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Radiofrequency Electromagnetic Energy and Health: Research Needs

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Foreword

Modern telecommunications have transformed our lives and perpetual technological advances are likely to continue to influence the way we communicate; a good example is the modern mobile phone which has become an indispensable device for most people. At the same time concerns have been raised about the radiofrequency (RF) electromagnetic energy (EME) that is being emitted from wireless telecommunications sources and whether they cause any health effects. Exposure to man-made EME is not new and people have been living with artificial sources of RF EME in one form or another since Marconi sent the first wireless telegraphs in the 1890s.

For decades researchers have been investigating the effects of RF EME on human health and guidelines have been developed, including an Australian standard, to protect humans from excessive exposure. The assessment of potential health risks of exposure to RF EME includes some uncertainty and gaps have been identified for further research. There is an extensive worldwide research effort to address any gaps in knowledge which have been previously identified in a research agenda developed by the World Health Organization in 2010.

In Australia, there is a research program which funds studies of relevance and interest to the Australian community whilst complementing international efforts. This report aims at identifying the current research gaps on RF EME and health. It is encouraged that Australian researchers consider the recommendations of this report when planning new research in this area. Continuing research will ensure that public health policies are based on the most up-to-date information as telecommunications and other technologies continue to develop.

Carl-Magnus Larsson
CEO of ARPANSA

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Executive summary

There is currently no established evidence that exposure to radiofrequency (RF) electromagnetic energy (EME) at levels below the safety limits of the Australian RF Standard causes any health effects. However there are gaps in the knowledge that require further research. This report uses information from the latest reviews on RF and health to outline research needs in this area. Researchers applying for funding can use the information in this report when planning the research to be undertaken in Australia. The report makes the following recommendations on research needs:

Epidemiology

1. Prospective cohort studies in adults investigating the long-term effects of RF EME associated with the use of mobile phones

2. Ongoing ecological studies investigating time-trends in mobile phone use and brain tumour types and sub-types including investigating latency periods longer than 10 years.

3. Prospective cohort studies of children and adolescents investigating exposure to RF EME and various outcomes including cancer and behavioural and neurological disorders.

Human studies

4. Further provocation studies on neurophysiological effects with improved methods including adequate sample sizes, predefined exposure and analysis protocols and varied populations.

Animal studies

5. Animal studies investigating whether mobile phone RF EME exposure promotes cancer.

6. Further animal studies investigating non-cancer outcomes, including development and behaviour, neurodegeneration and male fertility that are well designed including well-characterised exposure systems incorporating detailed dosimetry.

Cellular studies

7. Replication of in vitro studies reporting RF EME effects on cellular function and DNA damage.

Exposure assessment and dosimetry

8. Ongoing assessment of personal and environmental exposure to RF EME from new and emerging technologies including total exposure from multiple sources and changes in exposure over time.

9. Ongoing research on the characterisation of RF EME exposure in epidemiological and experimental studies.

10. Ongoing research on setting the appropriate limits in the Australian RF Standard based on development in dosimetric methods.

Special areas of research

11. Research into Electromagnetic Hypersensitivity with the aim of understanding the etiology of the condition and finding ways to provide effective treatment for sufferers.

12. Research on millimetre waves including investigating potential hazards and the adequacy of the current limits in the Australian RF Standard.

13. Continued research on RF risk perception and communication by considering the needs identified in the 2010 WHO Research Agenda and addressing further gaps.

The World Health Organization (WHO) is currently reviewing all of the scientific evidence on RF EME and health with the intention of publishing an Environmental Health Criteria Monograph and an accompanying Research Agenda. Australian health authorities are planning to review the updated WHO research agenda when it is published.

Background

Radiofrequency (RF) electromagnetic energy (EME) is the transfer of energy by radio waves in the frequency range between 3 kilohertz (kHz) to 300 gigahertz (GHz). RF EME is part of our natural environment, emitted by sources like the sun, the Earth and the ionosphere. Artificial sources of RF EME are mainly used for telecommunications purposes such as radio and television broadcasting, mobile telephony, Wi-Fi and other wireless communications. Other sources of RF EME include microwave ovens, radar, specific industrial uses, and various medical applications. There are continually emerging technologies that use RF EME particularly in telecommunications and there is some concern of potential health effects which is not fully alleviated by existing scientific data.

RF EME is non-ionising radiation, meaning that it has insufficient energy to break chemical bonds or remove electrons (ionisation). In contrast, ionising radiation (such as X-rays) can remove electrons from atoms and molecules thus leading to damage in biological tissue. It is known that exposure to sufficiently high levels of RF EME can heat biological tissue and potentially cause tissue damage. The amount of environmental RF EME routinely encountered by the general public is too low to produce significant heating or increased body temperature.

International and national safety guidelines and standards have been developed on the basis of current scientific knowledge to ensure that RF EME exposure is not harmful to human health (ICNIRP 1998). In Australia, the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) published the Radiation Protection Standard 'Maximum Exposure Levels to Radiofrequency Fields - 3 kHz to 300 GHz' in May 2002 (ARPANSA 2002). The ARPANSA Standard is designed to protect people of all ages and health status against all currently known adverse health effects from exposure to RF EME. The ARPANSA Standard is based on scientific research that shows the levels at which harmful effects occur and it sets limits, based on international guidelines, well below these harmful levels.

In March 2014 ARPANSA published the Report by the ARPANSA Radiofrequency Expert Panel on Review of Radiofrequency Health Effects Research – Scientific Literature 2000–2012 (ARPANSA 2014). The report concluded that the science behind the ARPANSA RF 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 EME.

Notwithstanding the large body of research underpinning the existing exposure limits in the Australian Standard, the issue of whether or not they are adequate to provide complete protection from harmful effects of exposure to RF EME remains a subject of research and of active debate within the scientific and wider community. In 2010 the World Health Organization (WHO) published a research agenda for RF in order to facilitate and coordinate research in this area worldwide and to present a focused research programme to potential funding agencies (WHO 2010).

Since 2010 a number of research programs have addressed the gaps identified by the WHO Research Agenda. The WHO is currently reviewing all of the scientific evidence on RF EME and health with the intention of publishing an Environmental Health Criteria Monograph on the subject. The Monograph will also include an updated research agenda for addressing areas where there are gaps in the knowledge.

Purpose

The purpose of this report is to outline the research needs into RF EME and health at the time of publication. Researchers applying for funding can use the information in this report when planning the research to be undertaken in Australia. A joint committee has been set up by ARPANSA and the National Health and Medical Research Council (NHMRC) to review the updated WHO research agenda when it is published.

Scope

This report addresses research priorities on RF EME and health within the frequency range of 100 kHz to 300 GHz. Although the current ARPANSA RF Standard also covers frequencies between 3 KHz and 100 kHz, effects at these intermediate frequencies are similar to extremely low frequencies and research needs below 100 kHz are not covered in this report.

This report covers RF EME exposure of the general public and workers but is not applicable to patients that are exposed to medical RF exposure. This report also does not apply to other potential hazards of RF fields such as the ignition of explosives or flammable gases, interference to electronic equipment or other electromagnetic compatibility issues.

Process

Since the 2010 WHO Research Agenda a number of reviews of the research on RF EME and health have been conducted by international or national health authorities including:

- The former Health Protection Agency in the UK (now Public Health England) (HPA 2012)
- The International Agency for Research on Cancer (IARC 2013)
- The Royal Society of Canada (RSC 2014)
- The ARPANSA expert panel (ARPANSA 2014)
- The Swedish Radiation Safety Authority (SSM 2014 & 2015)
- The Scientific Committee on Emerging and Newly Identified Health Risks (SCENIHR 2015)
- The Health Council of the Netherlands (HCN 2016).

The research recommendations in this report are based on the research gaps identified in these reviews and the overall assessment of the research by ARPANSA. Specifically:

- The listed reviews were examined looking specifically at research from the WHO Agenda that has been achieved to date.
- Further research gaps mentioned in the listed reviews were identified.
- Research recommendations by the most recent reviews were given greater weight since recent research may have already covered recommendations by older reviews.

Research hierarchy

When looking at the research into RF EME and health, various disciplines of science, including biology, epidemiology and medicine, as well as physics, engineering and social sciences, need to be considered.[1] Studies involving humans are directly related to human health and are given the greatest weighting in health research. Epidemiological studies directly address the exposure and disease occurrence in the population and are suited to investigating long-term effects. Human experimental studies are constraint by ethical considerations and are better suited to investigating short-term physiological responses. Animal studies are useful but may not be applicable to human health and cellular studies are suited to investigating the interaction mechanisms of RF EME. All types of studies have to be supported by adequate exposure assessment and dosimetry.

Epidemiology

Cohort studies investigating long-term effects

Since the publication of the 2010 WHO Research Agenda a large number of epidemiological studies have investigated RF EME and a variety of chronic diseases, the majority of which have looked at whether mobile phone use causes cancer (SCENIHR 2015 & HCN 2016). Overall, the epidemiological studies do not indicate a causal relationship between RF EME and long-term effects however there are gaps that have been identified in recent reviews. A key concern across all studies is the quality of assessment of RF exposure. In particular, some case-control studies (e.g. Hardell 2006 & INTERPHONE 2010) have shown no overall increase in brain tumours from the use of mobile phones but have reported a small increase in certain types of brain tumour for long-term and heavy mobile phone use. Limitations of the methodology including recall bias of phone use prevent conclusions of causality being drawn from these observations. Based largely on this limited evidence IARC has classified RF fields as possibly carcinogenic to humans (IARC 2013).

The long-term risk affecting individuals who report heavy mobile phone use will require further research however given the inherent methodological problems of case-control studies it is unlikely that they will fulfil the gaps in knowledge. Both the SCENIHR (2015) and HCN (2016) reviews have recommended as a high priority prospective cohort studies evaluating the long-term effects of mobile phone use, in order to provide more conclusive evidence. One such study, called COSMOS, is currently underway in five European countries (Schuz et al. 2011). The 2010 WHO Research Agenda identified that the COSMOS study should be continued until a reasonable follow-up time has been achieved to evaluate potential long-term risks.

Recommendation 1: Prospective cohort studies in adults investigating the long-term effects of RF EME associated with the use of mobile phones.

[1] More information on the different types of studies is available from ARPANSA http://www.arpansa.gov.au/RadiationProtection/Factsheets/is_assessingevidence.cfm

The SCENIHR review pointed out that the cohort studies should be of sufficient size and duration and should reflect the latest developments in exposure assessment. The studies should investigate a variety of long-term effects including cancer and other effects such as neurobehavioural, developmental, reproductive and cerebrovascular outcomes.

Ecological studies investigating brain tumour

The 2010 WHO Research Agenda identified as a high priority the monitoring of brain tumour incidence trends through well-established population-based cancer registries, if possible combined with population exposure data. Since then a number of ecological studies have generally shown that although the prevalence of mobile phone use (usually measured through mobile phone subscription rates) has seen a massive increase, the time trends of brain tumour incidence have remained fairly stable (SCENIHR, 2015; HCN 2015). Further, a few recent studies including one from Australia have shown that modelled expected incidence rates based on the associations reported by the Hardell and Interphone studies for heavy mobile phone users are higher than the observed rates (Chapman 2016). The Australian study in particular, reported overall brain tumour incidence but lacked in showing the brain tumour sub-type incidence. Further, the simulation of expected rates was only performed for a latency period of 10 years. It is useful to continue investigating time-trends of brain tumour incidence by including tumour sub-type analysis and latency periods longer than 10 years. Although such ecological studies are limited in many ways and provide the least evidence for a causal association they can be performed quite quickly and inexpensively (WHO 2010).

Recommendation 2: Ongoing ecological studies investigating time-trends in mobile phone use and brain tumour types and sub-types including investigating latency periods longer than 10 years.

Studies on children

The 2010 WHO Research Agenda identified a lack of sufficient evidence relating to children and this is still the case. The WHO Agenda recommended a prospective cohort study to investigate whether the use of mobile phones and other RF sources by children and adolescents is associated with long-term health effects including cancer and developmental, cognitive and behavioural disorders. Given that no long-term prospective study has looked at this issue to date this research need remains a high priority.

For cancer in particular only one completed case-control study involving four European countries has investigated mobile phone use among children or adolescents and risk of brain tumour; showing no association between the two (Aydin et al. 2011). Another international multicentre study (called MOBI-KIDS) involving 13 countries, including Australia, is currently investigating mobile phone use during childhood and adolescence and later onset of brain tumours (Sadetzki et al. 2014). Given this paucity of information regarding children using mobile phones and cancer the SCENIHR (2015) review identified that more epidemiological studies are needed. The SCENIHR review further recommended that epidemiological studies investigating mobile phone use and brain tumour should include children of a younger age than those that have been studied to date, and be of sufficient duration to include assessments of cancer risk later in life. The SCENIHR review also recommended that studies should include sources other than mobile phones that may contribute high exposure to the brain. Given the methodological problems of case-control studies mentioned earlier future epidemiological studies on children should employ a prospective design.

Recommendation 3: Prospective cohort studies of children and adolescents investigating exposure to RF EME and various outcomes including cancer and behavioural and neurological disorders.

Human studies

The 2010 WHO Research Agenda identified research needs related to neurophysiological outcomes. Since then a number of human provocation studies have investigated whether RF exposure (mainly related to mobile phones) causes neurophysiological but also cognitive effects. Overall, these studies demonstrated a lack of evidence that mobile phone RF EME affects cognitive function in humans and as pointed out in the HPA (2012) review studies on cognitive function are not a research priority. For neurophysiological outcomes there is consistent evidence from EEG studies during wake and sleep that mobile phone RF EME may affect brain activity. However, the relevance of these EEG effects to human health remains unclear and responsible mechanisms for the effects have not been shown (SCENIHR 2015). Based on this the SCENIHR review made a number of research recommendations:

> "Most neurophysiological studies on possible effects of RF exposure on brain function in volunteers have been performed with young and predominantly male subjects. Since brain structure and brain physiology changes with age possible RF EMF effects may also show age dependencies. It is not known whether effects may change with age, and further studies using elderly and children and adolescent subjects are recommended as a medium high priority on sleep and sleep EEG power, waking EEG, and a medium priority on cognition. In particular, every study assessing EEG during exposure must ensure that the RF signal does not affect the acquisition of the EEG. If the device used to record the EEG does not offer an adequate resistance against electromagnetic interference, either detectable artefacts in the EEG signal or subtle changes of the electrical properties of the recording system might occur and bias the results. Future studies should report that they have considered this problem.
>
> Overall, there is a high priority research need for (preferably multicentre) neurophysiological studies in volunteers with pre-defined effect sizes, based on a priori considerations of power and sample size (type I and type II errors and adequate sample size for the statistical test(s) to be used) for data analysis according to a predefined analysis protocol. There are a few studies indicating that women are more affected than men, exposure effects vary with age, and that patient populations could be more affected than healthy subjects. Hence, proposed studies should cover a wide range of ages, look at data for females and males separately and, if possible, include patient populations, e.g. insomniacs in sleep studies or patients with neurological disorders including neurodegenerative diseases".

Recommendation 4: Further provocation studies on neurophysiological effects with improved methods including adequate sample sizes, predefined exposure and analysis protocols and varied populations.

As indicated in the HPA (2012) review any future human research should also consider whether any effects of RF EME on brain activity are relevant for health.

Animal studies

Cancer

A large number of animal studies which have investigated whether exposure to RF EME causes cancer have not established a carcinogenic effect. The SCENIHR (2015) review consequently recommended "no further studies investigating the genotoxic or carcinogenic potential of RF fields in animal models". The SCENIHR review further recommended that the need for further research in this area should be reconsidered following the completion of a large-scale study by the US National Toxicology Program which is investigating cancer and non-cancer outcomes.[2]

The HCN (2016) review also agreed that the animal data to date does not provide substantiated evidence for the induction of cancer. However the review mentioned that more recent evidence does provide an indication for a promoting effect of RF fields. The HCN recommended that a possible promoting effect of RF warrants further investigation.

Recommendation 5: Animal studies investigating whether mobile phone RF EME exposure promotes cancer.

Non-cancer outcomes

The 2010 WHO Research Agenda identified a number of end-points where more in vivo research was required including studies on development and behaviour, neurodegeneration and male fertility. Since then, animal studies have investigated these and other outcomes including studies that have investigated whether exposure to RF has a protective effect.[3] The animal studies on RF and non-cancer outcomes have produced largely inconsistent results. It has been pointed out that the majority of animal studies lack an adequate study design and the exposure systems and dosimetry are poorly described (SSM 2014). The SCENIHR (2015) review recommended that reported effects in single studies need to be replicated in better designed studies.

Recommendation 6: Further animal studies investigating non-cancer outcomes, including development and behaviour, neurodegeneration and male fertility that are well designed including well-characterised exposure systems incorporating detailed dosimetry.

[2] https://ntp.niehs.nih.gov/results/areas/cellphones/

[3] For example, the studies from Arendash et al. (2009 & 2010) reported that mice exposed to mobile phone type RF fields were protected against the development of Alzheimer´s disease.

Cellular studies

There has been more in vitro research (including studies in tissues, living cells and cell-free systems) in the area of RF EME and health than any other type of study. Cellular studies of the effects of RF fields have looked at both genotoxic effects (DNA damage) and non-genotoxic effects (changes in cellular function) and have included studies on combined exposures to RF and other agents. To date the in vitro results are weak and inconsistent and have not provided substantiated evidence that RF EME affects human health at a cellular level (SCENIHR 2015).

The 2010 WHO Research Agenda identified that many cellular studies are technically incomplete as they lack sufficient experimental repetition, replication and confirmation through the use of more precise quantitative measures. WHO added that the magnitude of any changes in cellular studies is usually small and difficult to interpret (WHO 2010); i.e. it is difficult to determine the significance of small in vitro changes to human health. Based on these issues the WHO Research Agenda did not identify any in vitro gaps as a high-priority research need. Nevertheless, numerous cellular studies have been carried out since then on both genotoxic and non-genotoxic end-points the majority of which have not shown an effect at non-thermal levels (SCENIHR 2015). But certain effects have been reported in some studies. A review by the Swedish Radiation Safety Authority concluded that "in some investigations effects on parameters related to oxidative stress are reported and in a few cases some slight and transient variations relative to sham-controls have been recorded" (SSM 2015). The SCENIHR review mentioned that several in vitro studies have reported effects on DNA damage including DNA migration, spindle disturbance and foci formation. More research on these effects was recommended by the reviews (SSM 2015 & SCENIHR 2015).

Recommendation 7: Replication of in vitro studies reporting RF EME effects on cellular function and DNA damage.

Exposure assessment and dosimetry

Exposure assessment of new and emerging technologies

The 2010 WHO Research Agenda identified a number of research needs related to exposure assessment including the assessment of RF from new and emerging technologies, the quantification of personal and environmental exposure and the monitoring of RF EME in the workplace. Since then numerous studies have addressed these gaps in exposure assessment and although personal and environmental exposure to RF EME remains below the levels that have been shown to cause harm there is merit in continuing to characterise exposure. The RSC (2014) review pointed out that given the development and proliferation of new technologies the characterisation of exposure to RF EME should be ongoing as part of a risk communication strategy to address community concern (RSC 2014).

Recommendation 8: Ongoing assessment of personal and environmental exposure to RF EME from new and emerging technologies including total exposure from multiple sources and changes in exposure over time.

Exposure characterisation in health studies

A specific concern in research on RF EME and health is the exposure characterisation in both experimental and epidemiological studies (SCENIHR 2015 & HCN 2016). In epidemiological studies in particular the exposure characterisation continuous to be poor in describing the real exposure so it is very important that ongoing and future studies incorporate more accurate and objective assessment of RF EME exposure (HCN 2016). The HCN review commented that "this is even more important since personal exposure to RF continues to change due to evolving patterns of use and new mobile telecommunication devices" (HCN 2016). The HPA (2012) review added that exposure assessment in epidemiological studies should be complemented by dosimetric evaluations.

Recommendation 9: Ongoing research on the characterisation of RF EME exposure in epidemiological and experimental studies.

The 2010 WHO Research Agenda also identified a need to monitor the personal exposure of RF workers who are often exposed to industrial sources with higher than normal RF EME levels. Although there has been some work in describing occupational exposures, the assessment of occupational exposure in epidemiological studies also continues to be poor. Improvements in the monitoring and characterisation of occupational exposure should be considered as part of Recommendation 9.

The 2010 WHO Research Agenda also pointed out that there is a lack of adequate instrumentation for monitoring RF EME exposure. Little development has been achieved in this area since then and the SCENIHR review recommended the manufacture of new affordable instrumentation or the improvement of existing specialised exposure meters. Although no specific recommendation will be made in this report regarding research into exposure meters, this should also be considered as part of Recommendation 9.

Appropriate limits in the RF Standard

Since the ARPANSA (2002) RF Standard was published there has been considerable development in dosimetry of more realistic numerical models of the human body. The 2014 ARPANSA Expert Panel review noted that while recent advances in numerical dosimetry have confirmed the conservatism of current exposure limits in most circumstances, the inclusion of a wider range of body sizes has produced strengthening evidence that the Reference Levels may not be providing the intended safety margins at some frequency ranges for certain body sizes. However because of the large safety factors between the Basic Restrictions and the levels where adverse effects are seen, there is no evidence that this reduced margin in conservatism impacts on health. The RSC (2014) review recommended that the effectiveness of the Reference Levels should be examined against a larger number of new dosimetry studies. Further the ARPANSA Expert Panel review noted there is also the question of whether the Basic Restrictions continue to be an accurate indicator of local rise in temperature, particularly in the limbs under resonant conditions and hence the degree of protection against protein denaturation and other adverse thermal effects. The ARPANSA Expert Panel found that the limits in the RF Standard continue to provide high levels of protection against the known thermal effects of RF EME; however there is a need for ongoing research in determining the thresholds of effects to guide appropriate limits in the Standard.

Recommendation 10: Ongoing research on setting the appropriate limits in the Australian RF Standard based on development in dosimetric methods.

Special areas of research

Electromagnetic hypersensitivity

Some individuals have reported a wide range of non-specific health problems (e.g. headaches, fatigue and dizziness) that they attribute to low-level electromagnetic fields including RF EME from common telecommunications sources such as mobile phones and base stations, Wi-Fi, smart meters etc. According to the WHO the collection of these symptoms is not part of any medically recognised syndrome (WHO 2005). This presumed sensitivity to electromagnetic fields is often termed 'Electromagnetic Hypersensitivity' or EHS. EHS resembles reported sensitivities to other low-level environmental exposures (e.g. sensitivity to chemicals) so a more general term that is often used in biomedical literature is *idiopathic environmental intolerance attributed to electromagnetic fields*.

The association between RF EME exposure and EHS has been investigated by several provocation and epidemiological studies and these have been reviewed by several expert bodies including HPA (2012) and more recently SCENIHR (2015). The reviews point out that, overall, meta-analyses of provocation and epidemiological studies have shown that exposure to RF EME is unlikely to be causally connected to EHS. Whatever the aetiology of EHS it is acknowledged by health authorities that the condition leads to functional impairment of activities of daily living and occupation (WHO 2005).[4] It is therefore important that research continues into investigating the problems faced by EHS individuals. The ARPANSA Electromagnetic Energy Reference Group[5] established an EHS Working Group to investigate strategies for an improved understanding of the issues associated with EHS in Australia. Expert advice provided to the Working Group included three main areas of future research into EHS:

(i) Investigating whether RF is causally connected with EHS – It is not clear that there is sufficient evidence to justify further research in this area. Both the HPA and SCENIHR reviews have identified that given the consistency of well conducted provocation studies further research using this approach is not a high priority. Improving the methodology in provocation studies may justify further research as a low to medium priority. The epidemiological evidence also shows an overall lack of association between RF and EHS however the quality of these studies is generally poor (SCENIHR 2015).

(ii) Exploring other causes – There has been very little previous research identifying factors other than RF EME that may be linked to an EHS individual's symptoms. Potential direction for enquiry may arise from exploring the commonalities of EHS individuals and those sufferers of other disorders linking the evolving understanding of central sensitisation and the various forms of Central Sensitivity Syndrome.

4 http://www.arpansa.gov.au/RadiationProtection/Factsheets/is_ehs.cfm

5 http://www.arpansa.gov.au/AboutUs/collaboration/emerg.cfm

(iii) Investigating treatment options – The suffering of the EHS individual can be debilitating, and in spite of our current lack of knowledge regarding the aetiology of EHS, sufferers need constructive support and treatment. Ad hoc endeavours have appeared over time without clear evidence of efficacy. Strategies typically focus on either RF EME avoidance, or symptom alleviation through medications or various psychological therapies to build resilience. However, there has been very little research to evaluate such options, with clinicians typically forced to manage symptoms rather than the EHS condition itself.

Recommendation 11: Research into Electromagnetic Hypersensitivity with the aim of understanding the aetiology of the condition and finding ways to provide effective treatment for sufferers.

New technology using millimetre waves

New and emerging technologies are operating at frequencies greater than 6 GHz, for example, millimetre wave scanners, the 5G mobile phone network and wireless power transfer systems. In the frequency range above 6 GHz and up to 300 GHz the current safety guidelines (including the Australian RF Standard) prevent excessive heating at the surface of the skin and in the eye. At such frequencies the depth of penetration of RF EME in tissue is relatively short (less than 8 mm) and surface heating is the predominant effect (ARPANSA 2002). Both the RSC (2014) and SCENIHR (2015) reviews identified that the dosimetry in the 6 GHz to 300 GHz range is still developing and further research is required to examine the effects of exposure to new and emerging technologies. The SCENIHR review in particular mentioned that "considering the expected increase in use of THz technologies, more research focusing on the effects on skin (long-term, low-level exposure) and cornea (high intensity, short-term exposure) is recommended".

Recommendation 12: Research on millimetre waves including investigating potential hazards and the adequacy of the current limits in the Australian RF Standard.

Risk perception and communication

The majority of the population seems to have low concern about adverse health effects resulting from exposure to RF EME. Some people however perceive risks from RF EME exposure as likely and even possibly severe. The invisible and often involuntary nature of RF EME exposure and the possibility of health effects including cancer, particularly among children, have all heightened public concern for some members of the public. Consequently, media and internet coverage has been intense and the issue has been brought to a wide public awareness. The 2010 WHO Research Agenda mentioned that communicating the risk of RF EME "should build on evidence from both scientific risk assessments and insights from social studies that investigate these concerns through well-formulated research". The WHO made a number of social research recommendations related to the perception of risk from RF EME exposure and communicating effectively the scientific evidence to the public. Since then a number of papers have been published on RF risk perception and communication however none of the major reviews on RF EME and health have covered social research and whether the needs identified by WHO in 2010 have been addressed. Researchers should consider the needs previously identified by WHO on RF risk perception and communication and address further gaps in this area.

Recommendation 13: Continued research on RF risk perception and communication by considering the needs identified in the 2010 WHO Research Agenda and addressing further gaps.

Guidance on research methods

In line with the recommendations by the 2010 WHO Research Agenda it is advised that researchers comply with existing standards for best practices in research, including those related to ethics and to good laboratory practice (WHO 2010). Guidance on responsible conduct of research has also been provided in Australia by the NHMRC.[6] Further, as advised by WHO it is recommended that researchers follow high quality research methods including "clearly defined hypotheses; measurable endpoints; sample sizes with sufficient statistical power to answer the relevant questions; and the use of protocols that are consistent with good scientific and ethical practice" (WHO 2010). Guidance specifically on RF related research methods has been provided by the International Commission on Non-Ionizing Radiation Protection (2002) and more recently by the SCENIHR (2015) review.

6 https://www.nhmrc.gov.au/research/responsible-conduct-research-0

References

Arendash GW, Mori T, Dorsey M, Gonzalez R, et al. 2012, Electro*magnetic treatment to old Alzheimer's mice reverses β-amyloid deposition, modifies cerebral blood flow, and provides selected cognitive benefit*. PLoS One, 7(4), e35751.

Arendash GW, Sanchez-Ramosa J, Mori T, Mamcarz M, et al. 2010, *Electromagnetic field treatment protects against and reverses cognitive impairment in Alzheimer's disease mice*. J Alzheimer's Disease, 19, 191-210.

ARPANSA (Australian Radiation Protection and Nuclear Safety Agency) 2002, *Radiation Protection Standard for Maximum Exposure Levels to Radiofrequency Fields – 3 kHz to 300 GHz*, Radiation Protection Series, No. 3.

ARPANSA 2014, *Report by the ARPANSA Radiofrequency Expert Panel on Review of Radiofrequency Health Effects Research – Scientific Literature 2000–2012*, ARPANSA Technical Report, No 164.

Aydin D, Feychting M, Schüz J, Tynes T et al. 2011, *Mobile phone use and brain tumors in children and adolescents: a multicenter case-control study*, J Natl Cancer Inst;103(16):1264-76.

Chapman S, Azizi L, Luo Q, Sitas F 2016, *Has the incidence of brain cancer risen in Australia since the introduction of mobile phones 29 years ago?* Cancer Epidemiol. 2016 Jun;42:199-205.

Hardell L, Carlberg M, Hansson Mild K, 2006, *Pooled analysis of two case-control studies on use of cellular and cordless telephones and the risk for malignant brain tumours diagnosed in 1997-2003*, Int Arch Occup Environ Health. 79(8):630-9.

HCN (Health Council of the Netherlands) 2016, *Mobile phones and cancer: Part 3. Update and overall conclusions from epidemiological and animal studies*.

HPA (Health Protection Agency) 2012, *Health effects from radiofrequency electromagnetic fields: the independent Advisory Group on Non-ionising Radiation*, Documents of the Health Protection Agency.

IARC (International Agency for Research on Cancer) 2013, *Non-Ionizing Radiation Part 2: Radiofrequency Electromagnetic Fields*, IARC Monographs on the evaluation of carcinogenic risks to humans, Vol 102.

INTERPHONE 2010, *Brain tumour risk in relation to mobile telephone use: results of the INTERPHONE international case-control study*, Int J Epidemiol. 2010 Jun;39(3):675-94.

ICNIRP (International Commission on Non-Ionizing Radiation Protection) 1998, *Guidelines for limiting exposure to time-varying electric, magnetic, and electromagnetic fields (up to 300 GHz),* International Commission on Non-Ionizing Radiation Protection, Health Phys. 1998 Apr;74(4):494-522.

ICNIRP 2002, *ICNIRP Statement on General approach to protection against non-ionizing radiation*, Health Physics 82(4):540-548.

RSC (The Royal Society of Canada) 2014, *The Royal Society of Canada Expert Panel: A Review of Safety Code 6 (2013): Health Canada's Safety Limits for Exposure to Radiofrequency Fields*,

Sadetzki S, Langer CE, Bruchim R, Kundi M et al. 2014, *The MOBI-Kids Study Protocol: Challenges in Assessing Childhood and Adolescent Exposure to Electromagnetic Fields from Wireless Telecommunication Technologies and Possible Association with Brain Tumor Risk*, Front Public Health. 2:124.

SCENIHR 2015, *Potential health effects of exposure to electromagnetic fields*, Scientific Committee on Emerging and Newly Identified Health Risks.

Schüz J, Elliott P, Auvinen A, Kromhout H et al. 2011, *An international prospective cohort study of mobile phone users and health (Cosmos): design considerations and enrolment*, Cancer Epidemiol, 35(1):37-43.

SSM (Swedish Radiation Safety Authority) 2014, *Recent Research on EMF and Health Risk: Ninth Report from SSM's Scientific Council on Electromagnetic Fields.*

SSM 2015, *Recent Research on EMF and Health Risk: Tenth Report from SSM's Scientific Council on Electromagnetic Fields*, Swedish Radiation Safety Authority.

WHO (World Health Organization) 2010, *WHO research agenda for radiofrequency fields*.

WHO 2005, *Electromagnetic fields and public health: Electromagnetic hypersensitivity*.