

REVIEW ARTICLE

International policy and advisory response regarding children's exposure to radio frequency electromagnetic fields (RF-EMF)Mary Redmayne^{1,2}¹Population Health Research on Electromagnetic Energy (PRESEE), Monash University, Melbourne, VIC, Australia and ²School of Geography, Environment and Earth Sciences, Victoria University of Wellington, Wellington, New Zealand**Abstract**

Radiofrequency electromagnetic field (RF-EMF) exposure regulations/guidelines generally only consider acute effects, and not chronic, low exposures. Concerns for children's exposure are warranted due to the amazingly rapid uptake of many wireless devices by increasingly younger children. This review of policy and advice regarding children's RF-EMF exposure draws material from a wide variety of sources focusing on the current situation. This is not a systematic review, but aims to provide a representative cross-section of policy and advisory responses within set boundaries. There are a wide variety of approaches which I have categorized and tabulated ranging from ICNIRP/IEEE guidelines and "no extra precautions needed" to precautionary or scientific much lower maxima and extensive advice to minimize RF-EMF exposure, ban advertising/sale to children, and add exposure information to packaging. Precautionary standards use what I term an exclusion principle. The wide range of policy approaches can be confusing for parents/carers of children. Some consensus among advisory organizations would be helpful acknowledging that, despite extensive research, the highly complex nature of both RF-EMF and the human body, and frequent technological updates, means simple assurance of long-term safety cannot be guaranteed. Therefore, minimum exposure of children to RF-EMF is recommended. This does not indicate need for alarm, but mirrors routine health-and-safety precautions. Simple steps are suggested. ICNIRP guidelines need to urgently publish how the head, torso, and limbs' exposure limits were calculated and what safety margin was applied since this exposure, especially to the abdomen, is now dominant in many children.

Keywords

Radiofrequency guidelines, children, precautionary approach, ICNIRP, WHO International EMF Project

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There is continuing concern among researchers and the public about possible detrimental effects for young people from their exposure to radiofrequency electromagnetic fields (RF-EMF).

Safety regulations/guidelines in most parts of the world only consider short-term heat and shock effects, and have not traditionally considered chronic or very low exposure. Concerns are, therefore, warranted since there has in recent years been an amazingly rapid uptake in the use of not only mobile phones but other wireless devices also, by increasingly younger children. Uptake of Bring Your Own Device (BYOD) in schools is growing with the encouragement of industry (Intel Education, 2014) and government departments (Stavert, 2013). This requires WiFi routers, which are often installed throughout the school. Parents commonly provide their

pre-school children and even infants with a tablet or smart phone to play games. Since a large proportion of homes also have WiFi, many children are exposed to RF-EMF round-the-clock. With the use of baby monitors and lie-on motion sensor mats, near-field exposure can start from birth, while the use of tablets and phones against a pregnant belly can provide even earlier near-field exposure. There is a growing, unchecked and unregulated availability of a range of transmitting equipment specifically aimed at parents of babies and young people including a teething ring/rattle with a dribble-proof space to hold a smartphone in the centre! There are several circumstances under which transmitting devices are exempt from compliance evaluation testing (Industry Canada, 2015). For instance, it is common policy that if the output of an RF-EMR emitting device is below 20 mW, then no exposure testing is required before being put on the market.

Ofcom, Britain's independent regulator and competition authority for the United Kingdom (UK) communications industries, reports that by 2012 37% of 3–4 year olds in the UK were using the Internet via a PC, laptop, or netbook, 6% via a tablet, and 3% with a mobile phone, making (Ofcom, 2012).

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Many governments have addressed, and are addressing, children's increasing RF-EMF exposure via policy, while assorted Non-Governmental Organisations (NGO), associations and concerned professional groups have made recommendations. This paper examines the status quo regarding international responses to children's exposure to RF-EMF. For the purposes of this paper, "children" refers to those *in utero* to <18 years.

Methods

Search material was drawn from a wide variety of sources. These included: national policy documents from a broad range of countries; meeting minutes, reports, and papers published by national and international organizations researching and advising on mobile phone use and health effects (including World Health Organization (WHO) International EMF Project country reports); peer-reviewed, published journal articles; hearings; parliamentary and conference proceedings; expert advice; and technical papers. The date limits were 1998–2013 March 2014, although the main focus is on the recent and current situation.

This is not a systematic review, as the breadth, volume, and complexity of sources (many of which are not of the type to have had peer-review) makes this unrealistic. However, it aims to provide a representative cross-section of policy and advisory responses within the set boundaries.

Results

Results are considered in two main categories. The first is the legal or official policy approach and advice related to children's RF-EMF exposure in various countries. This includes (a) exposure standards, and (b) regulations and official advice. The second is a selection of other sources of advice related to children, which includes Governmental scientific advisory bodies; independent, professional bodies comprised of scientists, and health professionals with peer-reviewed publications in the field of RF-EMF; and individual research scientists in the fields of RF-EMF exposure effects, medicine, and pediatrics.

There are a multitude of public action groups offering advice and opinions. Many of these include highly qualified people with relevant scientific qualifications who have read the literature extensively. This category includes the voice of the RF-EMF exposed public, including parents and their children, and is important for that reason, however, it is not discussed in this paper.

Legal/official policy and advice

There are two types of legal and/or official policy approach regarding children's RF-EMF exposure. The first relates to exposure standards with or without greater stringency than for the general population, and the second is composed of regulations and official advice concerning children's RF-EMF exposure and their type and extent of use of RF-EMF emitting devices. The first is generally related to environmental (far-field) exposures when special steps are introduced, while the second refers to personal (near-field) exposure.

RF-EMF exposure standards are, in most countries, based on the International Commission on Non-Ionising Radiation

Protection (ICNIRP, 1998) or IEEE (Institute of Electrical and Electronics Engineers, 2005) guidelines. The United States (US) does not have a federally mandated RF exposure standard, but relies instead on those recommended by ANSI/IEEE C95.1-1992 for near-field and, NCRP, 1996, for far-field exposures (cited by Federal Communications Commission, 2010). These Western guidelines are extensively described and commented upon elsewhere and only address, "short-term, immediate health effects such as stimulation of peripheral nerves and muscles, shocks and burns caused by touching conducting objects, and elevated tissue temperatures resulting from absorption of energy during exposure to EMF" p. 496 (ICNIRP, 1998). The ICNIRP guidelines specify that infants and young children were taken into consideration as "a general variable" in the 50× built-in safety factor applied to the whole body heat response calculation (ICNIRP, 1998).

There is a wide variety of policy approaches in the legal/official category. For this review, I have assigned each to one of the five categories. Results are presented at Table 1. Additional aspects of the five approaches to exposure standard and then the accompanying policy, law and advice will be discussed in turn below.

Approach 1

The first approach is for the exposure recommendations, or law, to follow the IEEE or ICNIRP guidelines, or something close to this. This is the official approach of several countries (Table 1) and is the course recommended the European Union (Council of the European Union, 1999) and supported, by inference, by the WHO which administer the WHO EMF project and actively collaborate with the ICNIRP (World Health Organisation, 2011).

The main difference between the IEEE and ICNIRP is whether the specific absorption rate (SAR) is averaged over 1 g or 10 g of tissue, the latter resulting in a higher exposure being permitted.

Approach 1 may or may not include an As Low As Reasonably Achievable (ALARA) clause.

Countries taking this approach do not recommend any precautionary steps for children due to the 50-fold built in safety margin in the guidelines. As the Swedish Radiation Safety Authority puts it, "Since exposure of the general public, including children, to radio waves from the wireless local area networks and base stations is far below the exposure limits, there is no need to further limit exposure from these radio wave sources" (Swedish Radiation Safety Authority, 2013).

In 2011, the Health Council of the Netherlands emphasized that there was no reason to recommend lower exposure limits for children, but went on to point out that the ICNIRP reference levels around 2 GHz are not correct and need to be lowered as they currently equated to Netherlands report pointed out that the reference levels around 2 GHz are not correct and "must be corrected downwards" as they exceed the maximum SAR allowance in small people (Health Council of the Netherlands, 2011). They added that this meant, "the reference levels for GSM, UMTS and Wi-Fi applications will be lowered from about 40–70 V/m to 28 V/m" (Health Council of the Netherlands, 2011).

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Table 1. International approach categories to RF-EMF exposure standards, showing countries only.

Basis of guidelines/law	USA	Netherlands	New Zealand	Norway	Hungary	Japan	Estonia	Sweden	United Kingdom	Canada	Germany	Denmark	Australia	Finland	France	Peru	Austria	South Korea	Turkey	Switzerland	Peru	India	Israel	Belgium	Bulgaria	Lithuania	Luxembourg	Italy	Slovenia	Hong Kong	Greece	Russia	China	Poland				
<i>Exposure standard</i>	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	*	3	3	3	4	4	4	4	4	4	4	4	4	4	4	4	4			
To prevent acute thermal or shock effects. Based wholly on ICNIRP or IEEE guidelines, based on thermal scientific research. May include an ALARA clause																																						
ICNIRP or IEEE, plus a precautionary tier for public exposure in sensitive sites																																						
Based wholly on precautionary approach																																						
Aim: to address acute thermal and chronic "non-thermal" effects. Based on range of scientific research																																						
<i>Advice re children's exposure</i>																																						
No precautionary steps regarded as necessary for children	1	1	1	1	1	1	1																															
Formal precautionary advice for children to minimise/reduce exposure								2†	2†	2	2	2	2	2	2	2	2	2		3	3	3	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	
Additional advice/law re children's exposure (see Table 3)																																						

Some regions and cities (not shown) also have a precautionary Standard and/or advisory policies.
 *Turkey follows the ICNIRP guidelines for total exposures, but has a tier set at 0.25 of that for emissions from individual sources.
 †Refers only to mobile phone use (Centre for Health Protection, 2011; Public Health England, 2013; Swedish Radiation Safety Authority, 2013).
 #Ministerial Resolution, 2005.

A more carefully worded stance over the last few years has often meant an added note of advice on steps parents can take if they are concerned. However, countries using Approach 1 offer this as information, not advice. For instance, New Zealand's Ministry of Health states, "It's your choice whether to let your children use cellphones. ... If you want to reduce your exposure to radiofrequency energy from your mobile, it's easy to do" (Ministry of Health, 2014).

Such approaches on official websites have sometimes included information (or links to websites) on how to reduce personal RF-EMF exposure for those who wish to do so. A more educational approach has most recently been added, such as naming the circumstances under which a mobile phone transmits (Ministry of Health, 2014) or providing information about the rapid decrease in power density, and therefore exposure, with distance (World Health Organisation, 2014).

Approach 2

The second approach is the same as Approach 1, but also issues formal precautionary advice to children to reduce or minimize RF-EMF exposure and information on reducing exposure (Table 1).

An example of this is, "Parents are reminded not to give a mobile to children until old enough to follow Recommendations [issued by the National Board of Health] to limit exposure, such as using hands-free kit" p. 26 (European Commission, May 2008).

National moves towards a more precautionary stance seem to occur in stages. For example, in 2008, the Australian ARPANSA EME series Fact Sheet 11 stated, "if individuals

are concerned, they should choose to limit their own or their children's RF EME exposure" (Australian Radiation Protection and Nuclear Safety Agency Committee on Electromagnetic Energy, 2008). By 2010, this was updated with a press release recommending that, "parents encourage their children to limit their exposure" (Australian Radiation Protection and Nuclear Safety Agency, 2008). This advice now appears in both Fact sheet No. 13, which was updated in 2014 (ARPANSA, 2011) and Fact sheet No. 14 (ARPANSA, 2013, updated July 2014).

Approach 3

Approach 3 is like Approach 2, but adds a precautionary tier for public exposures in sensitive sites. The definition of these zones varies by country. For children, this can mean schools and childcare facilities and playgrounds, to anywhere that children spend more than a set number of hours daily, including residences.

Some Approach 3 countries (see Table 1) have recommendations or laws requiring other actions such as compulsory SAR labelling either on cartons, devices or at the point of sale.

Approach 4

The fourth group has a different basic approach by setting guidelines (or laws) that are referred to as "precautionary" (Table 2). They are based on what I refer to as an exclusion principal; that is:

A low but technically manageable level that excludes a wide range of exposures demonstrated as being biologically active in certain circumstances.

Table 2. Countries with a precautionary Standard for locations where children spend time (Approaches 3 and 4), year of implementation, and where specified zones to which they apply.

Year	Country	Max. $\mu\text{W}/\text{cm}^2$ (power density) or V/m (E-Field) (at 900 MHz except as specified)	Area it applies
1980	Poland	6 V/m; 10 $\mu\text{W}/\text{cm}^2$	
1996	Ukraine	3 V/m; 10 $\mu\text{W}/\text{cm}^2$	
2000	Salzburg	1 $\mu\text{W}/\text{cm}^2$	
	Switzerland	4 V/m	Sensitive areas, e.g., playgrounds
	THB, Canada	4.5 $\mu\text{W}/\text{cm}^2$	Areas accessible to public
2001	Turkey	15 V/m; 250 $\mu\text{W}/\text{cm}^2$	
2003	Italy	6 V/m; 10 $\mu\text{W}/\text{cm}^2$	Precautionary
2004	Paris	1-10 $\mu\text{W}/\text{cm}^2$	
2005	Peru	30 V/m (2 GHz)	Sensitive sites inc. schools
	Monaco	6 V/m; 10 $\mu\text{W}/\text{cm}^2$	
	Lithuania	1 $\mu\text{W}/\text{cm}^2$	Work & living places (special restriction in child zones and school internet rooms)
2006	Greece	600 $\mu\text{W}/\text{cm}^2$	<300 m of "Child" zone perimeters
2008	Slovenia	6 V/m; 10 $\mu\text{W}/\text{cm}^2$	Sensitive areas, e.g., school, day care, playgrounds, housing
2009	Brazil (regional)	6 V/m; 10 $\mu\text{W}/\text{cm}^2$	
	Israel	4 V/m	
	Spain (Plenum)		ALARA in sensitive/child zones
2010	Brussels reg., Belgium	3 V/m	All accessible places
	Wallonia reg., Belgium	3 V/m per antenna	All residential areas
	Flanders reg., Belgium	3 V/m	Sensitive areas, e.g., schools
2011	Bulgaria	10 $\mu\text{W}/\text{cm}^2$	Zones
2012	India	10 $\mu\text{W}/\text{cm}^2$	All base stations
	Luxembourg	3 V/m per antenna	Extended human presence areas
	Greece	450 $\mu\text{W}/\text{cm}^2$	Existing base stations <300 m of school perimeter. New BS at pre/school perimeter banned

Sources include WHO International EMF project, listed representatives, EC Report (European Commission, May 2008).

As the exposure circumstances under which biological effects begin to occur are still being investigated, this approach is usually based on a fixed percentage of the ICNIRP guidelines. Typically, this is 1% of the reference level (Figure 1).

More than 20 countries, regions, or cities take a precautionary approach to RF-EMF exposure to all members of the community. The countries are shown in Table 1. Regions include Plenum and Catalonia in Spain; Brussels, Wallonia and Flanders in Belgium; various regions in Brazil; and the city state of Monaco and the Principality of Liechtenstein. Cities include Paris, Salzburg, and Toronto Health Board.

Almost all countries following Approaches 2–5 also issue formal advice for children to reduce the exposure to RF-EMF, and/or have specific advice or regulations (Table 3).

Approach 5

The Russian Federation, China, and Poland have RF-EMF exposure guidelines that address acute thermal and chronic “non-thermal” effects, based on scientific research conducted in those countries. That is, they are not “precautionary” but scientifically based.

The Russian Reference levels take account of epidemiological and experimental findings over the last 60 years and are based on real conditions faced by the population (Grigoriev, 2008). This includes consideration of processes of adaptation under chronic influence of RF-EMF exposure



Figure 1. An infant fluent at scrolling, selecting a game, playing, and closing it. © Photo: M Redmayne.

(Grigoriev, 2008). Fundamentally, the Russian Standards have the requirement that “EMF exposure should not affect homeostasis or activate protective and adaptation-compensatory mechanisms either acutely or in the long term” (Grigoriev, cited by Gajšek et al., 2002)).

The Russian Federation advises that those under the age of 18 should not use a mobile phone at all; recommends low-emission phones; and requires the following: on-device labelling notifying users that it is a source of RF-EMF, user guide information advising that “it is a source of harmful RF-EMF exposure” (p. 4), and the inclusion of courses in schools regarding mobile phones use and RF-EMF exposure issues (RNCNIRP, 2011). The advisory committee has issued strong research-based warnings about anticipated short- and long-term health implications from not doing so (RNCNIRP, 2008).

Regulations and policy advice to protect children

Nations that take one of the approaches 2–5, above, also have policies that provide advice (or law) intended to reduce children's RF-EMF exposure (Table 3). Most of this advice refers to personal exposure, although WiFi routers are included.

Introduction of such policies is sometimes included in the International EMF Project annual country reports. The project has 51 registered countries. In 2012–2013, half of the countries filed reports; of these, 35% (9) included a new law or advice regarding children: Israel, Finland, Belgium, Bulgaria, India, Australia, Tunisia, Malaysia, and Switzerland. The first six of these were towards precaution, while the last three did not quite fall in this category. Australia, India, and Finland recommended that children's exposure should be limited, with advice or encouragement to be given by parents (this was also recommended by Health Canada in 2009). India also reported on their new Standard, which is one-tenth of the ICNIRP guidelines recommendation.

Tunisia implemented a seminar for health, education, and child protection professional to promote knowledge of RF exposure and address concerns. Malaysia produced a brochure about the precautionary principle and how to reduce exposure, concluding that “parents and your people should therefore decide on their usage”. Switzerland reported on developing

Table 3. Most common international RF-EMF related advisory policies for children.

Policy advice/law	Country/city/organisation/committee
Take steps to minimise RF-EMF exposure ^a	Denmark, Finland, France ^b , Germany, India, Israel, Switzerland, Turkey; Toronto Health Canada; ICEMS, EEA, European Parliament, BioInitiative Group ^c
Ban mobile phone advertising	Belgium ^b , France, Russia; CEHAPE, ICEMS
Have SAR labelling (on device, packaging, point of sale)	Belgium ^b , France ^b , India, Israel, South Korea, Russia
Ban sale of children's mobile phones	Belgium ^b , France, Israel
Prefer wired over WiFi/WLAN in schools and/or pre-schools	Austria, Bavaria, France, Israel ^b , Switzerland, Germany, Russia; Frankfurt, Salzburg; Council of Europe
Children not to use mobile phone except in emergencies	Austria (check), France, Russia; San Francisco, Toronto (< ^b)
Use headset for calls	Finland, Germany, India, Israel
Have an education programme (schools/education professionals)	Russia, Tunisia, Turkey; CEHAPE

^aFor mobile phones these generally include: increase distance/use hands free, wired headset or speaker phone, use a wired landline, use texting rather than calling, avoid use in a moving vehicle.

^bInternational EMF Project reports 2012–2014.

^cAll items in this list are recommended by the BioInitiative Group (2012).

Table 4. NGO advisory and independent expert advice re children and RF-EMF exposure.

No comment OR Advise no precaution is necessary if ICNIRP or IEEE guidelines are adhered to	Advise precautionary steps and year of most recent published advice
SCENIHR (Scientific Committee on Emerging and newly Identified Health Risks, European Commission) (SCENIHR, 2009)	Children's Environment and Health Action Plan for Europe (PECCM, 2013)
Health Council of the Netherlands (2011)	Russian National Committee of Non-Ionizing Radiation (RNCNIRP, 2011)
Nordic Radiation Safety Authorities (2013)	Advisory Group on Non-Ionising Radiation, UK (Public Health England, 2013)
	Australian Radiation Protection and Nuclear Safety Agency (ARPANSA, 2013)
	Swedish Radiation Safety Authority (SSM, 2013)
	French agency for Food, Environmental and Occupational Health & Safety (ANSES, 2013)
	Finland Radiation and Nuclear Safety Authority (STUK) (Heitnanan & Jokela, 2013)
	Bio-Initiative Group (2012)
	ICEMS (International Commission for Electromagnetic Safety) 51 publishing research scientists, Porto Alegre Resolution (2009)
	Environmental Health Trust (US) (2014)
	Parliamentary Assembly of the Council of Europe, Resolution 1815 (PACE, 2011)

new brochures, and said that lack of knowledge justifies use of low-emission phones, especially for children and adolescents.

In the International EMF Project 2013–2014 round, only 29% of registered countries had returned a report as of October 2014. Of these, six European countries reported on a new law or policy regarding children: Austria, Belgium, Finland, France, Israel, and Bulgaria.

Some of the recommendations appear in Table 3. Some others follow. Israel is in the midst of proceedings to ban WiFi in schools. The Supreme Court in Israel gave an interim decision indicating that the government needed to provide good reason why it could not remove WiFi from all schools. It then decided a further hearing is required before it can make that a permanent decision. This had not occurred at the time of writing. Belgium has brought in a limit of 3 V/m (at 900 MHz) for antennas in certain locations such as indoors, schools, and playground. The Ghent region has also banned WiFi in spaces catering for children age 0–3 years. France has also passed a draft law requiring child-specific headsets, and turning off WiFi (further detail not given), and banning all publicity of any wireless devices aimed at <14 year olds; this is still to go through National Assembly and Senate. As of February 2014, WiFi equipment was banned in French nurseries and daycare facilities.

Only Bulgaria's was, technically, towards less precaution; the country has had a Standard review in process for some years that contained a recommendation to reduce child-sensitive sites to a maximum of 1 $\mu\text{W}/\text{cm}^2$. That recommendation was decided against and the exposure limit remains at 10 $\mu\text{W}/\text{cm}^2$, the normal precautionary maximum elsewhere.

France has been more proactive than many countries with legislation. In 2010, the National Assembly passed a law with several requirements including banning advertising to under 14-year olds, compulsory SAR labeling along with possible risks of excessive use, and an exposure-reduction device with all phones sold (e.g., headset) (Assemblée Nationale de France, 2010). The Minister of Health may prohibit distribution (free or for payment) of items containing radio equipment

which are aimed at under 6-year-olds, and schools/colleges may legally ban use of mobile phones during teaching activities.

Other recent policies include steps in late 2012 by India to remove mobile towers from education institution, hospital and playgrounds (Sharma, 2012). Turkey has reported that it is currently developing regulations to prohibit mobile phone use by children under 14 years.

Advice from other sources

The other category of advice considered in this review is a sampling of that from Governmental scientific advisory bodies; independent, professional bodies composed of scientists with peer-reviewed publications in the field of RF-EMF; and individual research scientists in the fields of RF-EMF exposure effects (Table 4).

Some advisory bodies, such as those for the Nordic countries, consider that there are no risks related to exposures that comply with the ICNIRP or IEEE guidelines. A formal statement from the Nordic radiation safety authorities specifically states that, "since exposure of the general public, including children, to radio waves. . . is far below the exposure limits, there is no need to further limit exposure" (Danish Health and Medicines Authority, Swedish radiation Safety Authority, Norwegian Radiation Protection Authority, Iceland Radiation Safety Authority, & Finland Radiation and Nuclear Safety Authority, 2013).

Qualifiers to such statements are sometimes added, and in some cases counter-advice that exposure from mobile phones should be reduced, partly due to a lack of studies involving children and partly as a precaution. This applies to the Swedish webpage that provides the link to the Nordic statement (Swedish Radiation Safety Authority, 2013) and also to the annual report to the WHO EMF Project that year which reports that STUK advises restricting mobile phone use by children (Heitnanan & Jokela, 2013).

In 2007, Germany published a report on the country's implementation of the WHO Children's Environment and Health Action Plan for Europe (CEHAPE) (Federal Ministry

of Health and Federal Ministry for the Environment and Nature Conservation and Nuclear Safety, 2007). They report that in Germany there was a 2003 brochure for adolescents on how mobile phones work, with guidance on avoiding their radiation. By 2006, teaching material had been supplied to German schools for use with children in year 5 and above, “as they need early background information on aspects related to radiation protection” p. 58.

Austrian parents have been strongly advised by the Federal Ministry for Health to tell their children how to minimize their RF-EMF exposure (Stöger, 2014). The latest French Agency for Food, Environmental and Occupational Health & Safety (ANSES) report contained several recommendations such as SAR labelling on all devices used near the body, including baby monitors (Merckel and Paul, 2014).

The International Commission for Electromagnetic Safety (ICEMS) was established in 2003 by a body of deeply concerned scientists working in this field. Its purpose is “to promote research to protect public health from electromagnetic fields and to develop the scientific basis and strategies for assessment, prevention, management and communication of risk, based on the precautionary principle” (International Commission for ElectroMagnetic Safety, 2003). Members of the Commission are signatories to a series of resolutions with each new one expressing greater concern about guidelines that only guard against thermal effects of radiofrequencies. The two most recent are the Venice Resolution of 2008 (International Commission for ElectroMagnetic Safety, 2008) and the Porto Alegre Resolution the next year (International Commission for ElectroMagnetic Safety, 2009). The Venice Resolution, which had 55 scientist signatories, strongly advised children and teenagers to limit their use of wireless phones and similar devices. The Porto Alegre signatories (69 scientists) agreed that children under 16 years should only use cell or cordless phones for emergency calls.

The Environmental Health Trust has placed a focus on education, running several campaigns to inform the public and young people about RF-EMF exposure and how to minimize their exposure.

The strongest voices for reducing children's RF-EMF exposure have come from the RNCNIRP and the BioInitiative Group. In 2008, the RNCNIRP published a report entitled, “Children and mobile phones: the health of the following generations is in danger” (RNCNIRP, 2008). The document lists health hazards that the scientific advisory committee regards as likely for the nearest future and others that are expected/possible for the future. The former includes several cognitive, learning and mood problems, increased sensitivity to stress, and increase epileptic readiness. The latter includes brain tumors, Alzheimer's disease and other types of degeneration of the central nervous system. The statement finishes by emphasizing the urgency to defend children's health.

The BioInitiative Group has published two reports (BioInitiative Working Group, 2007, 2012) stating the case for biologically based exposure standards for low-intensity electromagnetic radiation. It does this by presenting research evidence that has indicated effects due to EMF exposure. Special concern is voiced for, “the care of the fetus and newborn, the care for children with learning disabilities, and consideration of people under protections of the Americans

With Disabilities Act, which includes people who have become sensitized and physiologically intolerant of chronic exposures” (p. 3). This very substantial review document concludes by expressing concern for children and the potential damage they face from the beginning from in-crib devices (pp. 55–57). A broad range of specific precautionary steps are recommended (pp. 58–59).

Discussion

Clearly, there is a wide range of approaches to both exposure Standards and advisory policy regarding children's exposure to RF-EMF. This, at least in part, reflects different interpretations of the research, different definitions of words such as “health”, different criteria for including studies in reviews, and different approaches to public health and safety, as well as political, industry, and financial influences.

Exposure standards

Despite infants and young children being included as “a general variable” in the ICNIRP guidelines (ICNIRP 1998), a 2002 ICNIRP publication stated, “Different groups in a population may have differences in their ability to tolerate a particular NIR [non-ionizing radiation] exposure. For example, children...[I]t may be useful or necessary to develop separate guideline levels for different groups within the general population” (ICNIRP, 2002).

The 50 × safety margin is based on the output at which (under specified conditions) there is a whole body increase of 1 °C over 30 min (4 W/kg), and set accordingly at 0.08 W/kg for the public, including children. Whole body heating of 1 °C over 30 min is almost impossible to achieve from public exposure in permitted areas and using it as an endpoint for establishing basic restrictions was ridiculed by an invited speaker at a 2014 ICNIRP meeting (personal communication, comment during presentation by Vitas Anderson, ICNIRP meeting, Wollongong, 11 September 2014). Further, there is no mention in the guidelines as to how the ICNIRP calculated the basic restrictions for head and body, or for limbs, which are considerably higher, at 2 W/kg and 4 W/kg, respectively. It is, therefore, impossible to know what safety margin applies to these exposures. Extremities and the brain will cool more rapidly than the body's core temperature, since the extremities are exposed and the brain has a high blood circulation, but what of the abdomen? Do the much more lenient exposure limits that apply to these body parts really protect children and adolescents even from short-term thermally related exposure damage resulting from extended use of a laptop against the abdomen; a smartphone in the hand or pocket while it is operating at full power due to ongoing updates from apps.; or a cordless or mobile phone against the head?

The issue of whether children's RF-EMF exposure is of concern revolves around core beliefs about whether “non-thermal” exposures can cause any effects, and fundamental definitions of a “health effect”. Are health effects those which are short-term, well-understood physiological responses, or do they include poorly understood, but repeatedly demonstrated, changes in homeostasis or activated protective and adaptation-compensatory mechanisms effects? Those following the first tend to explain away positive

findings as poorly conducted studies, as with Feychting (Redmayne, 2014), while those following the latter acknowledge that effects have been observed but are not understood. This is a generalization.

Time-averaged exposure is the only consideration for the thermally based Standard. Spikes in energy output are, thus, smoothed out and considered of no import. In 4G transmissions, for instance, energy spikes of up to 10 dB resulting from the modulation protocol are not considered. Similarly, a 10 Hz WiFi beacon signal, present when active but not in use, averages out to a fraction of a percent of the permitted exposure; the fact that there is a chronic pulsed signal at a frequency also used by the central nervous system is treated as irrelevant. Could it be that in some cases the brain interprets it in a similar way to a strobe light?

If such energy spikes affect homeostasis or activate protective and adaptation-compensatory mechanisms, the Russian Federation and China's approach means that their policy approach will address it.

Advisory policy

There is a divide in advice which also depends on basic premises. Those nations following Approach 1 in this paper, generally state that no particular precautions are necessary for children, while many to most of those taking the remaining approaches issue a range of precautionary advice.

There is a policy gap regarding advice about using RF-EMF devices against the body. Tablets and similar devices have usually been tested for compliance at 20 cm, which is referred to in user-manuals as a “standard operating position”. However, for many people, the standard operating position of tablets, laptops, and even smartphones is on the lap against the abdomen or stomach area.

Some countries have more recently developed or adopted policy that requires only 2 cm or no gap during testing. When this is not the case, devices may expose reproductive organs and the growth plate in the femur to levels of RF-EMF that may well not comply. Even with compliance, the abdominal area is being exposed to low-levels of pulsed RF-EMF, and precautionary advice and labelling to use devices away from the body is warranted.

Conclusion

The situation is fluid as policy changes occur frequently. From one perspective, this is reasonable as common exposure sources and protocols, and “typical” use, also change rapidly. The rapid changes in exposure types (e.g. modulation or carrier frequency) means there has generally been no research examining either long- or short-term effects from permitted exposures to new transmission protocols. This suggests that there is merit in recommending minimizing RF-EMF exposure.

The wide range of policy approaches can be confusing to parents and educational facilities wanting to know what to do for the best for their children. It would be helpful if some consensus among advisory organizations could be reached whereby there was acknowledgement that, despite extensive research, the highly complex nature of both RF-EMF and the human body, and the frequent updates in technology, means

that simple assurance of safety over a long period for the wide range of endpoints researched, as well as the many that are not researched, cannot be guaranteed. Therefore, parents are advised to minimize their children's exposure to RF-EMF as a precautionary step. This does not need to be alarming, nor does it assume health and well-being will suffer following RF-EMF exposure, but rather can mirror the everyday recommended precautions taken daily, such as washing fruit before eating it and keeping out of the midday sun or using sunblock.

The following simple steps are suggested. First, when using the internet or communicating with someone, keep the device away from the body by at least 20 cm (based on testing protocols used for many devices such as laptops); second, when using devices offline, put them in flight mode as this prevents them transmitting RF-EMF signals to the base station or router; third, turn equipment including WiFi routers off at night and have no transmitting devices in the bedroom.

Finally, the ICNIRP guidelines on which so many countries rely need to urgently publish how the head, torso, and limbs exposure limits were calculated and what safety margin was applied to them. This omission in the guidelines appears to have been entirely overlooked to date despite these exposures being the most relevant. This oversight needs addressing urgently as age and duration of use, and parts of the body closest to antennae, have changed so dramatically since the guidelines were published.

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