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

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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.[1]

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)[2] 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[3] (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 (μT)* for the magnetic field and 5 kilovolts per metre (kV/m) for the electric field. For occupational exposures, the reference levels are 1000 μT and 10 kV/m.**

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* The microtesla (μT) 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 μT = 10 mG.

** The corresponding magnetic field reference levels in the 1998 ICNIRP guidelines were 100 μT for the public and 500 μT 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,[4] which are based on a careful review of the health effects research and were reaffirmed in 2009[5] following a review of more recent research in this area.[6]

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*).* 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 μT. Some aspects of the methodology of these studies introduce uncertainties in the hazard assessment. Laboratory evidence and mechanistic studies do not support a causal relationship, but the evidence is sufficiently strong to remain a concern.
- If the relationship is causal, 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.

* 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 μT, 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,[7] 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:[8]

> 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.[9] 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,[10] 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[11] 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[12] concluded that there may be an association, but noted limitations in the data on which this finding was based. Since then a further study[13] found no association, and an accompanying editorial[14] 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.[15,16] 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,[17] 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[18]), 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,[19] 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,[20] UK[21] and Scandinavia[22]) 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.[23]

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* 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.[24]

The IARC classification has received widespread publicity, and a paper by the working group chair and IARC staff published subsequently[25] 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,[26] 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[27] 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, [28,29]). 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,[30,31] and a variety of health complaints including sleep disturbance, headaches, and poor physical health[32]) 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[33] (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,[34,35] and the WHO organised a further workshop* in 2011.[36]

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.[37]

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[38] 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[34] 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[35] 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†), and the UK-based SCAMP (Study of Cognition, Adolescents and Mobile Phones) programme.††
- 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[39] and Lagorio[40]) 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.[41]

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 μT 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).[42] 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.[43] A 2011 survey[44] 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[45,46] 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).[47] 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 aver 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[48] (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 μT, compared with the IEEE/ICES recommendation of 904 μT.) 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[49] (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.[50] 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 μT.

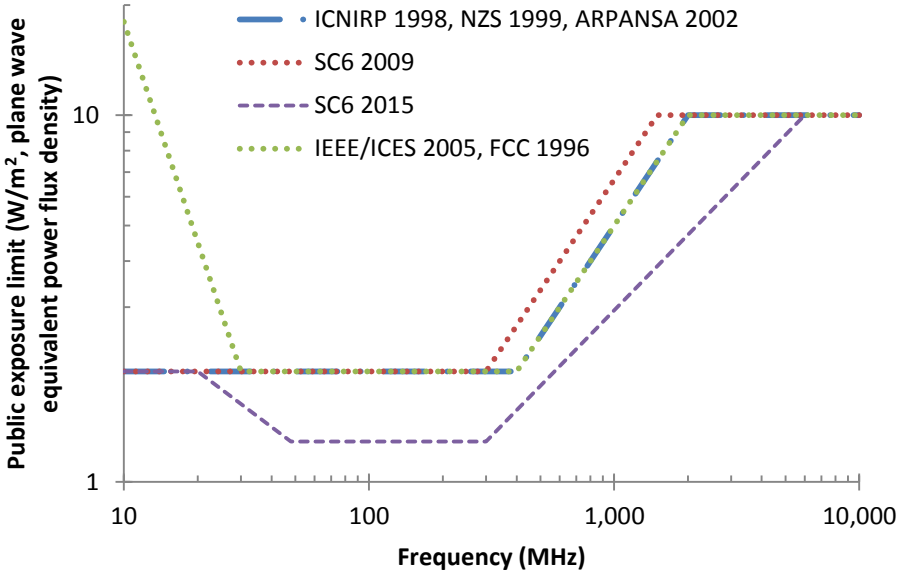
5.5.2 Occupational exposures

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 μT 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.[51] 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[52] 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[53] (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 is 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.

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* 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,[54] the results could be also combined in meta-analyses.[55,56]

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.*[57] 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.[58]