

**Interagency Committee on the Health  
Effects of Non-ionising Fields:  
Report to Ministers 2015**

---

Citation: Ministry of Health. 2015. *Interagency Committee on the Health Effects of Non-ionising Fields: Report to Ministers 2015*. Wellington: Ministry of Health.

Published in April 2015  
by the Ministry of Health  
PO Box 5013, Wellington 6145, New Zealand

ISBN: 978-0-478-44811-5 (online)  
HP 6181

This document is available at [www.health.govt.nz](http://www.health.govt.nz)

# Contents

Executive summary .....	v
1 Introduction .....	1
2 Current Ministry of Health policies and recommendations in New Zealand.....	2
2.1 Extremely low frequency fields .....	2
2.2 Radiofrequency fields.....	3
3 Research: ELF fields.....	6
3.1 Introduction .....	6
3.2 Review by WHO in 2007 .....	6
3.3 Work since publication of the WHO review.....	7
3.4 Overseas reviews in the past three years.....	9
3.5 Future work .....	9
3.6 Conclusions .....	10
4 Research: RF fields.....	11
4.1 Introduction .....	11
4.2 RF and cancer.....	11
4.3 Electrohypersensitivity and other symptoms.....	14
4.4 Children.....	15
4.5 EEG effects.....	16
4.6 Recent overseas reviews .....	16
4.7 Future work .....	16
4.8 Conclusions .....	18
5 Exposure limits in other jurisdictions.....	19
5.1 Australia .....	19
5.2 European Union .....	19
5.3 Canada .....	20
5.4 IEEE/ICES .....	21
5.5 USA .....	21
5.6 Comparison of limits for RF field exposures .....	22
6 Issues in New Zealand .....	23
6.1 How exposures in New Zealand are covered under current legislation.....	23
6.2 New technologies.....	25
6.3 How EMF / health issues are handled in New Zealand.....	28
6.4 Key EMF research carried out in New Zealand .....	30

Appendix A: Common concerns about the New Zealand RF field exposure standard .....	32
Appendix B: The IARC classification scheme.....	34
Appendix C: Recent ELF reviews .....	35
Appendix D: Recent RF reviews.....	38
Appendix E: The Bioinitiative Report .....	45
Appendix F: Terms of reference of the Interagency Committee on the Health Effects of Non-ionising Fields.....	47
Appendix G: Background material on ELF and RF fields .....	49
References .....	53

# Executive summary

The Ministry of Health convenes a technical advisory committee, the Interagency Committee on the Health Effects of Non-ionising Fields (the Committee), to monitor and review research on the health effects of electromagnetic fields. The Committee reports to the Director-General of Health but also periodically prepares a report for Ministers to provide them with background information and a current summary of key research findings.

This report is not intended to be an exhaustive or systematic review of recent research. Rather, it highlights key findings from comprehensive reviews undertaken in recent years by national and international health and scientific bodies, illustrated in places by examples from individual studies of interest or that exemplify work carried out in particular areas.

## *Extremely low frequency magnetic fields*

The questions over whether exposures to extremely low frequency (ELF) magnetic fields have any effect on the development of leukaemia in children, and neurodegenerative diseases in adults (such as Alzheimer's disease and amyotrophic lateral sclerosis), remain unresolved. Further studies on childhood leukaemia have not led to any more definitive conclusions on whether the associations between long-term exposure to ELF magnetic fields and childhood leukaemia show a true cause and effect relationship or are simply the results of biases (acknowledged as a possibility), confounding by unidentified factors (less likely), or something else.

This work has confirmed, however, that even if there is some effect of magnetic fields, this would be responsible for only a very low percentage of childhood leukaemias. A comprehensive review by the World Health Organization (WHO) published in 2007 recommended the use of exposure guidelines such as those used in New Zealand, together with very-low-cost measures to reduce exposures where this can be readily achieved. The Committee and the Ministry of Health support these recommendations.

## *Radiofrequency fields*

Research into the possible effects of radiofrequency (RF) fields on health also has some open questions. Although studies into brain tumour risks associated with cellphone use have found a small association in the heaviest users, the researchers acknowledge that this could simply reflect biases in the data. Nevertheless, the suggestion that there may be a risk has meant that the International Agency for Research on Cancer (IARC) classified RF fields as a 2B 'possible' carcinogen in 2011.\*

---

\* As noted in the 2004 *Report to Ministers*, IARC classified ELF fields as 2B in 2002.

Animal studies do not suggest an effect of RF fields on cancer. Analysis of brain tumour registrations in relation to numbers of cellphone subscriptions does not show any trends suggesting a link, but this could be due to long latencies, or (perhaps, more improbably) some other factor that is simultaneously acting to reduce brain tumours. Research published since the IARC classification tends to weigh against the possibility of any risk, but may just reflect the fact that exposures from the newer cellphone technologies are much lower than those in use at the time most of the data used in the IARC evaluation was acquired.

RF research is continuing in a number of areas, but data currently available provides no clear or persuasive evidence of any other effects. For this reason, the Committee and the Ministry of Health continue to support the use of exposure limits for RF fields set in the current New Zealand Standard, which is based on guidelines published by an international scientific body recognised by the WHO for its independence and expertise in this area. Those guidelines were first published in 1998 and endorsed, following a review of more recent research, in 2009.

The Committee notes, however, that recent data suggests that at some frequencies the margin of safety may not be quite as high as previously thought. This is not of immediate concern, as public exposures are normally, at most, only small fractions of the allowable limit and a considerable safety margin still remains. However, the Committee recommends that the situation be reviewed following publication of a WHO evaluation of RF fields and health, expected in early 2016.

### *Overall conclusions*

Much new research has been published since 2004, when the Committee last prepared a report for Ministers, but none of this causes the Committee to consider that current policies and recommendations should be reviewed.

In view of the continuing public interest in this area, the ubiquitous nature of exposures and the open research questions that remain, the Committee will continue to monitor new research.

# 1 Introduction

The Interagency Committee on the Health Effects of Non-ionising Fields (the Committee) was originally established by the then Ministry of Economic Development in 1989 to monitor and review research on the health effects of extremely low frequency (ELF) fields. The scope was extended to include radiofrequency (RF) fields in 2001, at which time it became a Ministry of Health technical advisory committee. The current terms of reference and Committee membership are presented in Appendix F. Some background material on ELF and RF fields is presented in Appendix G.

A key function of the Committee is to review recent research findings, especially recent research reviews published by national and international health and scientific bodies, to determine whether any changes to current policies should be recommended. Periodically the Committee prepares a report for joint Ministers, most recently in 2004.<sup>1</sup>

The Committee considers that the fundamental basis for exposure limits currently recommended in New Zealand is still valid. The purpose of this report is to provide Ministers with the background to the reasoning behind that conclusion and update them on research findings since the previous report was prepared.

This report is not a systematic review of research reported in the 11 years since the previous report. There is a steady stream of such reviews from expert panels appointed by health agencies in other countries, and by international bodies such as the World Health Organization (WHO) and the European Union's Scientific Committee on Emerging and Newly Identified Health Risks. Instead, this *Report to Ministers* summarises the principal findings of these overseas reviews, concentrating on those published within the past three years but also referring back to important older publications which are still valid (eg, the WHO's 2007 review of ELF fields). Some key individual scientific papers are also discussed where these help to illustrate the research and the types of approach being followed to improve our knowledge. The cut-off date for research and reviews included in this report is 31 March 2015.

This paper also discusses how the issues are handled in New Zealand, and topics of particular interest that have arisen recently.

## 2 Current Ministry of Health policies and recommendations in New Zealand

### 2.1 Extremely low frequency fields

The Ministry of Health recommends the use of guidelines published by the International Commission on Non-Ionising Radiation Protection (ICNIRP)<sup>2</sup> to manage public exposures to ELF fields. (Worksafe recommends their use for occupational exposures.) ICNIRP is an independent scientific body, recognised by the WHO for its independence and expertise in this area. Their 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.

ICNIRP periodically reviews its guidelines to take account of new research data, and the most recent revision was published in December 2010 (replacing previous guidelines prepared in 1998). This latest version is largely based on the WHO review published in 2007<sup>3</sup> (discussed in section 3.2). The essential biological basis for the guidelines has remained unchanged for more than 20 years.

It is well known and understood that ELF electric and magnetic fields induce internal electric fields and currents in the body. If the external fields are strong enough, these induced electric fields can interfere with the body's nervous system. The ICNIRP guidelines set *basic restrictions* on the electric fields induced in the body by low frequency magnetic and electric fields in order to prevent such interference.

Induced electric fields are difficult to measure, so the guidelines also prescribe *reference levels* in terms of the external magnetic flux density and electric field strength, which can be measured easily. Compliance with the reference levels ensures compliance with the basic restrictions, and in most applications the reference levels can be considered to be the 'exposure limits' (although this term is not used as such).

If exposures exceed the reference levels, this does not necessarily mean the basic restriction is also exceeded. However, a more comprehensive analysis is required in order to verify compliance with the basic restrictions. The reference levels also limit the possibility of experiencing small shocks in strong external electric fields.

The recommended limit varies with the frequency of the ELF field. At a frequency of 50 Hz (the frequency of mains electricity), the reference levels for continuous exposures of the public are 200 microtesla ( $\mu\text{T}$ )\* for the magnetic field and 5 kilovolts per metre (kV/m) for the electric field. For occupational exposures, the reference levels are 1000  $\mu\text{T}$  and 10 kV/m.\*\*

---

\* The microtesla ( $\mu\text{T}$ ) is the unit for magnetic flux density measurement in the international system of units. In some literature on the subject an older unit, the milligauss (mG), is used.  $1 \mu\text{T} = 10 \text{ mG}$ .

\*\* The corresponding magnetic field reference levels in the 1998 ICNIRP guidelines were 100  $\mu\text{T}$  for the public and 500  $\mu\text{T}$  for occupational exposures. Electric field reference levels are unchanged. The main reason for the change in the magnetic field reference levels is improved dosimetry (ie, knowledge about the relationship between the external field to which someone is exposed and the electric field induced in the body by that field).



Different limits are set for people 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 the 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 such as electricians or others who are aware of their exposures and trained in any precautions that might be necessary. In homes, offices and most other work sites, the public limits should apply.

In addition to compliance with the numerical limits in the ICNIRP guidelines, the Ministry also encourages the use of low or no-cost measures to reduce or avoid exposures, and supports this approach for the siting of new electrical facilities. This is consistent with a recommendation in the 2007 WHO review of ELF fields, and with Ministry recommendations with regard to exposures from other agents. It recognises that it is impossible to prove that any agent is absolutely safe, and that there are some areas where further research is being undertaken to complete our understanding of how ELF fields interact with the body. As discussed in section 6.1.1.1, this approach has effectively been mandated in the 2008 *National Policy Statement on Electricity Transmission* made under the Resource Management Act 1991.

The Ministry has published an information booklet, *Electric and Magnetic Fields and Your Health*, which presents an overview of the nature and occurrence of ELF fields and the health effects research, along with the limits recommended by ICNIRP. The booklet is available in printed form or on the Ministry's website.

## 2.2 Radiofrequency fields

The Ministry of Health recommends using NZS 2772.1:1999 *Radiofrequency Fields Part 1: Maximum exposure levels – 3 kHz to 300 GHz* to manage exposure to RF fields. This standard is based on guidelines published in 1998 by ICNIRP,<sup>4</sup> which are based on a careful review of the health effects research and were reaffirmed in 2009<sup>5</sup> following a review of more recent research in this area.<sup>6</sup>

NZS 2772.1 sets limits for exposure to the RF fields produced by all types of transmitters, and covers both public and occupational exposures. Occupational limits should normally be applied only to people who are expected to work on RF sources (eg, radio technicians and engineers, riggers, RF welder operators), who have received training about potential hazards and the precautions that should be taken to avoid them. Their exposures to occupational levels would normally be limited to the working day and over their working lifetime. Occupational exposure limits are set at levels 10 times lower

than the threshold at which the research data provides clear evidence that adverse health effects might occur. The public limits have a safety factor of 50.

As with ELF fields, NZS 2772.1 sets basic restrictions. At frequencies above 10 GHz these are based on the incident power flux density. Below 10 GHz, the basic restriction sets a limit on the amount of RF power absorbed in the body (the *specific absorption rate*, or SAR) and (at the low end of the frequency range covered by the standard) on the RF current density induced in the body.

SAR and induced current density are difficult to measure, so the standard also specifies reference levels in terms of the more readily measured (or calculated) electric and magnetic field strengths and plane wave equivalent power flux density, and currents flowing through a limb when in the presence of the field or when making point contact with a conductive object.

Compliance with the reference levels ensures compliance with the basic restrictions, and in many situations they can effectively be regarded as the NZS 2772.1 'exposure limits', although this term is not used in the standard. If exposures exceed the reference levels, this does not necessarily mean the basic restriction has also been exceeded. However, as with ELF fields, a more comprehensive analysis is required before compliance can be verified.\*

As well as compliance with the numerical limits, clause 10(d) of NZS 2772.1 requires:

Minimizing, as appropriate, RF exposure which is unnecessary or incidental to achievement of service objectives or process requirements, provided that this can be readily achieved at modest expense.

An explanatory note to this clause comments:

Notwithstanding that ICNIRP considers that the basic restrictions and reference levels in this Standard provide adequate protection, it is recognized that community concerns over RF exposure may be able to be addressed by further minimization of exposure in accordance with the requirements of Clause 10(d).

Effectively, this means that when installing RF transmitters, simple steps should be taken to minimise exposures if this can be achieved at low or no cost and without compromising the performance of the system. Options that can be considered when seeking to minimise exposures include:

- site selection – if several suitable sites are available that meet the desired coverage objectives, the one that results in the lowest exposures in public areas should be preferred, all other things being equal

---

\* At frequencies between 100 kHz and 10 MHz, ICNIRP (and NZS 2772.1) requires assessment against limits based on both SAR and induced current density criteria. The limits based on induced current density criteria protect against nerve stimulation. The ICNIRP 2010 guidelines discussed in section 2.1 provide limits to protect against nerve stimulation up to frequencies of 10 MHz, and overlap with limits serving the same purpose in NZS 2772.1. While there are some differences between the ICNIRP 2010 and NZS 2772.1 limits, for now the Committee considers that it would be acceptable to use either when assessing the likelihood that exposures might cause nerve stimulation.

- transmitter power – transmitter power should be set so as to provide coverage in the desired areas, but not beyond that
- antenna placement – particularly on rooftop sites, antennas should be placed so as to minimise exposures in adjacent areas, consistent with achieving the required coverage.

In order to function efficiently, many modern wireless technologies include features that automatically minimise exposures. Mobile phone base stations (cell sites), for example, adjust the transmitter power up and down so as to be just sufficient to handle traffic through the site, as this reduces interference. WiFi devices and access points do not transmit unless they are transferring data (apart from very brief polling signals).

Information about NZS 2772.1 is presented on the Ministry website, along with other information on specific sources of interest (eg, mobile phones and WiFi) and how people can reduce their exposures if they wish to do so.

A companion standard, AS/NZS 2772.2:2011 *Radiofrequency Fields Part 2: Principles and methods of measurement and computation – 3 kHz to 300 GHz*, sets out methods to assess compliance with the standard.

Concerns are sometimes expressed about the validity of NZS 2772.1, and these are discussed in Appendix A.

## 3 Research: ELF fields

### 3.1 Introduction

For many years the key question relating to ELF fields and health has been whether long-term exposures to relatively high fields increases the risk of leukaemia in children. Although epidemiological studies find a small but consistent association, laboratory research does not provide any support for there being a link. This resulted in ELF magnetic fields being classified as a 2B 'possible' carcinogen by IARC in 2002 (as discussed in the 2004 *Report to Ministers*).<sup>\*</sup> Research activities in the past few years have slowed as it has been recognised that simply carrying out more studies similar to those that have been undertaken in the past is unlikely to make any progress.

### 3.2 Review by WHO in 2007

A milestone in the assessment of health effects caused by exposures to ELF fields was the publication in June 2007 of a substantial review in the WHO Environmental Health Criteria series. The review was prepared by a task group convened by the WHO, following its normal rules requiring a diversity of representation, agreement by consensus and freedom from actual or potential conflicts of interest.

The principal conclusions on health risks (section 1.1.11 of the review) were as follows.

- There are established acute effects of exposure to strong ELF electromagnetic fields, and compliance with existing international guidelines provides adequate protection.
- Epidemiological studies suggest an increased risk of childhood leukaemia for long-term (ie, periods of years) average exposures greater than 0.3–0.4  $\mu\text{T}$ . 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, ELF fields could be responsible for 0.2–4.9% of leukaemia cases worldwide. Hence the global impact on public health, if any, is limited and uncertain.
- Scientific data suggesting a link with other diseases (other childhood and adult cancers, depression, suicide, reproductive problems, developmental and immunological disorders, and neurological disease) is much weaker, but in some cases (eg, cardiovascular disease, breast cancer) is sufficient to rule out a causal relationship.

---

<sup>\*</sup> A brief overview of the IARC classification scheme is presented in Appendix B.

On the basis of these findings, the following protective measures were recommended.

- Exposure limits such as those recommended by ICNIRP and the Institute of Electrical and Electronic Engineers (IEEE)\* should be implemented to protect against the established acute effects of exposure to ELF electromagnetic fields (EMFs).
- In view of the conclusions on childhood leukaemia, 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 leukaemia, 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.
- When contemplating changes to existing ELF sources, ELF field reduction should be considered alongside safety, reliability and economic aspects.

At a workshop organised by the WHO just after the release of the Environmental Health Criteria review, the chair of the task group spoke about the great deal of thought that had gone into their recommendations on exposure limits and what form of precautionary approach was justified. The task group had carefully considered the possibility of reducing exposure limits in response to the childhood leukaemia findings but felt that this could not be justified. Nor could they justify any other reduction to existing limits.

### **3.3 Work since publication of the WHO review**

Since publication of the WHO review, research has concentrated in two main areas:

- epidemiological work on childhood leukaemias and other cancers, including several meta-analyses
- neurodegenerative diseases (Alzheimer's disease, amyotrophic lateral sclerosis, etc).

A key part of this work has been to try to understand the origin of the association between the increased risk of childhood leukaemia for chronic exposures to ELF magnetic fields greater than 0.3–0.4  $\mu\text{T}$ , and, in particular, whether the fields themselves are responsible or some other factor.

---

\* These are discussed briefly in section 5.4.1 of this report.

### 3.3.1 Epidemiological studies of childhood and other cancers

A few more epidemiological studies of childhood leukaemia incidence in relation to magnetic fields have been carried out since two major pooled analyses\* of similar research were published in 2000. These formed the basis for a pooled analysis published in 2010,<sup>7</sup> which concluded:

Our results are in line with previous pooled analyses showing an association between magnetic fields and childhood leukaemia. Overall, the association is weaker in the most recently conducted studies, but these studies are small and lack methodological improvements needed to resolve the apparent association. We conclude that recent studies on magnetic fields and childhood leukaemia do not alter the previous assessment that magnetic fields are possibly carcinogenic.

An editorial in the same journal posed the question whether, for childhood leukaemia studies of this type, 'enough is enough?', and commented:<sup>8</sup>

As long as no emerging new ideas become apparent (eg, better exposure assessment, biological mechanism, important confounders), we should accept the limits of epidemiological research. This is mainly true, as the percentage of highly exposed children is below 1%, and the public health impact is low.

One puzzling study on childhood leukaemia incidence in relation to transmission lines was published in 2005 by Draper et al.<sup>9</sup> This found increased risks of leukaemia associated with residence (at birth) at distances up to 600 m from transmission lines. These results did not appear compatible with an effect of magnetic fields, as the fields from distances of around 200 m would have been similar to or less than fields found from other sources in the home. An extension of this study published in 2014,<sup>10</sup> which looked at a longer time period and additional lines, found that the increased risk declined over time between 1962 and 2008, and the results did not support an effect of ELF magnetic fields.

A pooled analysis of studies investigating childhood brain tumours in relation to ELF magnetic fields<sup>11</sup> concluded that 'These results provide little evidence for an association between ELF-MF exposure and childhood brain tumours.'

The WHO 2007 review considered that data on breast cancer was sufficient to rule out an association with ELF fields. Subsequently, a meta-analysis in 2013<sup>12</sup> concluded that there may be an association, but noted limitations in the data on which this finding was based. Since then a further study<sup>13</sup> found no association, and an accompanying editorial<sup>14</sup> concluded that attention should now be focused on more promising avenues of research which could make a difference for public health and advance science.

---

\* A pooled analysis combines the raw data from several studies.

### **3.3.2 Neurodegenerative diseases**

The WHO 2007 review noted that only a few studies had investigated possible links between Parkinson's disease, multiple sclerosis and ELF fields, and that there was no evidence for an association. For Alzheimer's disease and amyotrophic lateral sclerosis (ALS) there had been more studies, some of which suggested increased risks of ALS in people working in electrical industries. It was noted that electric shocks could be a confounder in such studies. Research on Alzheimer's disease gave inconsistent results, but the higher-quality studies focusing on morbidity rather than mortality tended not to find associations with ELF fields.

Further studies, both residential and occupational, have been published since then, along with some meta-analyses of occupational studies.<sup>15,16</sup> A difficulty in analysing these studies is the range (and imprecision) of methods used to assess exposures, which include job titles, measurements, self-reports and job-exposure matrices. Results still show considerable heterogeneity. For ALS, associations tend to be with job titles rather than with measured magnetic fields,<sup>17</sup> and while there is a weak association with Alzheimer's disease, there are concerns about both exposure assessment and disease misclassification.

### **3.4 Overseas reviews in the past three years**

There have been no reviews devoted exclusively to ELF fields in the past three years. However, ELF fields have been included in more general reviews of the whole EMF area by a few groups, and their findings are summarised in Appendix C. These groups note that there are still open questions over the childhood leukaemia data, and that while some research on Alzheimer's disease and ALS reports associations, there is no clear pattern.

### **3.5 Future work**

A few novel approaches to resolving the childhood leukaemia question have been suggested. The intention is to identify a cohort with a relatively high proportion of exposed individuals, or a higher than normal background incidence of childhood leukaemia, so that the weaknesses identified in case-control studies carried out to date can be avoided. Suggestions include studying children living in apartment buildings, in which exposures in ground or first-floor apartments adjacent to a built-in mains transformer are found to be markedly higher than in other apartments; and studying children with Down's syndrome, who have a much greater risk of leukaemia than other children. Some preliminary work in these areas has been published.

In addition, new types of transgenic mice, which better model the development of childhood leukaemia, have recently been developed, but they have yet to be tested with magnetic fields.

A German research programme to better understand all aspects of childhood leukaemia (for which very few risk factors have been identified) is in progress and may suggest further avenues for magnetic field research.

The EU-funded ARIMMORA (Advanced Research on Interaction Mechanisms of electromagnetic exposures with Organisms for Risk Assessment) research programme, due to have been completed in late 2014, was tasked with investigating possible mechanisms by which ELF fields might interact with cells and influence the development of childhood leukaemia.

### **3.6 Conclusions**

Overall, the picture is largely unchanged since publication of the WHO review in 2007. The possibility that long-term exposures to relatively strong magnetic fields (albeit low in comparison to the recommended exposure limits) remains an open question, with the results from epidemiological studies not supported by laboratory research, and agreement that even if there were to be a causal relationship, ELF magnetic fields would only be responsible for a small fraction of childhood leukaemia cases. Research on possible links with neurodegenerative diseases has provided no consistent results.



## 4 Research: RF fields

### 4.1 Introduction

Applications and uses of technology incorporating radio transmitters have burgeoned over the past few years and are likely to continue to do so. Many new devices communicate over cellular phone networks or WiFi, and networks using these technologies have expanded considerably. Some of the new technologies and applications are discussed in section 6.2 of this report.

A great deal of research into the possible health effects of exposures to RF fields, especially at levels that comply with current exposure limits, and at frequencies used by modern communication technologies, has been published in recent years, and some of the key areas of interest are discussed in this section. Several health and scientific bodies have periodically reviewed recent research (typically two to four such reviews are published every year), and findings from these are summarised in section 4.6 and Appendix D.

### 4.2 RF and cancer

#### 4.2.1 Interphone and other cellphone / brain tumour studies

One of the key research topics is whether cellphone use (in particular, use holding the phone up to the ear) is associated with an increased risk of brain tumours. There are two main groups of investigations (the Interphone study and the Hardell group studies), as well as some other case-control and cohort studies, and cancer registry studies.

##### 4.2.1.1 *The Interphone study*

The Interphone study was coordinated by IARC and initiated in 1999. Fourteen research centres (including one in New Zealand) around the world followed an identical research protocol in case-control studies investigating the incidence of three types of brain tumour (meningioma, glioma and acoustic neuroma) in cellphone users. Additional work attempted to assess the reliability of the data collected.

The findings were reported in 2010 (meningioma and glioma) and 2011 (acoustic neuroma). For meningioma and glioma, the Interphone group concluded:

Overall, no increase in risk of glioma or meningioma was observed with use of mobile phones. There were suggestions of an increased risk of glioma at the highest exposure levels, but biases and error prevent a causal interpretation. The possible effects of long-term heavy use of mobile phones require further investigation.

The 'suggestions of increased risk' for glioma were observed in people who reported a cumulative call time greater than 1640 hours, but no increased risk was found for shorter call times. However, the researchers noted biases in the data (such as a tendency for people with brain tumours to overestimate their past usage), which could account for the apparent increased risk.

Findings for acoustic neuroma were similar to those for glioma.

The Interphone data has also been used in two studies, using different methods, which looked at glioma location in relation to the part of the brain that received the highest RF exposure. One of these (using data from five, mainly non-European, Interphone study centres) found an increased risk of tumours in the part of the brain with the highest exposure, while the other (using data from seven European study centres) did not.

#### *4.2.1.2 Hardell group*

A Swedish group under Lennart Hardell has published a series of case-control studies examining brain tumours in parts of Sweden in relation to both cellphone and cordless phone use. The same group has also published several pooled analyses of their data. Overall, these studies find associations between gliomas and acoustic neuroma and all types of wireless phone use, which increases with the number of years a person has been using a phone and with cumulative hours of use.

No explanation has been found for the differences between results from the Hardell and Interphone studies (which included a research centre in Sweden), although the greater quality control and accompanying data validation studies carried out by Interphone have been noted.

#### *4.2.1.3 Cohort studies*

There has been follow-up of a Danish cohort of some 420,000 people who signed a cellphone subscription between 1982 and 1995. Findings have been published in 2002 and 2011 and show no increased risk of brain tumours. This continuing study has several strengths and weaknesses (see, for example, the discussion in Frei et al<sup>18</sup>), but it is generally considered that the weaknesses do not prevent it providing useful information.

A second cohort study has been carried out in the UK,<sup>19</sup> which followed up 791,710 women over seven years. Cellphone use was not associated with brain tumours or non-central nervous system cancers.

#### *4.2.1.4 Registry studies*

Several studies of trends in incidence or mortality rates in cancer registry data (eg, in the USA,<sup>20</sup> UK<sup>21</sup> and Scandinavia<sup>22</sup>) have been published recently to determine whether there are any changes to trends in brain tumour incidence that might correlate with the increased use of cellphones. No such changes are evident, and while the data seems to exclude risks of the magnitude suggested by the Hardell studies, it is not yet sufficient to exclude either a small risk of the magnitude suggested by the Interphone studies or latencies\* greater than around 10–15 years.

A study of trends in New Zealand brain tumour incidence has recently been published, and shows no increases related to the uptake of mobile phones.<sup>23</sup>

---

\* Periods between when a cancer-causing or promoting exposure first occurred and the appearance of the cancer.

## 4.2.2 IARC classification

IARC assembled a working group in 2011 to review the research on RF fields and cancer and to determine where they fit into its classification scheme.\* The group concluded that exposures to RF fields fell into Group 2B – a ‘possible’ human carcinogen. This finding was based mainly on associations (ie, correlations) between heavy use of mobile phones and an increased risk of glioma, but the 2B classification means that while a causal relationship may be possible, chance, bias, or confounding cannot be ruled out as explanations for the association.

The working group also noted that while none of the studies in which animals were exposed over long periods showed an increased incidence of any tumour type, some experiments in which RF exposures were combined with a known carcinogen did. Other data provided only weak evidence of mechanisms relevant to an effect on cancer.<sup>24</sup>

The IARC classification has received widespread publicity, and a paper by the working group chair and IARC staff published subsequently<sup>25</sup> noted:

The classification as possibly carcinogenic to humans was trivialized by some who compared it with other agents having a 2B classification and acclaimed by others who found justification for their opinion that mobile phones present a danger. The subtlety of the 2B classification – that there is some, albeit uncertain evidence of risk, precluding classification as conveying no risk (Group 4) – proved difficult to communicate and did not fit well with media seeking a more definitive position.

Communication was further complicated by the restriction of the IARC Monograph Program to hazard identification because IARC does not quantify risk. A classification as possibly carcinogenic to humans may be misinterpreted by a lay person, meaning that there is indeed an increase in risk, but it is small. Although an underlying ‘weak association’ may reduce the certainty with which a hazard identification is made, the ‘possible’ categorization does not refer at all to the size of risk, but only to the strength of evidence.

The difficulties of communicating the meaning of the IARC finding were also discussed by Wiedemann et al,<sup>26</sup> who found that educated non-experts were likely to misunderstand both the characterisation of the probability of carcinogenicity and also the quantitative risk increase presented in the IARC press release.

The main difficulty appears to be that IARC apply a very strict technical definition to an everyday term (‘possible’), which is normally applied very loosely, so it is not too surprising that different people draw quite different conclusions as to what is really meant. Perhaps the key consideration is that IARC only refer to the quality of the evidence suggesting that there is a risk, and they consider this evidence to be ‘uncertain’.

---

\* See Appendix B.

Conclusions on brain tumour risks from health groups that have reviewed the data since the IARC classification are discussed in section 4.6. However, it is worth mentioning that almost all of the epidemiological data that went into the IARC review was based on GSM (2G) or older-generation cellphones, which typically operate at powers 50–100 times greater than 3G phones, and so produce exposures to the head that are correspondingly higher. For example, widespread roll-out of 3G networks in New Zealand only started in 2005 (although Telecom, as they were then, introduced a predecessor (CDMA2000), whose handsets also tended to operate at lower power than GSM, in 2001). All three mobile networks now offer a 3G service over the whole country.

### **4.3 Electrohypersensitivity and other symptoms**

Electrohypersensitivity (EHS) is the name given to a range of symptoms such as headaches, tiredness, dizziness, sleep disturbances and aching muscles, which some people attribute to EMF exposures. Although both ELF and RF fields have been suggested as a cause of the symptoms, most concern and research has focused on RF fields. The WHO held a workshop on the topic in 2004<sup>27</sup> and concluded that well-controlled and -conducted double-blind studies showed that the symptoms do not seem to be correlated with EMF exposure. For this reason it was proposed that the term ‘idiopathic environmental intolerance (IEI) with attribution to EMF’ be used instead of EHS, to remove any causal implications.

Since the WHO workshop, further laboratory and observational studies have been carried out. Recent reviews of these studies continue to conclude that people who consider themselves unusually sensitive to EMFs are, in fact, unable to detect EMFs, and the occurrence of symptoms appears unrelated to exposures (see, for example, <sup>28,29</sup>). There is experimental evidence suggesting a nocebo effect (ie, someone believing that they are exposed, even when they are not) could provoke the symptoms.

A criticism that has been made about these studies is that they take place in an unfamiliar laboratory setting and involve short-term exposures, rather than long-term exposures in a ‘normal’ environment. Having said that, many people who consider that they suffer from EHS report that they experience symptoms very soon after exposure starts. However, a few studies have been carried out which address those concerns (eg, studies looking at quality of sleep,<sup>30,31</sup> and a variety of health complaints including sleep disturbance, headaches, and poor physical health<sup>32</sup>) and these do not support a role for EMF in the development of EHS symptoms.

## 4.4 Children

The possibility that children might be more sensitive to the effects of RF fields was highlighted by the UK Independent Expert Group on Mobile Phones Report<sup>33</sup> (sometimes referred to as the Stewart Report) published in 2000. The reasoning for this was that children have a longer lifetime of exposure than adults, their nervous system is still developing and, because of higher tissue conductivity and thinner skulls their brains would absorb more RF energy than adults. A 2004 WHO workshop on children and EMF noted that there was no direct evidence of greater vulnerability in children, but neither was there much research that directly addressed the question, and a research agenda was drafted to fill the main gaps in knowledge.

Since then, research that is directly relevant to children has been reported in a number of areas:

- dosimetry (ie, the relationship between external fields to which someone is exposed and the RF power absorbed in the body)
- cancer risks related to cellphone use and residence near broadcast transmitters
- cognitive effects
- developmental studies in animals and humans.

In addition, two research reviews covering aspects of children's health have been published,<sup>34,35</sup> and the WHO organised a further workshop\* in 2011.<sup>36</sup>

The dosimetry studies have confirmed that absorption of RF fields from a cellphone in some parts of a child's head is greater than for adults, but the effect may be frequency dependent and less pronounced at ages greater than eight years. However, the maximum absorption (the highest SAR value) is similar for adults and children, and existing protocols for testing phones are conservative for both.<sup>37</sup>

Dosimetry studies looking at whole-body exposures have found that under some conditions, exposures at frequencies around 100 MHz and 1 GHz that comply with the reference levels may result in the basic restriction being exceeded in children. The amount by which the basic restriction is exceeded, however, is small in comparison to the safety factor of 50, and no adverse effects are anticipated.

One study investigating brain tumour risks in relation to cellphone use by children<sup>38</sup> has been published, and concluded that there was no association between the two. This conclusion was supported by cancer registry data. Overall, studies investigating childhood cancer incidence near broadcast transmitters do not suggest there is increased risk associated with increased exposure, but these studies would most likely not pick up a small increased risk, and exposures are quite low.

---

\* The workshop also covered exposures to ELF fields and ultra-violet.

Other research on development, cognition, etc has, overall, not found that children are especially susceptible. The Health Council of the Netherlands review<sup>34</sup> on the influence of RF fields on children's brain function concluded that there was no cause for concern, but that effects could not be ruled out and further research on possible long-term effects was needed. The Julich review<sup>35</sup> found that the existing scientific evidence did not suggest that children's health is affected by RF from cellphones or cell sites, but that evidence in some areas was limited and further research was needed.

#### **4.5 EEG effects**

A number of studies have investigated the effects of exposures to cellphone-like signals on the brain electrical activity recorded in the electroencephalogram (EEG). Some researchers report finding changes in some frequency bands of the EEG during some phases of sleep following exposure to cellphone-type signals before sleep. The changes are small (eg, they have been described as smaller than those that occur after blinking) and there do not seem to be any effects on sleep quality, or implications for health, and there appear to be considerable differences between individuals.

#### **4.6 Recent overseas reviews**

Several reviews of research into the effects of RF fields on health have been prepared by national and international health bodies in recent years. A summary of reviews published since January 2012 is presented in Appendix D. Overall, these reviews conclude that while there is weak evidence suggesting that heavy use of cellphones may be associated with an increased risk of brain tumours, further research is needed to clarify this. Most reviews consider that for periods of use up to 12–15 years, cellphone use has no effect on brain tumour incidence, and some suggest that research reported since the IARC evaluation goes against there being any link with cancer risk. There are links to these reviews on the Ministry website.

The Bioinitiative Report, first published in 2007 and partially updated in 2012 and 2014, is sometimes cited by people concerned about the possible health effects of exposures to RF fields. The Committee finds that this report has weaknesses that undermine its credibility and conclusions and does not place any weight on its findings or recommendations. This is discussed in more detail in Appendix E.

#### **4.7 Future work**

Several large projects investigating aspects of RF exposures and health are in progress.

- A large US National Toxicology Programme study investigating carcinogenicity in rats and mice exposed to cellphone signals for several hours per day, over periods up to two years, should be completed in 2015.

- The MOBI-Kids study, which is similar to the Interphone study but looking at cellphone use and brain tumours in children, is being carried out in 14 countries (including New Zealand, where the research group has received funding of \$466,148 from the Health Research Council). Data collection is currently in progress.
- A five-year research programme has been established in Australia at the Australian Centre for Electromagnetic Bioeffects Research (ACEBR), a National Health and Medical Research Council (NHMRC) Centre of Research Excellence.\* The planned research programme covers a diverse range of interests, including epidemiology (for which Professor Mark Elwood of the University of Auckland is the chief investigator), animal and cellular studies, dosimetry, human neurophysiology and risk communication.
- The COSMOS (cohort study of mobile phone use and health) study being undertaken in five European countries is tracking the health of 200,000 adult cellphone users for 20 to 30 years, looking at outcomes such as brain tumours and cerebrovascular diseases, and symptoms such as headaches and sleep disorders. A strength of this study is that exposure information will be obtained from ongoing questionnaires and operator traffic records rather than having to rely on the study participants' memories.
- There are several European research programmes in progress, including GERoNiMO (Generalized EMF Research using Novel Methods. An integrated approach: from research to risk assessment and support to risk management\*\*), LEXNET (investigating methods to reduce public exposures by at least 50% without compromising service quality<sup>†</sup>), and the UK-based SCAMP (Study of Cognition, Adolescents and Mobile Phones) programme.<sup>††</sup>
- The WHO EMF Project has completed a draft monograph on RF fields in its Environmental Health Criteria series. A WHO task group to review the monograph and develop conclusions and recommendations will meet in 2015, with publication expected in early 2016.
- ICNIRP has started to review their RF exposure guidelines and plans to publish them at about the same time the WHO monograph is published.
- A further publication from the Health Council of the Netherlands (the third and final publication in its series reviewing the research on mobile phones and cancer) and a French review on research into EHS are expected in the coming year.

---

\* <http://acebr.uow.edu.au>

\*\* <http://www.crealradiation.com/index.php/en/geronimo-home>

† <http://www.lexnet-project.eu>

†† <http://www.scampstudy.org/>

## 4.8 Conclusions

While a great deal of research has been carried out to investigate the potential effects of exposures to RF fields on health, particularly exposures associated with cellphone use, there are still no clear indications of health effects caused by exposures that comply with the limits in the New Zealand RF field exposure standard.

Although the research on cellphone use and brain tumours resulted in RF fields being classified as a 'possible' carcinogen by IARC, IARC considered that the research results giving rise to that classification could have arisen from chance, bias or confounding, rather than reflecting a true cause and effect relationship. Several reviews and meta-analyses published since the IARC assessment (eg, by Repacholi<sup>39</sup> and Lagorio<sup>40</sup>) consider that more recent research weighs against there being a cause and effect relationship, and the complexity of the existing data and difficulties in making further progress have also been highlighted.<sup>41</sup>

Recent dosimetry work has found that at some frequencies the reference levels in the New Zealand standard are not as conservative as expected, and that under some circumstances the basic restriction may be exceeded when small children are exposed to fields that are close to the reference level. This is not of immediate concern for two reasons: measurements in New Zealand show that exposures in areas where children might be expected are always very small fractions of the reference level (so the basic restriction will never be exceeded), and the amount by which the basic restriction might be exceeded is small in comparison to the safety factor of 50 built into the basic restriction. Nevertheless, this should be addressed in the medium term once the WHO RF review (discussed in section 5.3.2) has been published and ICNIRP has reviewed its RF exposure guidelines.



## 5 Exposure limits in other jurisdictions

### 5.1 Australia

#### 5.1.1 ELF fields

The Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) recommends the use of the *Interim Guidelines on Limits of Exposure to 50/60 Hz Electric and Magnetic Fields* (1989), originally published by the National Health and Medical Research Council. These are very similar to the 1998 ICNIRP ELF limits (ie, magnetic and electric field limits for the public of 100  $\mu$ T and 5 kV/m, respectively), although some relaxation is permitted for short-term exposures.

Revised limits have been in preparation over the past few years and are likely to be similar to the ICNIRP 2010 guidelines. They will most likely be advisory rather than mandatory.

#### 5.1.2 RF fields

ARPANSA published RF exposure limits in 2002 in Radiation Protection Series 3 (RPS3).<sup>42</sup> The numerical limits themselves, and the general requirements of the standard, are very similar to NZS 2772.1:1999. However, RPS3 includes more detailed supporting information providing the rationale for the standard and other supplementary material. ARPANSA has recently published a review of more recent research literature (discussed in Appendix D) to help determine whether the standard should be revised.

### 5.2 European Union

#### 5.2.1 Public exposures

The European Union can make recommendations on public exposure limits in member states but is unable to impose them. In 1999 the Council of the EU recommended that member states adopt the 1998 ICNIRP guidelines.<sup>43</sup> A 2011 survey<sup>44</sup> found that 17 EU countries had either adopted the ELF 50 Hz limits (either by regulation or recommendation) or had no limits, while the remaining 10 had adopted a range of measures, including lower limits, lower limits applied to new electrical infrastructure near 'sensitive areas' (eg, homes, playgrounds, schools), specified separation distances between homes and new electrical infrastructure, and the adoption of measures at 'reasonable' cost if average exposures exceed specified thresholds.

For RF limits (eg, at the frequencies around 900 MHz used by cell sites), 17 EU countries had either adopted the recommended limits (either by regulation or recommendation) or had no limits. The others had taken a variety of approaches, including:

- lower limits that apply everywhere (ranging from 70% to 0.5% of the EU recommended power flux density limit)
- a lower limit applied to each antenna

- lower limits that apply in ‘sensitive areas’.

Some countries have regional variations.

Where lower limits have been adopted, the levels chosen appear to be set on the basis of what levels exist already and what can be achieved with existing technology, rather than being derived from an analysis of the health research. However, ‘precaution’ is often cited as a reason for setting lower limits. In one instance, the limits have been raised subsequently to accommodate new technology. Exposure surveys in Europe<sup>45,46</sup> have not found any systematic differences in exposure levels between countries that follow the EU recommendation and those that have lower limits.

The UK recommends using the ICNIRP 1998 guidelines for public exposure.

### 5.2.2 Occupational exposures

After many years of preparation the EU Directive on occupational exposures to EMFs was adopted in 2013. Member states are obliged to pass this into national legislation by July 2016.

Exposure limits in the Directive are based on the ICNIRP 2010 low frequency guidelines, and the 1998 guidelines at higher frequencies. Relaxations are permitted for magnetic resonance imaging (MRI), the military and other industries provided all possible methods to reduce exposures have been attempted, and it can be demonstrated that no adverse effects will occur. A handbook to assist member states and businesses with the implementation of the Directive is in preparation.

### 5.3 Canada

Health Canada has developed exposure guidelines for RF fields, *Limits of Human Exposure to Radiofrequency Electromagnetic Energy in the Frequency Range from 3 kHz to 300 GHz – Safety Code 6 (2015)* (known as SC6).<sup>47</sup> An accompanying document, the *Technical Guide for Interpretation and Compliance Assessment of Health Canada’s Radiofrequency Exposure Guidelines*, contains technical information to assist in understanding the requirements of SC6 and provides recommended best practice for ensuring compliance with the maximum exposure levels, and information on RF survey methods and examples of calculations.

The SC6 basic restrictions are largely similar to those in the ICNIRP 1998 guidelines (and the 2010 guidelines for limits related to nerve stimulation at frequencies up to 10 MHz). However, the localised SAR restrictions in the head, neck and trunk for public and occupational exposures\* are set at 1.6 and 8 W/kg, respectively, averaged over 1 gm of tissue, rather than ICNIRP’s 2 and 10 W/kg averaged over 10 gm of tissue.

Health Canada commissioned the Royal Society of Canada to review and comment on the Code before it was published, and the findings of this review are summarised in Appendix D. The reference levels take into account recent dosimetry findings

---

\* SC6 uses the terms ‘uncontrolled’ and ‘controlled’ environment, rather than ‘public’ and ‘occupational’ exposures, but the terms are largely equivalent.

(discussed in section 4.4 of this report), and so are set somewhat lower than the ICNIRP's over much of the frequency range in order to be certain of maintaining the required safety factors under all circumstances.

At present there are no Canadian government guidelines for exposure to ELF fields. Health Canada does not consider guidelines necessary because the scientific evidence is not strong enough to conclude that typical exposures cause health problems.

## **5.4 IEEE/ICES**

The Institute of Electrical and Electronic Engineers (IEEE) has developed standards for electromagnetic fields since the 1960s. This work is now undertaken by the International Committee on Electromagnetic Safety (ICES), which operates under the rules and oversight of the IEEE Standards Association Standards Board to develop standards for the safe use of electromagnetic energy at ELF and RF frequencies. This includes both exposure and exposure assessment standards. Membership of ICES is open to anyone.

### **5.4.1 ELF fields**

The IEEE/ICES C95.6 standard<sup>48</sup> (published in 2002 and reaffirmed in 2007) covers ELF fields up to 3 kHz. While the fundamental concepts behind the IEEE/ICES limits are very similar to the ICNIRP 2010 ELF guidelines, there are some significant differences between the two, with the IEEE/ICES limits (especially the reference levels – called 'maximum permissible exposures' by IEEE/ICES) generally more relaxed than ICNIRP's. (For example, at 50 Hz, ICNIRP recommend a reference level for the public of 200  $\mu\text{T}$ , compared with the IEEE/ICES recommendation of 904  $\mu\text{T}$ .) These differences arise for a number of reasons, such as the choice of safety factors and the models used to derive reference levels from basic restrictions.

### **5.4.2 RF fields**

The IEEE/ICES C95.1 standard<sup>49</sup> (published in 2005) and ICNIRP also share very similar fundamental concepts in relation to radiofrequencies. At frequencies above about 10 MHz, the reference levels for the public are similar, but larger differences occur at lower frequencies, with the IEEE/ICES limits generally more relaxed. IEEE/ICES occupational reference levels are also more relaxed than ICNIRP occupational reference levels at higher frequencies (above 300 MHz).

## **5.5 USA**

### **5.5.1 Public exposures**

The US Federal Communications Commission (FCC) sets the rules on allowable levels of public exposure to RF fields in the USA and published its regulations in 1996.<sup>50</sup> The limits are a combination of limits recommended in National Council on Radiation Protection Report 86 and the 1991 version of the IEEE C95.1 standard. A review of these limits is currently in progress.

There are no national regulations covering ELF fields, but some states have adopted their own limits for magnetic fields at the edge of power line rights-of-way. These vary from 15 to 25  $\mu\text{T}$ .

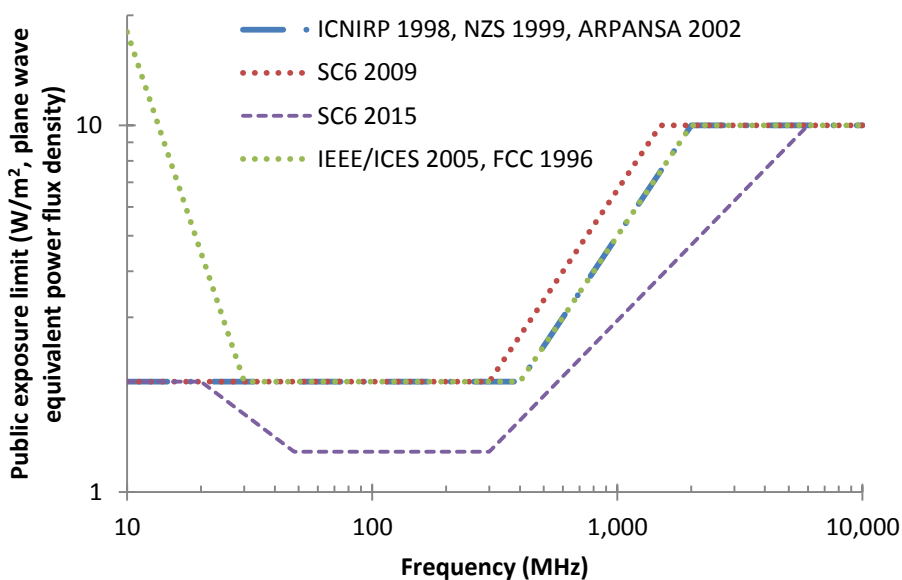
### 5.5.2 Occupational exposures

The US government does not set any limits on occupational exposures at ELF or RF frequencies. The American Conference of Government Industrial Hygienists, an organisation made up of industrial hygienists from within and outside government, recommends limits for a number of physical agents, including non-ionising fields. For 60 Hz ELF fields they recommend limits of 1000  $\mu\text{T}$  and 25 kV/m for magnetic and electric fields, respectively, and for RF fields they follow the IEEE/ICES occupational recommendations.

## 5.6 Comparison of limits for RF field exposures

The public reference levels (plane wave equivalent power flux density) recommended by ICNIRP, ARPANSA, Health Canada (SC6), IEEE/ICES and the FCC are plotted below for frequencies between 10 MHz and 10 GHz.

Figure 1: RF field reference levels recommended by various organisations



## 6 Issues in New Zealand

### 6.1 How exposures in New Zealand are covered under current legislation

#### 6.1.1 Environmental exposures

##### 6.1.1.1 ELF fields

Two instruments under the Resource Management Act 1991 (the RMA) provide national guidance for controls on exposures to ELF fields from transmission lines and associated infrastructure. Policy 9 of the 2008 *National Policy Statement on Electricity Transmission* (the Transmission NPS) states that:

Provisions dealing with electric and magnetic fields associated with the electricity transmission network must be based on the International Commission on Non-Ionising Radiation Protection *Guidelines for Limiting Exposure to Time Varying Electric Magnetic Fields (up to 300 GHz)* (Health Physics, 1998, 74(4): 494-522) and recommendations from the World Health Organisation monograph *Environment Health Criteria* (No 238, June 2007) or revisions thereof and any applicable New Zealand standards or national environmental standards.

The policy 'is to be applied by decision-makers under the Act' and so has the effect of requiring any rules or decisions about ELF fields from the national grid to be based on the ICNIRP 2010 guidelines (the successor to the 1998 guidelines) and the WHO recommendations (summarised in section 3.2 of this report).

The *Resource Management (National Environmental Standards for Electricity Transmission Activities) Regulations 2009* require that following certain types of upgrade or maintenance work to pre-2010 transmission lines, the electric and magnetic fields should comply with the (now superseded) 1998 ICNIRP guidelines. An evaluation of these regulations may take place in 2015, and this may provide an opportunity to consider referencing the ICNIRP 2010 guidelines, whose use is recommended by the Ministry of Health.

Both instruments only apply to transmission lines (and, in the case of the Transmission NPS, associated infrastructure such as substations), but not, say, to local electricity distribution infrastructure. Some district plans have guidance based on the Transmission NPS, and also cover other activities that produce ELF fields.

##### 6.1.1.2 RF fields

Clause 4 of the *Resource Management (National Environmental Standards for Telecommunication Facilities) Regulations 2008* (the Telecommunications NES) requires that when network operators establish a telecommunication facility:

- the site should be designed and operated in accordance with NZS 2772.1:1999
- before a site is established, the operator must assess exposures in publically accessible areas in the vicinity (both from the proposed site and other transmitters nearby) and submit a report to the local authority confirming that exposures comply with the limits
- if the exposures in publically accessible areas are calculated to exceed 25% of the limits, then measurements should be made within three months of the site becoming operational to confirm that exposures comply with the limits.

This requirement only applies to network operators as defined under the Telecommunications Act: this includes mobile phone network operators, and broadcasters such as Kordia, but does not cover, for example, amateur radio operators.

Local authorities are unable to override these requirements, but they may also include non-network operators through provisions in their district plans. A consultation document proposing changes to the telecommunications NES has been released but no changes to the exposure limits are suggested.

### **6.1.2 Occupational exposures**

There are no explicit limits set on EMF exposures from personal devices (eg, hand-held radios) or equipment used in the workplace (eg, high-frequency plastic welders). In practice, occupational exposures, either from equipment or from personal devices, would come under the scope of the employer's obligations to maintain safe working environments and practices. Equipment that may produce potentially hazardous levels of EMF should be identified and the exposures managed.

In some situations and industries this is reasonably straightforward. Operators of major broadcast facilities, for example, are well aware of the potential hazards and areas where these may be present, and the steps that should be taken to avoid, remedy or mitigate them. This may not always be the case, however, and small employers using, say, high frequency welding equipment may not be as aware.

### **6.1.3 Personal devices**

With respect to personal devices (eg, cellphones, tablets), there are also no legislative requirements that explicitly refer to any EMF exposure limits. Although the Consumer Guarantees Act requires that goods sold to the public be 'safe' (which in this situation could be taken to mean 'exposures comply with limits recommended by the Ministry of Health'), in practice the onus would be on the consumer to commission tests of devices that were considered not to comply with the limits, which is a very expensive exercise. A similar situation would apply if action were taken under the Fair Trading Act (eg, if a consumer believed that SAR claims made for a phone were false).

The Ministry of Consumer Affairs has the power to mandate product safety standards under the Fair Trading Act, but takes the view that in specialist areas such as this it is preferable for agencies more directly involved to develop and implement controls, should they be considered necessary.

Whether specific controls are necessary is debatable. Most major markets (eg, the USA, Europe, Australia, China, India) do mandate SAR limits and require evidence of compliance from accredited test laboratories, so in practice it is highly unlikely that manufacturers would produce phones that do not comply. In addition, the three cellphone network operators in New Zealand either require evidence that phones they sell comply with SAR limits or that this information is maintained in a compliance folder by their suppliers. In other words, the desired end is currently being met by non-regulatory means.

The SAR values reported for devices are worst-case values, and assume that devices connected to a mobile phone network transmit at maximum power, and that devices using WiFi transmit continuously. The actual SAR when devices are in use is invariably quite different to the reported value, due to the adaptive power control used in mobile networks and the WiFi duty cycle. 'Drive tests', in which mobile phones were taken on a fixed route around a city, have found that network characteristics are more important in determining exposures than the SAR value.<sup>51</sup> Hence reported SAR values should generally be taken as indicating whether or not a device can be guaranteed to comply with SAR limits under all circumstances, rather than as a meaningful comparative measure of exposures when in use.

## **6.2 New technologies**

This section discusses new RF technologies, especially those that have aroused some public interest, and how they might affect exposures.

### **6.2.1 New technologies and frequencies on mobile phone networks**

All three mobile phone networks operating in New Zealand are currently engaged in the introduction of new technology (4G/LTE\*) and new frequencies. The introduction of 4G/LTE is driven by the need for increased data capacity (around 80–90% increase per year over the past five years) and delivery rates. 4G makes more efficient use of the radio spectrum, allowing more data to be sent using the same transmitter power. Thus while the addition of 4G transmitters to a mobile phone site generally increases the exposure, the increase is less than it would have been had extra 3G transmitters been added to provide the same additional capacity.

As with previous mobile phone technologies, mobile phones and other devices communicating over a 4G/LTE cellphone network use adaptive power control to reduce their power (and hence the exposures they produce) to be just sufficient to maintain the link. The efficiency of power control in 3G phones and devices is well established, and transmit powers during a voice call are normally at least 100 times lower than the maximum possible. Data currently available on 4G/LTE phones suggests that the average transmitting power during a call is also at least 100 times lower than the maximum possible. Average output powers may be higher (but generally still well below the maximum possible) if large data files are being uploaded from the phone or device.

---

\* 4G: 4th generation; LTE: Long Term Evolution.

New frequencies have also been introduced, notably in the 700 MHz band freed up by the move to digital TV transmissions. The reference level at these frequencies is lower than at the frequencies around 900 MHz first used by mobile phone networks. This means that as a percentage of the limits in NZS 2772.1, an exposure in the far field of a radio transmitter at 750 MHz will be slightly greater than the same exposure at 900 MHz. (For example, an exposure of 5 microwatts per square centimetre is 1.3% of the limit at 750 MHz, but only 1.1% of the limit at 900 MHz.)

Independent monitoring commissioned by all three New Zealand operators has found that exposures in public areas near cell sites are generally well below 1% of the public limit in NZS 2772.1:1999, and maximum levels are normally no more than a few percent of the limit.

### **6.2.2 Smart meters**

Electricity retailers are progressively introducing smart meters (otherwise known as 'advanced metering infrastructure') throughout the country. Smart meters include a radio communication link, which allows them to be read remotely. Some also incorporate 'home area network' capability, through which they can control 'smart' appliances (eg, to turn them on at times of the day when electricity prices are lower), although this capability has not yet been activated.

Smart meters installed in New Zealand communicate in one of two ways.

- On the mobile phone network – these meters normally send their data once per day, in the early morning. The rest of the day they do not transmit, apart from brief 'handshakes' with the mobile phone network every hour or two.
- Via a 'mesh' network – meters transfer data back to access points (also called data concentrators), which may be mounted on power poles or lamp-posts, or inside a meter box. Normally the data is transferred from one meter to another, to another, until it arrives at the access point. The routing is automatically optimised by the network. In mesh networks, a meter not only transmits when sending its own data, but also when relaying data from other meters in the network back to the access point.

The transmitters in both types of meter operate intermittently and at low power. Measurements in New Zealand and overseas show that meters on mesh networks typically transmit for less than two minutes per day. Meters on mesh networks transmit at powers between about 0.1 and 1 watt (depending on the system being used), while meters communicating over the mobile phone network use a standard mobile phone module.

In practice, then, exposures from smart meters are very low, owing to:

- the relatively low power of the transmitter
- the intermittent nature of the transmissions
- the fact that most meters are mounted on an outside wall (which means that exposures inside a house are attenuated by the meter box and the house wall).



Measurements on the inside of a wall behind a smart meter in Hamilton<sup>52</sup> showed that the maximum exposure while the meter was transmitting was 0.18% (about one five-hundredth) of the public limit in NZS 2772.1:1999. The highest exposure averaged over 30 seconds (bearing in mind that the standard allows exposures to be averaged over six minutes) was 0.003% of the public limit.

Access points (or data concentrators) also operate at low power and produce very low exposures.

### 6.2.3 WiFi

Many modern devices establish network communications over WiFi (indeed many have no capability for a wired network connection). WiFi protocols have evolved over the years to allow faster data transmission rates, but the essential characteristics have not changed.

In a simple WiFi setup, the access point (or wireless router) acts as the connecting point between nearby WiFi devices and a wired network. For the system to work, only one device (or the access point) can communicate at a time, and there are mechanisms built in to the WiFi protocols to try and enforce this. The access point periodically transmits a brief signal to alert nearby devices that it is available if needed. Apart from that, the devices or access point only transmit when there is data to send.\*

The maximum transmit power of access points and WiFi devices is limited by radio spectrum management rules. Tests carried out by the UK Health Protection Agency<sup>53</sup> (now Public Health England) found that the transmit power of access points used in UK schools ranged from 3 to 29 mW, and the transmit power of laptops used in UK schools from 4 to 17 mW. (For comparison, the maximum transmit power of a 3G mobile phone is 125 mW, and the average power of a DECT cordless phone during a call is 10 mW.) Access points were found to transmit from between 36 seconds and 7 minutes per hour (and were silent the rest of the time) and laptops between 0.7 and 33 seconds per hour.

Tests in New Zealand schools commissioned by the Ministry of Health have confirmed that exposures from both access points and devices are very low, with a maximum exposure in classrooms equivalent to 0.024% (ie, four thousand times lower than) the public limit in the New Zealand standard, and generally less than half that figure. Similar levels have been found overseas.

A few countries recommend using wired connections in schools if a choice is available (eg, Germany, and current proposals in France), but many others state that there are no reasons to limit use of WiFi in schools. There are sometimes suggestions made that some countries (eg, Switzerland) or regions (eg, Bavaria) have banned the use of WiFi in schools, but follow-up with the relevant authorities has found that this is not the case. The Ministry suggests that if people wish to reduce exposures from WiFi exposures, they can place access points on a high shelf or high up on a wall, and WiFi-enabled devices could be used on a table rather than in the lap.

---

\* Some devices may also issue 'probe' signals to find nearby access points.

Although this discussion on exposures from WiFi has largely focused on the use of WiFi in schools, because that has been an area of particular interest, the results would apply equally to the use of WiFi in other settings, such as in the home or workplace.

#### **6.2.4 Changeover to digital TV**

Analogue TV transmissions stopped in late 2013, leaving only digital transmissions, which occupy a reduced portion of the frequency spectrum. Part of the spectrum previously used for TV transmissions has been reallocated to cellular phone services, and part (in the VHF bands) is currently unallocated.

Overall, this has led to a reduction in exposures from TV services. No formal comparison has been undertaken, but measurements made in south Christchurch in 2012 (when both analogue and digital services were being broadcast) found that on average digital TV accounted for about 8% of the total exposure attributable to TV at the time.\* Based on this data, it can be concluded that now all analogue transmissions have ceased, exposures attributable to TV are about one-tenth of what they were when there were only analogue transmissions.

#### **6.2.5 Others**

There has been a rapid rise in the use of 'machine to machine' (M2M) communication, often using mobile phone technologies. Current applications include, for example, food and drink dispensers, lift controllers, mussel farms and restaurant fridges. Often people are not aware that such systems are in use. Wearable wireless technologies are also being developed (eg, for health monitoring) either using Bluetooth or other low-power technologies. While these applications are covered by existing safety standards, it is important to keep up to date with developments in this area to ensure that health protection is not overlooked.

### **6.3 How EMF / health issues are handled in New Zealand**

#### **6.3.1 Ministry of Health acts as lead agency**

The Ministry of Health acts as lead agency in all matters concerning EMF and health. In this capacity it has advised, for example, the Ministry of Education on health aspects of WiFi in schools, and the Ministry for the Environment on suitable health-based standards to be applied in National Environmental Standards on radio transmitters and transmission lines. The Ministry also advises Worksafe.

In undertaking this work, the Ministry relies on the public health expertise of its own staff, but can also call on the more specialised knowledge of external providers where necessary. Two important external sources of information are discussed in more detail below.

---

\* Exposure expressed as a fraction of the applicable limit in the different TV frequency bands.

The Ministry has several pages on its website to provide EMF information.\* These include links to other sources of information. The Ministry website also contains links to recent research reviews carried out by national and international health and scientific bodies.\*\* These pages are updated as new reports and information become available.

The Ministry does not fund or commission EMF research. Funding is the responsibility of the Health Research Council, which, as noted in section 4.7, has provided money for the New Zealand arm of the international MOBI-Kids study. The Ministry would advise the Health Research Council (or other funding bodies) on EMF research priorities if asked. This advice would be based on documents such as the Research Agendas prepared by the WHO EMF Project (discussed in section 6.3.2).

### **6.3.2 WHO EMF Project**

The WHO's EMF Project was established in 1996 to coordinate research, identify areas where further research is needed, publish authoritative health risk assessments in the WHO's Environmental Health Risk Criteria (EHC) series, and facilitate the development of internationally acceptable exposure standards. In recent years it has published monographs in its EHC series on static fields (EHC 232) and ELF fields (EHC 238), and a monograph on RF fields is being prepared, with publication expected in early 2016. Members of the task group responsible for the final publication must cover the required range of expertise and are also selected to ensure there is balance on the range of opinions, geographical distribution and gender. Task group members must also comply with strict WHO rules on conflicts of interest.

New Zealand has long recognised the value offered by this international collaboration, which is funded entirely by *ad hoc* contributions from member states (ie, it does not receive any funding from WHO), and has been one of the few consistent contributors to the project. (Some countries have made contributions in kind; for example, by making staff available to work at WHO.) The quality of the material produced by the Project has far exceeded what would be possible had New Zealand chosen to try to develop it independently.

Further information is available on the WHO website.†

### **6.3.3 Interagency Committee on the Health Effects of Non-ionising Fields**

The Interagency Committee on the Health Effects of Non-Ionising Fields was originally established by the then Ministry of Economic Development in 1989 to monitor and review research on the health effects of ELF fields. The scope was extended to include RF fields in 2001, at which time it became a Ministry of Health technical advisory committee. The current terms of reference and committee membership are presented in Appendix F.

---

\* Linked from <http://www.health.govt.nz/our-work/radiation-safety/non-ionising-radiation>

\*\* <http://www.health.govt.nz/our-work/radiation-safety/non-ionising-radiation/research-non-ionising-radiation>

† <http://www.who.int/peh-emf/en/>

The sectors and government agencies represented on the committee are invited by the Director-General of Health. Government agencies and industry sectors nominate their own representatives, but representatives for other sectors are approached by the Ministry on the basis of their knowledge and experience in the area and ability to represent the sector.

A key function of the Committee is to review recent research findings, and especially recent research reviews published by national and international health and scientific bodies, to determine whether any changes to current policies should be recommended. Contributions from the academic representatives are especially valuable in this respect. The Committee's advice is provided to the Director-General of Health and is one input into Ministry of Health policy in this area.

While there is sometimes public concern over the presence of industry representatives on the Committee, in practice they have never attempted to influence the Committee's conclusions on the health effects research, and generally see the Committee as a means for them to stay abreast of recent developments. In addition, they are able to bring to the Committee's attention forthcoming developments in their industries that may have policy implications for government.

## **6.4 Key EMF research carried out in New Zealand**

New Zealand researchers have been, or are, involved in several large research projects investigating EMF and health. In addition to these major projects, individuals and small research teams at other New Zealand universities (including Auckland, Massey and Victoria) have also published EMF research.

### **6.4.1 University of Otago study on ELF fields and childhood leukaemia**

The University of Otago included consideration of ELF fields in a large epidemiological study into childhood leukaemia. ELF fields were measured over a 24-hour period in the homes of the children with cancer and comparison children, and information obtained about exposure to electrical appliances. The study was designed to be compatible with similar studies being carried out at the same time in other countries (including Canada, the UK and the USA) so that as well as being published independently,<sup>54</sup> the results could be also combined in meta-analyses.<sup>55,56</sup>

### **6.4.2 New Zealand arm of the Interphone study**

Researchers from the University of Auckland participated in the Interphone study (discussed in section 4.2.1.1) and coordinated the New Zealand arm of the study. In addition to identifying and interviewing cases and controls in New Zealand, the researchers also collaborated in the various studies to develop and validate the Interphone methodology.

The Massey University Centre for Public Health Research has been involved in the Interocc study, which uses data acquired through the Interphone study to investigate possible associations between brain tumours and a number of agents encountered in occupational settings (such as magnetic fields, solvents and combustion products).

### **6.4.3 New Zealand arm of the MOBI-Kids study**

The Massey University Centre for Public Health research is currently coordinating the New Zealand arm of the MOBI-Kids study. As discussed in section 4.7, this is a multinational study which builds on the experience gained through the Interphone research to investigate potential associations between mobile phone use and brain tumours in young people (aged 10–24 years).

# Appendix A: Common concerns about the New Zealand RF field exposure standard

## ***'The standard is out of date'***

Although the standard is now 15 years old, in 2009 (following a review of more recent research discussed above) ICNIRP reaffirmed the limits on which it is based. Reviews of the health research carried out since then by national and international expert panels have also found no good reason to revise the fundamental limits.

On the other hand, ICNIRP and others note recent dosimetry data which suggests that under circumstances (particular combinations of frequency, body size and radio signal polarisation), exposure at the reference levels might result in the basic restrictions being exceeded, although this seems unlikely to result in any health effects.

## ***'The standard only considers thermal effects'***

The ICNIRP limits used in the standard are based on a review of all relevant health effects research, regardless of the mechanism that might be involved. ICNIRP and other expert panels that have reviewed the data find that the only effects that show up with any clarity are consistent with the effects of heat stress, and occur at exposure levels at which absorption of RF energy in the body (as heat) exceeds the body's ability to dissipate that heat. Exposures below the ICNIRP limits would prevent these effects.

Most of the research conducted over the past 25 years has used exposures that are at or below the ICNIRP limits, but no consistently reproducible or persuasive evidence of health effects, from any cause, has been found.

In summary, the standard takes into account the possibility of health effects from any cause, but thermal effects are the only ones for which there is clear evidence.

## ***The standard does not consider long-term effects***

Limits in the standard are based on an evaluation of data from a range of sources, including laboratory studies on cell cultures, animals, or people exposed to RF fields under well-defined conditions, and observational (epidemiological) studies that compare the health of different groups of people who, because of their activities or where they live or work, may have different exposures.

Information on the effects of long-term exposures comes from both epidemiological studies and laboratory studies on animals that are exposed for large parts (or all) of their lifetimes. (In fact some studies have exposed laboratory animals over several generations.) These findings are all taken into account in determining what health effects are produced by exposures to RF fields, and the levels at which they occur.

### ***ICNIRP applies too high a standard of proof***

ICNIRP (and other expert panels) apply similar quality criteria to studies used in their evaluations as would be used in a health risk assessment for any other agent. Their approach was summarised in a 2002 statement *General Approach to Protection Against Non-ionising Radiation*.<sup>57</sup> Individual studies are assessed against criteria that allow the strength of the findings to be evaluated (eg, Were laboratory studies double blinded to safeguard against conscious or unconscious bias in their evaluation? Was the exposure properly evaluated and checked? Were appropriate statistical techniques used when analysing the data?).

As new research and new findings accumulate, they are assessed in the context of existing data, and an overall evaluation is made based on all the relevant data (not just the new material). In situations where the data is ambiguous or uncertain, informed judgements are made following schemes such as the Hill criteria.<sup>58</sup>

## Appendix B: The IARC classification scheme

Group	Meaning (number of agents)	Basis for classification		Everyday examples
		Evidence from human studies	Evidence from animal studies	
1	Carcinogenic (116 agents as at March 2015)	Positive associations: chance, bias and confounding can be ruled out.		X-rays Diesel engine exhaust Alcoholic beverages Ultra-violet (UV) radiation UV tanning devices
2A	Probably carcinogenic (73 as at March 2015)	Positive associations for which a causal interpretation is credible, but could also be due to chance, bias or confounding.	Causal relationship established in 2 or more species, or 2 or more independent studies in a single species.	PCBs Fumes from hot frying
2B	Possibly carcinogenic (287 as at March 2015)	<i>Either:</i> positive associations for which a causal interpretation is credible, but could also be due to chance, bias or confounding or has weaknesses that mean no conclusions can be drawn <i>or:</i> have weaknesses that mean no conclusions can be drawn.	The data suggests a carcinogenic effect but is too limited to make a definitive evaluation.  Causal relationship established in 2 or more species, or 2 or more independent studies in a single species.	Coffee Pickled vegetables (traditional in Asia) Petrol engine exhaust ELF magnetic fields RF fields
3	Not classifiable (503 as at March 2015)	Have weaknesses that mean no conclusions can be drawn.	<i>Either</i> the data suggests a carcinogenic effect but is too limited to make a definitive evaluation, <i>or</i> the data has major quantitative or qualitative limitations.	Chlorinated drinking water Tea Static electric and magnetic fields ELF electric fields
4	Probably not carcinogenic (1 as at March 2015)	Several studies, covering the range of human exposures, which consistently show no increased risk. Bias and confounding can be ruled out, and there is an adequate follow-up time.		Caprolactam (chemical used in the production of Nylon-6, which is widely used in fibres and plastics)

\* This table summarises the minimum requirements that must be satisfied in most cases, but there may be exceptions. For a full overview of the IARC process and classification scheme, refer to <http://monographs.iarc.fr/ENG/Preamble/CurrentPreamble.pdf>



## Appendix C: Recent ELF reviews

Date	Group	Mandate / area covered / method	Conclusions
March 2015 <sup>59</sup>	SCENIHR (EU Scientific Committee on Emerging and Newly Identified Health Risks)	<p>Updates previous reports by the same group in 2007 and 2009.</p> <p>Assessment based on articles in peer-reviewed journals, applying SCENIHR criteria for weight of evidence approach for risk assessment.<sup>60</sup></p> <p>Draft assessment released in 2014 for public consultation, before preparing final report.</p> <p>Review also covers RF fields.</p>	<p>No convincing evidence of a link between ELF exposures and self-reported symptoms.</p> <p>New epidemiology studies consistent with previous findings of an increased risk of childhood leukaemia. However, there is no experimental support for a link and no mechanism identified, which prevents a causal interpretation.</p> <p>Epidemiological studies provide no convincing evidence of an increased risk of neurodegenerative diseases, and no evidence for adverse pregnancy outcomes.</p> <p>Recent results show no effect on human reproductive functions.</p>
March 2014 <sup>61</sup>	SSM (Swedish Radiation Safety Authority) scientific council on electromagnetic fields	<p>Updates previous (usually annual) reports from the same group.</p> <p>Assessment based on articles in peer-reviewed journals. Articles are assessed to determine the weight they should be given in overall assessment; evidence from different types of research (eg, epidemiology, <i>in vivo</i> and <i>in vitro</i> studies) is integrated in final stage of evaluation. Epidemiology data given greatest weight. Studies considered to have insufficient scientific quality not included.</p> <p>Aim is to determine whether a hazard exists: the answer may not be a clear yes or no but express the likelihood that there is a hazard. If there is a hazard, the assessment should evaluate the exposure–response function.</p> <p>Review also covers RF fields.</p>	<p>A consistent association has been observed between exposure to ELF magnetic fields and childhood leukaemia, but a causal relationship has not been established.</p> <p>A large French study found some indications for an increased childhood leukaemia risk. A large pooled study found no evidence that survival of childhood leukaemia patients was affected by ELF field exposure, but the results may be affected by exposure misclassification.</p> <p>Absence of risk was confirmed in most studies of adult cancers.</p> <p>Any relationship with Alzheimer’s disease and ALS is still unresolved.</p> <p><i>In vitro</i> studies have investigated a large variety of effects, but few address the childhood leukaemia question. Several studies lack sham-exposed controls.*</p> <p>The results of <i>in vivo</i> studies are not very consistent and need replication. These should address the childhood leukaemia question.</p> <p>ELF magnetic fields do not seem to have any effects on general physiology. Effects on the EEG have been observed, but it is difficult to distinguish between statistically significant and physiologically meaningful effects.</p>

\* A sham-exposed control is an experimental animal or cell culture which has been handled in exactly the same way as the animals or cultures exposed to the agent under investigation, but has not received any exposure.

Date	Group	Mandate / area covered / method	Conclusions
May 2014 <sup>62</sup>	Biological Effects Policy Advisory Group of the Institution of Engineering and Technology	<p>Updates 2012 report from the same group.</p> <p>Assessment based on peer-reviewed literature retrieved by monthly searches of INSPEC, MEDLINE and BIOSIS databases.</p> <p>Review also covers RF fields.</p>	<p>On the balance of evidence from the last few decades, harmful health effects from environmental levels remain unsubstantiated.</p> <p>There is no generally accepted experimental demonstration of any biological effect from environmental levels.</p> <p>Pooled analyses of epidemiological studies show an association between childhood leukaemia and high field levels, but the lack of mechanistic or experimental evidence does not support there being a causal relationship. A major epidemiological study published in 2014 suggested that the incidence of leukaemia in children living near power lines has decreased over the past 40 years and is no longer elevated.</p> <p>The high proportion of EMF studies that report effects, but a subsequent inability to replicate them, suggests that better quality control should be applied before publication.</p>
March 2013 <sup>63</sup>	SSM (Swedish Radiation Safety Authority) scientific council on electromagnetic fields	<p>Updates previous (usually annual) reports from the same group.</p> <p>Assessment based on articles in peer-reviewed journals. Articles assessed to determine the weight they should be given in overall assessment; evidence from different types of research (eg, epidemiology, <i>in vivo</i> and <i>in vitro</i> studies) is integrated in the final stage of evaluation. Epidemiological data is given greatest weight. Studies considered to have insufficient scientific quality are not included.</p> <p>Aim is to determine whether a hazard exists: the answer may not be a clear yes or no but express the likelihood that there is a hazard. If there is a hazard, the assessment should evaluate the exposure–response function.</p> <p>Review also covers RF fields.</p>	<p>The question of whether ELF magnetic fields have any influence on the development of childhood leukaemia is still unresolved.</p> <p>A large number of other health endpoints have been studied, but mostly without finding consistent associations.</p> <p>Recent environmental and occupational studies on Alzheimer’s disease have reported associations but a causal relationship is not established.</p>

Date	Group	Mandate / area covered / method	Conclusions
October 2012 <sup>64</sup>	EFHRAN (European Health Risk Assessment Network on Electromagnetic Fields)	<p>Project funded by the European Commission. The Network includes participants from universities and research centres in 7 European countries, and collaborating partners from 8 other countries/organisations including WHO.</p> <p>Builds on previous European-funded collaborations investigating/collating results of EMF research.</p> <p>Evaluated strength of evidence using a system similar to IARC.</p> <p>Review also covers RF fields.</p>	<p>Limited evidence (ie, evidence restricted to a few studies, or unanswered questions about the design, conduct or interpretation of the studies, or confounding factors cannot be ruled out with confidence) was found of an association between ELF magnetic fields and leukaemia in children. A combination of chance, bias and confounding may have produced this result.</p> <p>Inadequate evidence (ie, studies of insufficient quality, consistency or statistical power to draw conclusions) was found for Alzheimer's disease, ALS and brain tumours in children. However, the data suggests that some risks may exist, particularly for Alzheimer's disease, so further studies would be useful. Evidence is also inadequate for all other cancers (except breast cancer), other neurodegenerative diseases, and non-specific symptoms, but it does not appear worthwhile to conduct further studies.</p> <p>The evidence suggests a lack of effects (ie, no effects found in several independent studies, under different protocols involving at least two species or cell types and a range of exposures) for breast cancer in adults, cardiovascular diseases, and EHS.</p>
May 2012 <sup>65</sup>	Biological Effects Policy Advisory Group of the Institution of Engineering and Technology	<p>Updates previous reports from the same group.</p> <p>Assessment based on peer-reviewed literature retrieved by monthly searches of INSPEC, MEDLINE and BIOSIS databases.</p> <p>Review also covers RF fields.</p>	<p>The balance of evidence suggests that the existence of harmful effects has not been substantiated but this remains a possibility. No generally accepted demonstration of a biological effect has been established.</p> <p>Pooled analyses of epidemiological studies show an association with childhood leukaemia, but in the absence of mechanistic and experimental evidence these findings do not provide good grounds to conclude that there is a causal relationship. Selection bias and confounding remain possible explanations for the results.</p>

## Appendix D: Recent RF reviews

Date	Group	Mandate / area covered / method	Conclusions
March 2015 <sup>59</sup>	SCENIHR (EU Scientific Committee on Emerging and Newly Identified Health Risks)	<p>Updates previous reports by the same group in 2007 and 2009. Assessment based on articles in peer-reviewed journals, applying SCENIHR criteria for weight of evidence approach for risk assessment.<sup>60</sup></p> <p>Draft assessment released in 2014 for public consultation before preparing final report.</p> <p>Review also covers ELF fields.</p>	<p>Overall, epidemiology studies do not show an increased risk of brain tumours or other cancers of the head and neck, although the possibility of an association with acoustic neuroma remains. Epidemiology does not suggest an increased risk of other malignant diseases, including childhood cancer.</p> <p>Recent studies support the possibility of an effect on the EEG. Pulse-modulated signals may affect different parts of sleep and different EEG frequencies. However, given the variety of exposure conditions used, no firm conclusions can be drawn.</p> <p>Research since the 2009 SCENIHR review supports the conclusion that RF field exposures do not cause the physical symptoms that some people attribute to them.</p> <p>Recent research does not suggest any effects on reproduction and development from exposures that comply with current limits. Human studies on child development and behaviour have had conflicting results and methodological limitations.</p> <p>Studies on male infertility are poor and provide little evidence.</p>
September 2014 <sup>66</sup>	Health Council of the Netherlands Electromagnetic Fields Committee	<p>The second of three reports investigating whether exposures from mobile phones could cause cancer (the first report, covering epidemiology, was published in 2013).</p> <p>Systematic review of animal studies investigating the potential carcinogenicity of RF fields.</p> <p>Assessment based on peer-reviewed literature retrieved searches of PubMed, EMF Portal and Web of Science databases.</p> <p>Quality of studies assessed using criteria based on the Gold Standard Publication Checklist.</p>	<p>On the basis of the results it is unlikely that long-term continuous or repeated exposure to RF fields may initiate or promote the development of cancer.</p> <p>While a few studies did indicate effects, the findings have either not been observed in repetition studies, or might be explained by thermal effects. The same comments apply to studies which suggested protective effects.</p> <p>Further research in this area should await the findings of a large study currently in progress in the USA.</p>

Date	Group	Mandate / area covered / method	Conclusions
May 2014 <sup>62</sup>	Biological Effects Policy Advisory Group of the Institution of Engineering and Technology	<p>Updates 2012 report from the same group.</p> <p>Assessment based on peer-reviewed literature retrieved by monthly searches of INSPEC, MEDLINE and BIOSIS databases.</p> <p>Review also covers ELF fields.</p>	<p>Existing data do not provide persuasive evidence of harmful effects.</p> <p>Recent analyses of historical brain tumour rates do not show increases corresponding to the rapid expansion of mobile phone use. Although the length of time before such effects would show is uncertain, this shows that some of the more extreme epidemiological findings are implausible.</p> <p>Experimental studies have not shown consistent effects, and no mechanism through which low level RF fields could produce effects has been found.</p> <p>An increasing proportion of mobile phone studies (currently 75%) report effects, which suggests that such effects are common and should be readily demonstrated. However, in practice this is not the case. The assumption that peer-reviewed published studies are robust and replicable does not appear to hold, and is increasingly being challenged in other areas. UK research programmes were unable to replicate key EMF studies.</p>
April 2014 <sup>67</sup>	Royal Society of Canada expert panel	<p>Panel appointed by Royal Society of Canada to review Health Canada's proposed RF exposure limits (Safety Code 6 – SC6).</p> <p>Specific focus on the emerging evidence on potential health risks of RF from wireless telecommunication devices, as well as from other sources in range 3 kHz – 300 GHz. The panel should determine whether: the proposed Code provides adequate protection, whether other potential health effects should be considered, and whether additional precautionary measures should be recommended.</p> <p>Based mainly on recent reviews by expert groups, but also looked at relevant papers published since those reviews.</p> <p>Consideration of recent dosimetry, several specific health outcomes (eg cancer, EHS, cognitive effects, reproductive effects, development), and thermal/non-thermal effects.</p>	<p>Basic restrictions are adequate for protection against heating effects. At some frequencies, exposures at reference levels might result in basic restrictions being exceeded, but it is very unlikely this will result in adverse effects.</p> <p>The balance of evidence does not indicate that exposures that comply with SC6 cause adverse health effects.</p> <p>The evidence that exposure below the limits causes cancer is weak.</p> <p>There is no firm evidence that RF exposures cause EHS, but the condition should be investigated further to try to understand the aetiology and possible treatments.</p> <p>If exposures comply with the limits, no health effects have been established (ie, health effects observed consistently in several studies with strong methodology) related to cognitive and neurological systems, reproduction, development, cardiac function, heart rate variability, or the eye.</p> <p>No additional precautionary measures should be incorporated into the SC6 limits. However, more information should be made available on RF exposures and the devices that produce them, and how people can reduce exposures if they wish.</p> <p>Further research is needed to clarify the RF-cancer question, and other possible effects at exposures that comply with the SC6 limits.</p>

Date	Group	Mandate / area covered / method	Conclusions
March 2014 <sup>68</sup>	ARPANSA RF expert panel	<p>Panel composed of three Australian academics with expertise in biophysics, human provocation and epidemiology, and three ARPANSA scientific staff.</p> <p>Panel requested to:</p> <ul style="list-style-type: none"> <li>• review research since 2000 to assess whether there have been significant changes to the science, and whether the findings would affect the guidance provided by RS3 (ARPANSA RF exposure standard)</li> <li>• recommend whether a formal review of RPS3 should be undertaken</li> <li>• prepare an independent assessment of the RF research literature for publication.</li> </ul> <p>Based on major reviews/review papers published between 2000 and 2012, an ARPANSA literature search covering the period 2000 to August 2012, and an ARPANSA review of epidemiological and human provocation research.</p>	<p><i>In vitro / in vivo</i> studies give indications of some effects, but these often appear to occur at levels higher than typical exposures or relate to subtle biological effects not necessarily related to disease, and that to date are not apparently replicable. Most discipline-based reviews conclude that thermal effects are adequate to explain the data, supporting the use of basic restrictions based on thermal effects. However, the variability of the science supports the rationale for a precautionary approach.</p> <p>Human provocation studies have investigated a range of possible effects (eg, cognitive effects, cardiovascular effects, subjective symptoms). The results support the adequacy of the RPS3 limits.</p> <p>Recent dosimetry research has confirmed the conservatism of current exposure limits under most circumstances. However, the current reference levels may not guarantee meeting basic restrictions for all body sizes in some frequency ranges (so the safety margins provided by RLs may be lower than intended). The localised SAR in limbs under resonant conditions may produce higher temperature rises than previously thought, and the acceptability of this should be reviewed.</p> <p>Epidemiology studies have not progressed with any dose–response relationships that would warrant significant changes to RPS3.</p> <p>Overall, the Expert Panel found that the underlying basis of the ARPANSA RF exposure standard remains sound and that the exposure limits in the standard continue to provide a high degree of protection against the known health effects of RF electromagnetic fields. While the findings of the Expert Panel in this report provide confidence that the 2002 standard provides adequate protection, they identify areas where RPS3 and its annexes could be updated to take account of increased knowledge and to better harmonise with international standards.</p>

Date	Group	Mandate / area covered / method	Conclusions
March 2014 <sup>61</sup>	SSM (Swedish Radiation Safety Authority) scientific council on electromagnetic fields	<p>Updates previous (usually annual) reports from the same group. Assessment based on articles in peer-reviewed journals. Articles assessed to determine the weight they should be given in overall assessment; evidence from different types of research (eg, epidemiology, <i>in vivo</i> and <i>in vitro</i> studies) is integrated in the final stage of the evaluation. Epidemiology data is given greatest weight. Studies considered to have insufficient scientific quality are not included.</p> <p>Aim is to determine whether a hazard exists: the answer may not be a clear yes or no but express the likelihood that there is a hazard. If there is a hazard, the assessment should evaluate the exposure–response function.</p> <p>Review also covers ELF fields.</p>	<p>Most <i>in vitro</i> studies do not support an effect of RF on DNA damage or cell death, only minimal effects on protein expression.</p> <p>Overall, <i>in vivo</i> studies provide weak indications of possible effects on oxidative stress and brain function, including behaviour and emotionality. Reported effects on genotoxicity, hormones, glucose, male fertility and reproduction mostly come from single studies and need well-designed replication. The majority of recent studies have no clear hypothesis, poor study design, and the dosimetry is poorly described.</p> <p>Two studies showed no effect on cognitive functions, while a third found that exposure improved performance. Effects on EEG may depend on age and any central nervous system pathologies (eg, epilepsy). Sleep studies find EEG effects at various frequency bands and stages of sleep. No effects on physiological parameters were observed.</p> <p>A new study by the Hardell group reported an increased risk of glioma with clear dose–response trends, but there is a discrepancy between these results and time trends in glioma incidence. A Swedish study found no increase in salivary gland tumours between 1979 and 2009. Many studies on non-cancer outcomes have limitations and no firm conclusions can be drawn.</p> <p>Experimental studies find no effects of acute RF exposure on EHS. Recent findings on the interaction between risk perception and EHS may be helpful for risk management.</p>

Date	Group	Mandate / area covered / method	Conclusions
October 2013 <sup>69</sup>	Expert working group set up by the French Agency for Food, Environmental and Occupational Health & Safety (ANSES)	<p>Update of 2009 opinion.</p> <p>Concentrate on effects potentially related to wavelengths used by new or developing technologies.</p> <p>Evaluate all potential health effects (except 'electro hypersensitivity', to be dealt with separately), based on a literature search covering the period since the previous appraisal.</p> <p>Quality of studies assessed; terminology of evaluation similar to IARC. Concentrate on studies in which exposure conditions could not cause overall temperature increase.</p>	<p>The working group concluded that for all the non-cancer health effects studied there was 'inadequate' evidence* to conclude there is a real effect on human health.</p> <p>For the cancer end points, the working group concluded that there was inadequate evidence except for a 'possible' effect on gliomas for heavy users, and a 'limited' level of proof for acoustic neuromas.</p> <p>Short-term effects have been observed on sleep EEG, but this seems to have no harmful effects.</p> <p>Users should be provided with information on SAR from devices, along with the means to reduce exposure, should they wish to do so.</p> <p>In addition to the recommendations from the working group, ANSES also recommended that:</p> <ul style="list-style-type: none"> <li>• children be encouraged to moderate their cellphone use, and heavy users and children should use hands-free kits and phones with a low maximum SAR.</li> <li>• there be no changes to existing French exposure limits.</li> </ul>
March 2013 <sup>63</sup>	SSM (Swedish Radiation Safety Authority) scientific council on electromagnetic fields	<p>Updates previous (usually annual) reports from the same group.</p> <p>Assessment based on articles in peer-reviewed journals. Articles assessed to determine the weight they should be given in the overall assessment; evidence from different types of research (eg, epidemiology, <i>in vivo</i> and <i>in vitro</i> studies) is integrated in the final stage of the evaluation. Epidemiology data is given the greatest weight. Studies considered to have insufficient scientific quality are not included.</p> <p>Aim is to determine whether a hazard exists: the answer may not be a clear yes or no but express the likelihood that there is a hazard. If there is a hazard, the assessment should evaluate the exposure–response function.</p> <p>Review also covers ELF fields.</p>	<p>Epidemiological studies on mobile phone use and brain tumour risk, together with national cancer incidence statistics from various countries, is not convincing in linking mobile phone use to tumours of the head in adults. There is scientific uncertainty for regular use longer than 13–15 years.</p> <p>It is too early to draw firm conclusions for children and adolescents regarding mobile phone use and brain tumour risk, but the literature to date does not indicate an increased risk.</p> <p>The most consistently observed biological effect from mobile phone exposure is an increase in power in part of the EEG spectrum in volunteer studies. The effect is weak and is unrelated to behavioural or health effects, and there is a large variation between individuals. The mechanism is unknown.</p> <p>Recent research does not indicate public health risks related to RF exposures from cell sites, broadcast transmitters or WiFi in homes or schools.</p> <p>Symptoms experienced by people with perceived EHS are real, and sometimes severe, but studies have not shown that they are caused by EMFs. Several studies have indicated a nocebo effect.</p>

\* A conclusion of 'inadequate' evidence overall is based mainly on there being inadequate evidence from human studies. According to the report, this means that the human evidence:

- showed no effect; or
- was of insufficient quality or consistency, or was not statistically powerful enough, to determine whether a cause and effect relationship exists or not; or
- does not exist.



Date	Group	Mandate / area covered / method	Conclusions
June 2013 <sup>70</sup>	Health Council of the Netherlands Electromagnetic Fields Committee	<p>First of three reports investigating whether exposures from mobile phones could cause cancer.</p> <p>Assessment based on peer-reviewed literature retrieved through searches, quality evaluation and systematic review.</p>	<p>There are some weak and inconsistent indications for an association between prolonged and intensive use of a cellphone and increased incidence of gliomas. This might be explained by bias and chance, but a causal relation cannot be excluded.</p> <p>For other types of tumour, indications of an increased risk are much weaker or are absent.</p> <p>Overall, there is no clear and consistent evidence of an increased risk associated with up to about 13 years of use of a cellphone, but a risk cannot be excluded. No comment can be made about use over longer periods.</p>
October 2012 <sup>64</sup>	EFHRAN (European Health Risk Assessment Network on Electromagnetic Fields)	<p>Project funded by the European Commission. The Network includes participants from universities and research centres in 7 European countries, and collaborating partners from 8 other countries/organisations, including WHO.</p> <p>Builds on previous European-funded collaborations investigating/collating the results of EMF research.</p> <p>Evaluated strength of evidence using system similar to IARC.</p> <p>Revision of a 2010 version of the report to include more recent RF/brain tumour studies.</p> <p>Review also covers ELF fields.</p>	<p>Limited evidence (ie, evidence restricted to a few studies, or unanswered questions about the design conduct or interpretation of the studies, or confounding factors cannot be ruled out with confidence) was found for an association between RF fields and adult brain tumours. The classification is uncertain because it is based on 2 large studies with unresolved questions about possible biases and errors. The time trends are incompatible with large increases in brain tumours caused by cellphone use.</p> <p>Inadequate evidence (ie, studies of insufficient quality, consistency or statistical power to draw conclusions) was found for neurodegenerative diseases, childhood cancers, other cancers, reproductive outcomes, cardiovascular diseases, or development of symptoms such as migraine and vertigo.</p> <p>Evidence suggesting lack of effects (ie, no effects found in several independent studies, under different protocols involving at least two species or cell types and a range of exposures) was found for EHS.</p>
September 2012 <sup>71</sup>	Expert committee appointed by the Norwegian Institute of Public Health	<p>Assessment based on recent research reports and expert review group reports by international and national expert groups.</p> <p>Focus on research investigating possible health effects of weak fields (defined as fields below ICNIRP reference levels).</p>	<p>A large number of studies examining the possible effects of weak RF fields have been carried out and provide no evidence that they cause adverse health effects. Some measurable biological or physiological effects cannot be ruled out.</p> <p>As exposures are typically well below the ICNIRP limits, there is no reason to assume they are associated with health risks. The uncertainty in this assessment is small.</p> <p>A large number of studies provide evidence that electromagnetic fields do not cause the symptoms experienced by people who consider themselves suffering from EHS. However, the problems are genuine and must be taken seriously.</p> <p>The expert committee does not recommend special measures to reduce exposure (eg, by changing limit values, currently based on ICNIRP levels). Administrative authorities can select the lowest level precautionary strategy that 'any exposure should not be higher than for the intended purpose to be achieved'.</p>

Date	Group	Mandate / area covered / method	Conclusions
June 2012 <sup>72</sup>	Swedish Council for Working Life and Social Research	<p>Council was commissioned by the Swedish government to monitor research into EHS and prepare reports on the state of research.</p> <p>Report covers the 10 years for which the mandate was active, and looks at the development of knowledge over that time.</p> <p>Also looks at epidemiological studies on RF and cancer risks.</p> <p>Focus on possible health risks related to RF exposures related to mobile communication.</p>	<p>A considerable number of provocation studies on RF exposures and symptoms have been unable to show any association.</p> <p>Overall, the data on brain tumours and mobile telephony does not support an effect of mobile phone use on cancer risk, in particular when taken together with national cancer trend statistics throughout the world.</p> <p>Research on mobile telephony and health started without a biologically or epidemiologically based hypothesis about possible health risks. Extensive research for more than a decade has not detected anything new regarding interaction mechanisms between RF fields and the human body and has found no evidence for health risks below current exposure guidelines.</p>
May 2012 <sup>65</sup>	Biological Effects Policy Advisory Group of the Institution of Engineering and Technology	<p>Updates previous reports from the same group.</p> <p>Assessment based on peer-reviewed literature retrieved by monthly searches of INSPEC, MEDLINE and BIOSIS databases.</p> <p>Review also covers ELF fields.</p>	<p>The data does not provide persuasive evidence that harmful effects exist.</p> <p>The Interphone study group concludes that its results do not show an increase in brain tumours that could be interpreted as causal, but possible effects of long-term heavy use of mobile phones require further investigation. Analyses of historical brain tumour rates have not observed increases commensurate with the rapid expansion of mobile phone use, although the length of time before effects would appear is unknown.</p> <p>Experimental studies have failed to demonstrate consistent effects, and no mechanism has been established whereby low-level exposures to RF fields could cause biological effects.</p>
April 2012 <sup>73</sup>	UK Health Protection Agency Advisory Group on Non-ionising Radiation	<p>Updates 2003 review by the same group, and concentrates on research published since then.</p> <p>Reviews quality of data to determine the weight given to individual findings.</p> <p>Generally considers human laboratory studies and epidemiological studies in greater detail than animal and cellular experiments as they are of greatest direct relevance to human health.</p>	<p><i>In vitro</i> experiments find no consistently replicable effects from exposures that do not produce detectable heating. There is no convincing evidence that RF fields cause genetic damage or increase the likelihood of malignancies.</p> <p>Animal experiments provide no evidence of health effects from exposures below international guidelines.</p> <p>Evidence suggests that RF field exposures below guidelines do not cause acute symptoms or cognitive effects, and cannot be detected.</p> <p>There is some evidence that RF fields might affect EEG and other markers of brain function, but these effects have not been consistent across studies. The size of the effects is small relative to normal physiological changes, and it is unclear whether they have any implications for health.</p> <p>The limited research on effects of long-term exposures on non-cancer outcomes provides no substantial evidence of effects on cardiovascular morbidity, reproductive function or mortality.</p> <p>Although some positive findings have been reported in a few studies, overall the evidence does not suggest that mobile phones cause brain tumours or any other types of cancer. However, the data is restricted to periods of less than 15 years since first exposure.</p>

## Appendix E: The Bioinitiative Report

The Bioinitiative Report<sup>74</sup> was first published in 2007 and was partially updated in 2012 and 2014. It reviews both ELF and RF research with the stated intention ‘to document the reasons why current public exposure standards for non-ionizing electromagnetic radiation are no longer good enough to protect public health’, and recommends much stricter limits than any national or international health agencies or review groups.

Several health and scientific bodies<sup>75,76,77,78</sup> have reviewed the Bioinitiative Report and noted that it has a range of weaknesses which undermine its credibility. These include:

- the stated objective of using the publications cited to support a particular point of view (rather than systematically reviewing publications, assessing them for their strengths and weaknesses, and forming conclusions after that review)
- the fact that the conclusions were not a consensus view of the chapter authors (some of whom disagreed with the conclusions)
- the selective use of data (eg, virtually no studies on long-term exposures of animals to RF fields were discussed), with little or no mention of reports that do not support the conclusions
- no rationale being presented for the very low RF exposure limits proposed.

Following are specific examples of weaknesses in the report.

**Section 6 on genetic effects** (supplement for the 2012 and 2014 versions) lists abstracts and counts up the numbers showing effects or no effects (65% and 35%, respectively, for RF fields). There is a brief uncritical discussion of the findings but no attempt to explain apparently contradictory results, or discussion of the strengths and weaknesses of the individual studies.

A note before the listing of abstracts comments:

It must be pointed out that, consistent with previous research, not very much of the cellular and animal genetic research data directly indicate that EMF (both RF and ELF EMF) is a carcinogen.

While the bare statistics on papers showing effects and no effects are carried through to the summary section 24 of the Bioinitiative Report, this comment is not.

**Section 12 on ELF fields and childhood leukaemia** (2012 update replaces the 2007 version) claims that ‘Except ionizing radiation no other environmental factor has been as firmly established to increase the risk of childhood leukemia’, and uses this as an argument to have ELF fields classified as carcinogenic. In contradiction to this statement, a 2012 review of *Childhood Leukemia and Environmental Factors* published jointly by the Health Council of the Netherlands, the Superior Health Council Belgium and the European Science Advisory Network for Health found that benzene, paternal smoking and PCBs were ‘likely’ risk factors; pesticides were ‘possible to likely’; and that ELF fields were ‘possible’ risk factors, along with formaldehyde, arsenic in drinking water, maternal smoking, parental alcohol consumption and plasticisers. (In addition, early social contacts and breast feeding were likely protective factors.)

The author of this section dismisses confounding as a possible explanation for the associations found between ELF fields and childhood leukaemia, on the grounds that the confounding agent must be quite strong and present wherever studies have been carried out. However, there are several examples that show flaws in the argument that ‘because no confounder has been identified we can rule out confounding as a cause of the association’.

**Electrohypersensitivity (EHS)** is covered in several sections (eg, the original section 8, section 9) and also in section 24 *Key Scientific Evidence and Public Health Policy Recommendations*. Section 24 highlights a single clinical case study which claims to demonstrate an EHS individual, and discusses two reviews by Johansson which conclude that EHS symptoms are caused by EMFs, but does not mention other reviews by Rubin (2005,<sup>79</sup> 2010,<sup>80</sup> 2011<sup>29</sup>) which conclude the opposite. The majority of the 16 papers reviewed in Rubin 2010 are not covered in Bioinitiative 2012, nor are alternative explanations for EHS, such as the ‘nocebo’ effect, even though some of the relevant papers are cited in section 9.

**Section 24 Key Scientific Evidence and Public Health Policy Recommendations** claims that:

At least five new cell tower studies with base-station level RFR at levels ranging from 0.003  $\mu\text{W}/\text{cm}^2$  to 0.05  $\mu\text{W}/\text{cm}^2$  published since 2007 report headaches, concentration difficulties and behavioral problems in children and adolescents; and sleep disturbances, headaches and concentration problems in adults.

The studies are not listed, but from the preceding text they are presumably Buchner and Eger 2012,<sup>\*81</sup> Eskander et al 2012,<sup>82</sup> Heinrich et al 2010,<sup>83</sup> Thomas et al 2008,<sup>84</sup> Thomas et al 2010<sup>85</sup> and Mohler et al 2010<sup>86</sup>. An analysis of these six studies shows that two do not permit any meaningful quantitative (or even qualitative) analysis, the findings of three are the opposite of those claimed in the BioInitiative Report 2012, and one reports possible effects but cautions that further studies should be undertaken before forming definitive conclusions.

It is also worth noting that several other relevant studies on the effects of exposures to RF fields from cell sites, which found no effects on sleep quality or other health effects (Mohler et al 2012,<sup>31</sup> Danker-Hopfe et al 2010,<sup>30</sup> Leitgeb et al 2008<sup>87</sup> and Berg-Beckhoff et al 2009<sup>32</sup>), are not mentioned.

---

\* Cited as 2012 in Section 24, but correctly listed in the references as 2011.

## Appendix F: Terms of reference of the Interagency Committee on the Health Effects of Non-ionising Fields

The Interagency Committee on the Health Effects of Non-Ionising Fields (the Committee) will provide the Director-General of Health with high-quality, independent scientific and technical advice on any potential health effects from exposures to extremely low or radiofrequency fields including:

- the quality and completeness of information on which findings and recommendations have been made
- assessment and review of the impact of research and information published locally and overseas, on policies, guidelines and advice promulgated by the Ministry of Health, Ministry for the Environment or Ministry of Business, Innovation and Employment
- other technical, scientific and epidemiological matters in relation to the extremely low or radiofrequency fields as may be required.

The Committee will report to the Director-General of Health, with copies of meeting notes provided to the Chief Executives of the Ministry for the Environment and the Ministry of Business, Innovation and Employment. Should there be reasonable suspicion of health hazards, or other issues of significance, these will be brought to the attention of joint Ministers. Annual and/or occasional reports will also be provided to joint Ministers.

### *Composition of the Committee*

The membership of the Committee will include representatives from the following agencies, organisations and sectors:

- Ministry of Health (including the National Radiation Laboratory): Martin Gledhill, Sally Gilbert
- Ministry of Business, Innovation and Employment: Energy Safety Service, Workplace Health and Safety, Radio Spectrum Management
- Ministry of Education
- Ministry for the Environment
- public health units
- local government
- academics/scientists
- consumers
- electrical industry: transmission and supply
- telecommunications industry.

Observers may also be in attendance from the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA), and from the members' agencies or organisations. The Ministry of Health will provide the Chair and secretarial support for the Committee.

**Media policy:** In carrying out their functions as members of the Committee, no member shall make media statements of any kind on behalf of the Committee or about the proceedings of the Committee unless requested to do so by the Director-General of Health. If members wish to discuss media issues, they should contact the Ministry of Health's Corporate Communications Unit in the first instance (tel. 04 496 2008, mobile 021 366 111).

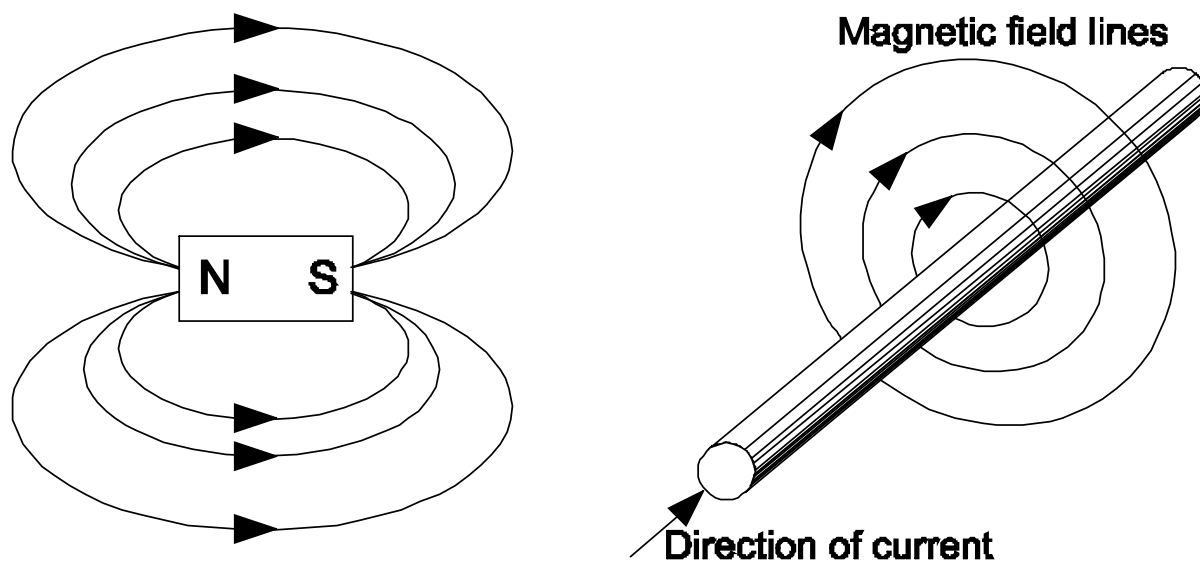
# Appendix G: Background material on ELF and RF fields

## G1 ELF 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 figure below.



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.

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.

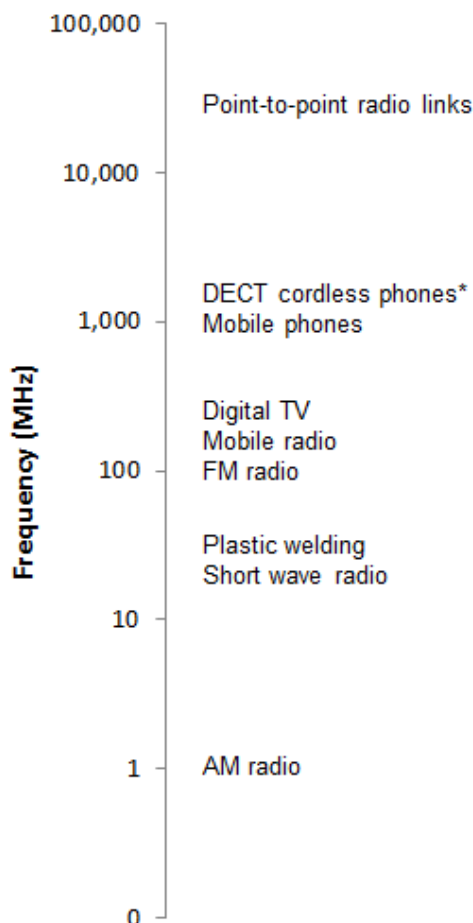
More generally, ELF is taken to cover frequencies up to about 100 kilohertz (kHz). (This was the upper end of the frequency range considered in the WHO 2007 review discussed in section 2.2.) However, some discussions may only consider a lower maximum frequency. The sources that are usually of most interest in discussions about the health effects of ELF fields are cables or equipment carrying mains electricity at 50 Hz. In recent years, however, other sources of ELF fields have become more common, including induction cooktops and electronic article surveillance equipment (with frequencies of a few tens of kHz). In industry, induction heaters use frequencies of a few kHz.

## G2 RF fields

RF fields are normally understood to include alternating electric and magnetic fields at frequencies greater than 100 kHz, but here too other frequencies may be used to define the lower frequency. The New Zealand radiofrequency field exposure standard, for example, covers frequencies all the way down to 3 kHz. The upper limit is usually taken to be 300 GHz.

The diagram below shows the main applications of radiofrequency fields as a function of frequency.

**Figure G1: Main applications of RF fields as a function of frequency**



\* DECT (digital enhanced cordless telecommunications) cordless phones are the most common type of cordless phone in use.



### G3 Terminology

**Radiation** is generally defined as the propagation of energy away from some source, often (but not necessarily) in the form of waves. For example, sound emitted from a loudspeaker could be described as a form of radiation, transporting energy away from the loudspeaker cone in the form of a compressional wave in the air. *Nuclear* or *atomic* radiation can involve the emission of energetic sub-atomic particles from unstable atoms.

**Electromagnetic radiation** (EMR) refers to radiation in which the energy is propagated in the form of an **electromagnetic wave** – linked electric and magnetic fields which bear a fixed relationship (in their strengths and orientations) to one another. Unlike a sound wave, which needs a medium in which to travel (such as air or water), an electromagnetic wave can travel through empty space. X-rays, light and microwaves are all forms of EMR.

EMR can be characterised by its frequency or by its wavelength. These two parameters are inter-related: if one is known, the other can be calculated.\* The parameters refer to the wave-like properties of EMR. Their meaning can be visualised by thinking about waves in the sea. If you are standing at the end of a pier watching waves come in to the shore, the wave *frequency* is the number of wave crests that pass you each second. The *wavelength* is the distance between each crest. The physical properties of EMR, and the way it interacts with the body, depend on its frequency.

**Ionising radiation** is radiation that has sufficient energy to knock electrons out of (ie, *ionise*) atoms. X-rays and gamma rays are types of ionising radiation, as are the particulate radiations of alpha and beta particles that are found in some types of nuclear decay.

**Non-ionising radiation** (NIR) is radiation that does not have enough energy to cause ionisation. Although the term can apply to radiations such as sound and ultrasound, it is often used to refer specifically to electromagnetic radiation with frequencies in the ultra-violet region and below. Light and microwaves are both types of non-ionising electromagnetic radiation (NIEMR).

The term *non-ionising radiation* is also applied to electric and magnetic fields that do not constitute EMR according to the usual definition of radiation. An electric current flowing through a wire creates a *magnetic field* around the wire, which is similar in its nature and properties to the magnetic field found around a bar magnet. The voltage on the wire creates an *electric field*. If the current through the wire changes in strength and direction, this is reflected in changes in the strength and direction of the magnetic field. Changes in the voltage cause changes in the electric field.

---

\* Frequency x wavelength =  $3 \times 10^8$

However, these electric and magnetic fields do not constitute EMR, as their strengths and orientations are unrelated, and they do not transport energy away from the electric current which causes them. Technically, these fields are referred to as *reactive* or *fringing* fields.\* This distinction becomes important at lower frequencies, such as those at which mains electricity is transmitted.

**Electromagnetic field (EMF)** is an umbrella term usually used to include both ELF and RF fields.

**Radiofrequency (RF) fields** are electromagnetic fields at radio frequencies (usually taken to be from ~100 kHz to 300 GHz).

**Extremely low frequency (ELF) fields** are electromagnetic fields at low frequencies (usually taken to be from ~1 Hz to ~100 kHz).

---

\* True EMR is produced by the acceleration of electric charges, whereas the reactive magnetic field is related to the velocity of the charge. Any source of true EMR will also produce some reactive fields, but normally these fields only extend about one wavelength away from the source. For example, around an FM radio transmitter broadcasting at a frequency of 100 MHz (wavelength 3 metres), reactive fields can be detected up to about 3 metres away from the antenna. A measurement of the electric or magnetic fields within 3 metres of the antenna is not representative of the power being radiated. Only measurements more than 3 metres from the antenna give a true indication of the amount of the radiated power. This distinction is perhaps most important when considering power lines. Very often, reference is made to people being exposed to 'power line radiation' or 'magnetic radiation', when in fact no radiation is involved. The magnetic fields measured around power lines do not transport energy away from their source, and their nature and effects are not the same as 'true' EMR. In fact if they did represent true radiation (ie, propagation of energy away from their source), this would be the cause of a significant loss of the electrical energy being transmitted along a power line.)

# References

- 1 Interagency Committee on the Health Effects of Non-ionising Fields. 2004. *Report to Ministers*. Wellington: Ministry of Health.
- 2 ICNIRP. 2010. Guidelines for limiting exposure to time-varying electric and magnetic fields (1 Hz–100 kHz). *Health Physics* 99(6): 818–36. URL: [www.icnirp.org](http://www.icnirp.org).
- 3 WHO. 2007. *Environmental Health Criteria 238: Extremely low frequency fields*. Geneva: WHO. URL: [www.who.int/peh-emf/publications/elf\\_ehc/en/index.html](http://www.who.int/peh-emf/publications/elf_ehc/en/index.html)
- 4 International Commission on Non-Ionizing Radiation Protection. 1998. Guidelines for limiting exposure to time-varying electric and electromagnetic fields (up to 300 GHz). *Health Physics* 74(4): 494–522. URL: [www.icnirp.org](http://www.icnirp.org)
- 5 International Commission on Non-Ionizing Radiation Protection. 2009. ICNIRP statement on ‘Guidelines for limiting exposure to time-varying electric and electromagnetic fields (up to 300 GHz)’. *Health Physics* 97(3): 257–8. URL: [www.icnirp.org](http://www.icnirp.org)
- 6 ICNIRP. 2009. Exposure to High Frequency Electromagnetic Fields, Biological Effects and Health Consequences (100 kHz–300 GHz): Review of the scientific evidence and health consequences. Munich: International Commission on Non-Ionizing Radiation Protection.
- 7 Kheifets et al. 2010. Pooled analysis of recent studies on magnetic fields and childhood leukaemia. *British Journal of Cancer* 103: 1128–35.
- 8 Schmiedel et al. 2010. The association between extremely low-frequency electromagnetic fields and childhood leukaemia in epidemiology: enough is enough? *British Journal of Cancer* 103: 931–2.
- 9 Draper et al. 2005. Childhood cancer in relation to distance from high voltage power lines in England and Wales: a case-control study. *BMJ* 330: 1290.
- 10 Bunch et al. 2014. Residential distance at birth from overhead high-voltage powerlines: childhood cancer risk in Britain 1962–2008. *British Journal of Cancer* 110(5): 1402–8.
- 11 Kheifets et al. 2010. A pooled analysis of extremely low-frequency magnetic fields and childhood brain tumours. *American Journal of Epidemiology* 172: 752–61.
- 12 Chen et al. 2013. A meta-analysis on the relationship between exposure to ELF-EMFs and the risk of female breast cancer. *PLoS One* 8(7): e69272.
- 13 Li et al. 2013. Occupational exposure to magnetic fields and breast cancer among women textile workers in Shanghai, China. *American Journal of Epidemiology* 178(7): 1038–45.
- 14 Feychting. 2013. Invited commentary: extremely low-frequency magnetic fields and breast cancer—now it is enough! *American Journal of Epidemiology* 178(7): 1046–50.
- 15 Zhou et al. 2012. Association between extremely low frequency electromagnetic fields occupations and amyotrophic lateral sclerosis: a meta-analysis. *PLoS One* 7(11): e48354. DOI:10.1371/journal.pone.0048354.
- 16 Vergara et al. 2013. Occupational exposure to extremely low frequency magnetic fields and neurodegenerative disease: a meta-analysis. *Journal of Occupational and Environmental Medicine* 55(2): 135–46.
- 17 Vergara et al. 2015. Case-control study of occupational exposure to electric shocks and magnetic fields and mortality from amyotrophic lateral sclerosis in the US, 1991–1999. *Journal of Exposure Science and Environmental Epidemiology* 25(1): 65–71.
- 18 Frei et al. 2011. Use of mobile phones and risk of brain tumours: update of Danish cohort study. *BMJ* 343: d6387. DOI: 10.1136/bmj.d6387.
- 19 Benson et al. 2013. Mobile phone use and risk of brain neoplasms and other cancers: prospective study. *International Journal of Epidemiology* 42(3): 792–802. See also Benson et al. 2013. Authors’ response to: the case of acoustic neuroma: comment on mobile phone use and risk of brain neoplasms and other cancers. *International Journal of Epidemiology* epub 10.1093.
- 20 Little et al. 2012. Mobile phone use and glioma risk: comparison of epidemiological study results with incidence trends in the United States. *BMJ* 344: e1147. DOI: 10.1136/bmj.e1147.
- 21 De Vocht et al. 2011. Time trends (1998–2007) in brain cancer incidence rates in relation to mobile phone use in England. *Bioelectromagnetics* 32(5): 334–9.
- 22 Deltour et al. 2012. Mobile phone use and incidence of glioma in the Nordic countries 1979–2008: consistency check. *Epidemiology* 23(2): 301–7.

- 23 Kim et al. 2015. Trends in incidence of primary brain cancer in New Zealand, 1995 to 2010. *Australian and New Zealand Journal of Public Health*. DOI: 10.1111/1753-6405.12338.
- 24 Baan et al. 2011. Carcinogenicity of radiofrequency electromagnetic fields. *Lancet* 12(7): 624–6.
- 25 Samet et al. 2014. Mobile phones and cancer: next steps after the 2011 IARC review. *Epidemiology* 25(1): 23–7.
- 26 Wiedemann et al. 2014. Do people understand IARC’s 2B categorisation of RF fields from cell phones? *Bioelectromagnetics* 35(5): 373–8.
- 27 Proceedings available at [www.who.int/peh-emf/publications/reports/EHS\\_Proceedings\\_June2006.pdf?ua=1](http://www.who.int/peh-emf/publications/reports/EHS_Proceedings_June2006.pdf?ua=1)
- 28 Baliatsas et al. 2012. Non-specific physical symptoms and electromagnetic field exposure in the general population: can we get more specific?: a systematic review. *Environment International* 41: 15–28.
- 29 Rubin et al. 2011. Do people with idiopathic environmental intolerance attributed to electromagnetic fields display physiological effects when exposed to electromagnetic fields?: a systematic review of provocation studies. *Bioelectromagnetics* 32(8): 593–609.
- 30 Danker-Hopfe et al. 2010. Do mobile phone base stations affect sleep of residents?: results from an experimental double-blind sham-controlled field study. *American Journal of Human Biology* 22(5): 613–18.
- 31 Mohler et al. 2012. Exposure to radiofrequency electromagnetic fields and sleep quality: a prospective cohort study. *PLoS One* 7(5): e37455.
- 32 Berg-Beckhoff et al. 2009. Mobile phone base stations and adverse health effects: phase 2 of a cross-sectional study with measured radio frequency electromagnetic fields. *Occup-Env-Med* 66: 124–30.
- 33 Available at <http://webarchive.nationalarchives.gov.uk/20101011032547/http://www.iegmp.org.uk/>
- 34 Health Council of the Netherlands. 2011. *Influence of Radiofrequency Telecommunications Signals on Children’s Brains*. Publication no. 2011/20E. The Hague: Health Council of the Netherlands.
- 35 Wiedemann et al. 2009. *Children’s Health and RF EMF Exposure*. Jülich: Forschungszentrum Jülich GmbH. URL: <http://ro.uow.edu.au/cgi/viewcontent.cgi?article=1300&context=hbspapers>
- 36 Proceedings. 2011. Progress in Biophysics and Molecular Biology 107(3): 311–482.
- 37 Foster K et al. 2014. Are children more exposed to radiofrequency energy from mobile phones than adults? *IEEE Access*. DOI: 10.1109/ACCESS.2014.2380355.
- 38 Aydin et al. 2011. Mobile phone use and brain tumors in children and adolescents: a multicenter case-control study. *Journal of the National Cancer Institute* 103: 1–13.
- 39 Repacholi et al. 2012. Systematic review of wireless phone use and brain cancer and other head tumors. *Bioelectromagnetics* 33(3): 187–206.
- 40 Lagorio et al. 2013. Mobile phone use and risk of intracranial tumors: a consistency analysis. *Bioelectromagnetics*. DOI: 10.1002/bem.21829.
- 41 Elwood. 2014. Mobile phones, brain tumors, and the limits of science. *Bioelectromagnetics* 35(5): 379–83.
- 42 ARPANSA. 2002. Maximum Exposure Levels to Radiofrequency Fields – 3 kHz to 300 GHz: Radiation protection series publication no. 3. Melbourne, VIC: ARPANSA.
- 43 Council Recommendation of 12 July 1999 on the limitation of exposure of the general public to electromagnetic fields (0 Hz to 300 GHz). *Official Journal of the European Union* L 199: 59–70. URL: <http://eur-lex.europa.eu/LexUri-Serv/LexUriServ.do?uri=OJ:L:1999:199:0059:0070:EN:PDF>
- 44 Stam. 2011. Comparison of International Policies on Electromagnetic Fields (Power Frequency and Radiofrequency Fields). Bilthoven, The Netherlands: National Institute for Public Health and the Environment.
- 45 Thuroczy et al. 2011. Report on the Level of Exposure (Frequency, Patterns and Modulation) in the European Union: Part 1: Radiofrequency (RF) radiation. Deliverable report D4 of EFHRAN project. URL: <http://efhran.polimi.it>
- 46 Urbinello et al. 2014. Radio-frequency electromagnetic field (RF-EMF) exposure levels in different European outdoor urban environments in comparison with regulatory limits. *Environment International* 68: 49–54.
- 47 Health Canada. 2015. *Limits of Human Exposure to Radiofrequency Electromagnetic Energy in the Frequency Range from 3 kHz to 300 GHz – Safety Code 6*. Ottawa, ON: Health Canada. URL: [www.hc-sc.gc.ca/ewh-semt/consult/\\_2014/safety\\_code\\_6-code\\_securite\\_6/final\\_finale-eng.php](http://www.hc-sc.gc.ca/ewh-semt/consult/_2014/safety_code_6-code_securite_6/final_finale-eng.php)
- 48 IEEE Standards Coordinating Committee 28. 2007. IEEE Standard for Safety Levels with Respect to Human Exposure to Electromagnetic Fields, 0–3 kHz. New York: IEEE. URL: [www.ices-emfsafety.org](http://www.ices-emfsafety.org)

- 49 IEEE International Committee on Electromagnetic Safety (SCC39). 2005. IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz. New York: IEEE. URL: [www.ices-emfsafety.org](http://www.ices-emfsafety.org)
- 50 A list of references is available at [www.fcc.gov/encyclopedia/radio-frequency-safety](http://www.fcc.gov/encyclopedia/radio-frequency-safety)
- 51 Kuhn et al. 2012. Field evaluation of the human exposure from multiband, multisystem mobile phones. *IEEE Transactions on Electromagnetic Compatibility* 55(2): 275–87.
- 52 URL: [www.wel.co.nz/UserFiles/WelNetworks/File/RF%20fields%20from%20a%20WEL%20Networks%20Smart%20Meter.pdf](http://www.wel.co.nz/UserFiles/WelNetworks/File/RF%20fields%20from%20a%20WEL%20Networks%20Smart%20Meter.pdf)
- 53 Summarised in Appendix 1 of reference 73.
- 54 Dockerty et al. 1998. Electromagnetic field exposures and childhood cancers in New Zealand. *Cancer Causes and Control* 9: 209–309. Erratum in 1999; 10: 641.
- 55 Ahlbom et al. 2000. A pooled analysis of magnetic fields and childhood leukaemia. *British Journal of Cancer* 83(5): 692–8.
- 56 Greenland et al. 2000. A pooled analysis of magnetic fields, wire codes, and childhood leukemia. *Epidemiology* 11(6): 624–34.
- 57 International Commission on Non-Ionizing Radiation Protection. 2002. General approach to protection against non-ionizing radiation. *Health Physics* 82(4): 540–48. URL: [www.icnirp.org](http://www.icnirp.org)
- 58 Hill. 1965. The environment and disease: association or causation? *Proceedings of the Royal Society of Medicine* 58(5): 295–300. URL: [www.ncbi.nlm.nih.gov/pmc/articles/PMC1898525/](http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1898525/)
- 59 SCENIHR (Scientific Committee on Emerging and Newly Identified Health Risks). 2015. *Potential Health Effects of Exposure to Electromagnetic Fields (EMF)*. URL: [http://ec.europa.eu/health/scientific\\_committees/consultations/public\\_consultations/scenih\\_r\\_consultation\\_19\\_en.htm](http://ec.europa.eu/health/scientific_committees/consultations/public_consultations/scenih_r_consultation_19_en.htm)
- 60 SCENIHR (Scientific Committee on Emerging and Newly Identified Health Risks). 2012. Memorandum on the Use of the Scientific Literature for Human Health Risk Assessment Purposes: Weighing of evidence and expression of uncertainty. European Commission. URL: [http://ec.europa.eu/health/scientific\\_committees/emerging/docs/scenih\\_r\\_s\\_001.pdf](http://ec.europa.eu/health/scientific_committees/emerging/docs/scenih_r_s_001.pdf)
- 61 SSM's scientific council on electromagnetic fields. 2014. *Recent research on EMF and health risk. Ninth report from SSM's scientific council on electromagnetic fields, 2014*. Report no. 2014:16 ISSN:2000-0456. Swedish Radiation Safety Authority, Stockholm. 2014. URL: [www.stralsakerhetsmyndigheten.se/Global/Publikationer/Rapport/Stralskydd/2014/SSM-Rapport-2014-16.pdf](http://www.stralsakerhetsmyndigheten.se/Global/Publikationer/Rapport/Stralskydd/2014/SSM-Rapport-2014-16.pdf)
- 62 The Institution of Engineering and Technology. 2014. Are There Harmful Biological Effects of Low-Level Electromagnetic Fields at Frequencies up to 300 GHz?: 2014 position statement provided by the Institution of Engineering and Technology. London: Institution of Engineering and Technology. URL: [www.theiet.org/factfiles/bioeffects/emf-position-page.cfm](http://www.theiet.org/factfiles/bioeffects/emf-position-page.cfm)
- 63 SSM's scientific council on electromagnetic fields. Eighth report from SSM's scientific council on electromagnetic fields, 2013. Report no. 2013:19 ISSN:2000-0456. Swedish Radiation Safety Authority, Stockholm. 2013. URL: <http://www.stralsakerhetsmyndigheten.se/Global/Publikationer/Rapport/Stralskydd/2013/SSM-Rapport-2013-19.pdf>
- 64 EFHRAN. 2012. *Risk Analysis of Human Exposure to Electromagnetic Fields*. Revised version. URL: [http://efhran.polimi.it/docs/D2\\_Finalversion\\_oct2012.pdf](http://efhran.polimi.it/docs/D2_Finalversion_oct2012.pdf)
- 65 The Institution of Engineering and Technology. 2012. Are There Harmful Biological Effects of Low-Level Electromagnetic Fields at Frequencies up to 300 Ghz?: 20124 position statement provided by the Institution of Engineering and Technology. London: Institution of Engineering and Technology.
- 66 Health Council of the Netherlands. 2012. *Mobile Phones and Cancer: Part 2: Animal studies on carcinogenesis*. Publication no. 2014/22. The Hague: Health Council of the Netherlands. URL: [www.gezondheidsraad.nl/en/publications/environmental-health/mobile-phones-and-cancer-part-2-animal-studies-carcinogenesis](http://www.gezondheidsraad.nl/en/publications/environmental-health/mobile-phones-and-cancer-part-2-animal-studies-carcinogenesis)
- 67 Demers et al. 2013. *Expert Panel Report on a Review of Safety Code 6: Health Canada's safety limits for exposure to radiofrequency fields*. Ottawa, ON: Royal Society of Canada. URL: [https://rsc-src.ca/sites/default/files/pdf/SC6\\_Report\\_Formatted\\_1.pdf](https://rsc-src.ca/sites/default/files/pdf/SC6_Report_Formatted_1.pdf)

- 68 ARPANSA Radiofrequency Expert Panel. 2014. Report by the ARPANSA Radiofrequency Expert Panel on Review of Radiofrequency Health Effects Based on Scientific Literature 2000–2012. Technical Report Series no 164. Yallambie, VIC: ARPANSA. URL: [www.arpansa.gov.au/pubs/technicalreports/tr164.pdf](http://www.arpansa.gov.au/pubs/technicalreports/tr164.pdf)
- 69 Agence nationale de sécurité sanitaire de l'alimentation, de l'environnement et du travail (ANSES). 2013. *Radiofréquences et santé : Mise à jour de l'expertise: Avis de l'Anses: Rapport d'expertise collective*. Maisons-Alfort: ANSES. Full report (in French) URL: [www.anses.fr/sites/default/files/documents/AP2011sa0150Ra.pdf](http://www.anses.fr/sites/default/files/documents/AP2011sa0150Ra.pdf). English translation of the summary of findings of the expert group, and the ANSES opinion, URL: [www.anses.fr/sites/default/files/documents/AP2011sa0150RaEN\\_1.pdf](http://www.anses.fr/sites/default/files/documents/AP2011sa0150RaEN_1.pdf)
- 70 Health Council of the Netherlands. 2012. *Mobile Phones and Cancer: Part 1: Epidemiology of tumours of the head*. Publication no. 2014/22. The Hague: Health Council of the Netherlands. URL: [www.gezondheidsraad.nl/en/publications/environmental-health/mobile-phones-and-cancer-part-1-epidemiology-tumours-head](http://www.gezondheidsraad.nl/en/publications/environmental-health/mobile-phones-and-cancer-part-1-epidemiology-tumours-head)
- 71 Norwegian Institute of Public Health. 2012. *Low Level Radiofrequency Electromagnetic Fields: An assessment of health risks and evaluation of regulatory practice*. Oslo: Norwegian Institute of Public Health. English translation of report summary URL: [www.fhi.no/dokumenter/545eea7147.pdf](http://www.fhi.no/dokumenter/545eea7147.pdf)
- 72 Swedish Council for Working Life and Social Research. 2012. *Research During the Last Ten Years: Radiofrequency electromagnetic fields – Risk of disease and ill-health*. Stockholm. URL: [www.fas.se/en/News/2012/10-years-of-research-on-the-health-risks-of-radiofrequency-fields/](http://www.fas.se/en/News/2012/10-years-of-research-on-the-health-risks-of-radiofrequency-fields/)
- 73 Health Protection Agency. 2012. Health Effects from Radiofrequency Electromagnetic Fields: Report of the Independent Advisory Group on Non-ionising Radiation: RCE-20. URL: [www.gov.uk/government/publications/radiofrequency-electromagnetic-fields-health-effects](http://www.gov.uk/government/publications/radiofrequency-electromagnetic-fields-health-effects)
- 74 Available at [www.bioinitiative.org](http://www.bioinitiative.org)
- 75 Health Council of the Netherlands. 2008. *Letter to the Minister of Housing, Spatial Planning and the Environment (VROM)*. Publication 2008/17E (2008). URL: [www.gezondheidsraad.nl/sites/default/files/200817E\\_0.pdf](http://www.gezondheidsraad.nl/sites/default/files/200817E_0.pdf)
- 76 EMF-NET. 2007. *Comments on the BioInitiative Working Group Report (BioInitiative Report)*. EMF-NET Coordination Action. European Commission, Brussels.
- 77 Committee on Man and Radiation (COMAR). 2009. COMAR technical information statement: expert reviews on potential health effects of radiofrequency electromagnetic fields and comments on the Bioinitiative Report. *Health Physics* 97(4): 348–56.
- 78 Agence française de sécurité sanitaire de l'environnement et du travail [French Agency for Environmental and Occupational Health Safety – AFSSET]. 2009. *Update on the State of Radiofrequency Research*. Reference #2007/007. URL: [www.radiofrequences.gouv.fr/IMG/pdf/Afsset\\_rapport\\_RF\\_octobre\\_2009.pdf](http://www.radiofrequences.gouv.fr/IMG/pdf/Afsset_rapport_RF_octobre_2009.pdf)
- 79 Rubin et al. 2005. Electromagnetic hypersensitivity: a systematic review of provocation studies. *Psychosomatic medicine* 67: 224–232.
- 80 Rubin et al. 2010. Idiopathic environmental intolerance attributed to electromagnetic fields (formerly 'Electromagnetic hypersensitivity'): an updated systematic review of provocation studies. *Bioelectromagnetics* 31: 1–11.
- 81 Buchner et al. 2011. Changes of clinically important neurotransmitters under the influence of modulated RF fields – A long-term study under real-life conditions. *Umwelt-Medizin-Gesellschaft* 24: 44-57. [Original study in German.]
- 82 Eskander et al. 2012. How does long term exposure to base stations and mobile phones affect human hormone profiles? *Clin Biochem* 45: 157–61.
- 83 Heinrich et al. 2010. Association between exposure to radiofrequency electromagnetic fields assessed by dosimetry and acute symptoms in children and adolescents: a population based cross-sectional study. *Environmental Health* 9: 75.
- 84 Thomas et al. 2008. Personal exposure to mobile phone frequencies and well-being in adults: a cross-sectional study based on dosimetry. *Bioelectromagnetics* 29: 463–470.
- 85 Thomas et al. 2010. Exposure to radio-frequency electromagnetic fields and behavioural problems in Bavarian children and adolescents. *Eur J Epidemiol* 25: 135–141.
- 86 Mohler et al. 2010. Effects of everyday radiofrequency electromagnetic-field exposure on sleep quality: a cross-sectional study. *Radiation Research* 174: 347: 356.
- 87 Leitgeb et al. 2008. Do mobile phone base stations affect sleep of residents? Results from an experimental double-blind sham-controlled field study. *Am J Hum Biol* 22: 613–618.