne particulate pollutants are cardiorespiratory disease and lung cancer and the health risk could be enhanced due to the particles being charged. However, a very comprehensive report by AGNIR[13] and its Ad Hoc Group on Corona Ions concluded that *'The extent to which corona ions increase the dose of pollutants to target tissues in the body can not be estimated precisely'* and that *'some increases observed have been attributed to the design of the experiments'*. The group stated that it seems unlikely that corona ions would have more than a small effect on long term health risks and that *'In public health terms, the proportionate impact will be even lower because only a small fraction of the general population live or work close to sources of corona ions'*

(b) Biophysical Mechanisms

A wide range of biophysical mechanisms have been put forward as possible explanations for alleged health effects of power lines and very low frequency EMFs. Lack of biophysical mechanisms operating at such low levels argues against causality. Recent investigations of the problem[14] found *'that some of the mechanisms are impossible and others require specific conditions for which there is limited or no evidence as to their existence in a way that would make them relevant to human exposure.'* The authors concluded that effects below 5μT are implausible and *'that health effects of environmental electric and magnetic fields are impossible'* at this level of exposure.

6. Precautionary Measures and Reducing Exposure to EMF

The International Commission on Non-Ionising Radiation Protection (ICNIRP) is the organisation responsible for non-ionising radiation protection for the World Health Organisation (WHO). The ICNIRP guidelines limiting public and occupational exposure to EMF have been adopted by many countries, including Ireland. The guidelines attempt to ensure the protection of citizens from adverse effects that might arise from exposure to EMF. Based on the findings of extensive international research, ICNIRP has set a guideline on exposure of 100μT for the general public. This internationally accepted guideline is about 10 times greater than the maximum exposure near a power line.

Several methods to reduce public exposure to power lines have been considered, particularly their burial underground, but implementing them is often complicated due to cost-benefit considerations. A recent report[15]on the Northern Ireland Electricity (NIE) and Eirgrid 400kV power line between Cavan/Tyrone and Meath/Cavan, estimated costs of underground and overhead systems as €588m and €73m, respectively and ~70% higher running costs for the underground option over the course of its lifetime.

Options including the location of power lines to avoid public buildings, homes and schools, and improved electrical appliances and

home wiring are constantly under review.

7. Conclusions

There is a body of epidemiological evidence which suggests that time-weighted average exposure to power line magnetic fields above 0.4μT is associated with a small increase in the risk of leukaemia in children. If real, this is a "threshold response"' with no observed effect below this approximate value. The general public is exposed to average fields of this magnitude very rarely. If the risk were real, it would correspond to an increase of about 1 case of childhood leukaemia in Ireland every four years. Effects with such a low frequency are very difficult to detect with any reasonable level of certainty. The lack of positive findings in controlled experiments or in studies on animals further weakens the belief that this association is in fact, a real one. Furthermore, there is no known biological explanation for the effect. It is simply not possible for the level of energies associated with power lines to cause cancer. The World Health Organisation, ICNIRP (International Commission on Non-Ionising Radiation Protection), the Irish authorities[1,3] and several other international and national radiation authorities consider that the evidence for increased risk of all other types of cancer, as a result of exposure to power frequency electric and magnetic fields, to be scientifically unconvincing.

8 Brief Glossary

Biological Effect: A measurable change in a biological system in response to (for example) an electromagnetic field.
Confounding: Spurious findings due to the effect of a variable that is correlated with both the exposure and the disease under investigation.
Corona: The partial breakdown of air near a high voltage conductor which produces clouds of negative and positive ions.
Electric Field Strength: The force on a stationary unit positive charge at a point in an electric field.
Epidemiology: The study of the distribution of disease in populations and of the factors that influence this distribution
Frequency: The number of cycles per second for a periodically varying quantity.
Ionising Radiation: Capable of completely removing an electron from an atom or molecule in matter. X-rays and high energy particles can do this because they have sufficient energy.
Magnetic Field Strength (flux density): The force on a moving unit positive charge at a point in a magnetic field per unit velocity.
Non-Ionising Radiation: Electromagnetic radiation that does not possess sufficient energy to remove an electron from an atom or molecule. Visible light, power frequency EMFs and microwaves are examples.

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