Radiofrequency Exposure and Human Health

J. A. Elder, C-K. Chou, and J. J. Morrissey

Motorola Labs, 8000 W. Sunrise Blvd., Ft. Lauderdale, FL 33322, USA

Abstract—Research on the biological and health effects of radiofrequency (RF) fields has been conducted for more than 50 years and the RF database available in the 1990's proved adequate for the development of the human exposure limits recommended in 1998 by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) [1]. The ICNIRP guidelines are recommended by the World Health Organization (WHO) and have been adopted by more than 35 countries. The database that led to the development of the ICNIRP guidelines has grown, with about 500 studies at mobile phone frequencies including many modulated signals. The WHO database [2] has more than 1500 original, peer-reviewed papers useful for public health risk assessment of RF exposure. The database provides even stronger evidence today that RF exposures within ICNIRP limits associated with mobile telephony pose no known health risks and warrant no special precautions for any segments of the population. WHO has stated that scientific knowledge on electromagnetic fields including RF fields is now more extensive than for most chemicals [3]. Expert scientific organizations, international organizations and government agencies that have reviewed the available database since the publication of the ICNIRP guidelines include the UK Independent Expert Group on Mobile Phones (Stewart Report) (2000); German Commission on Radiological Protection (2001); Australian Communications Authority (2003); French Environmental Health and Safety Agency (2003); Swedish Radiation Protection Authority (2003), Health Council of the Netherlands (2004); UK Advisory Group on Non-Ionising Radiation (2004), UK National Radiological Protection Board (2004); US Food and Drug Administration (2005); and the World Health Organization (2005, 2006). All of these reviews have consistently concluded that there is no credible or convincing evidence that RF exposure within ICNIRP limits causes adverse human health effects. This paper describes a) the extensive database on the biological and health effects of exposure to RF energy, b) the ICNIRP RF safety guidelines, and c) recent conclusions of national and international expert groups that have evaluated the scientific and medical evidence on the potential health effects of RF exposure.

DOI: 10.2529/PIERS060906133215

1. RADIOFREQUENCY (RF) DATABASE

The WHO database [2] on biological and health effects of RF energy is extensive. It has more than 2500 scientific items from countries around the world. In addition to reviews, engineering studies and non-peer-reviewed articles, the database has more than 1500 peer-reviewed papers that satisfy criteria for use as a basis to assess the possible public health impacts of RF exposure (see Table 1). The first table shows the number of ongoing, reported-but-not-published research and published entries in the database for each of the following types of scientific studies on RF fields: epidemiological, human, animal, and cellular studies. The WHO database is unique in that it includes summaries of published papers and summaries of ongoing and reported-but-not-published research.

Although all peer-reviewed studies in the RF database (Table 1) are considered relevant to the mobile phone issue, it is of interest to note the large number of studies using radiofrequencies specific to mobile telephony as shown in Table 2. In this table, the number of studies in each of the four types of scientific investigations is shown. There are 749 entries listed in the database using mobile telephony-specific signals and 484 of these have been published. The RF database is available to the public on the WHO website shown in Tables 1 and 2.

The accepted process of evaluating any chemical or physical agent for their potential for causing human health effects can be described as follows. Such assessments place emphasis on human data (epidemiology and other human studies) but also rely on animal data, particularly long-term exposure studies, when human data are weak or nonexistent. In vitro data are only used as supportive evidence of a mechanism if evidence exists in vivo. A recent paper describing a pooled analysis of 12 epidemiology publications investigating tumors in mobile phone users [4] found no association between RF exposure and cancer. This review included papers from several laboratories
involved in the INTERPHONE Project, a large multi-centre case-control study of head and neck
tumors in mobile phone users directed by the International Agency for Research on Cancer (IARC).
At the time of writing this paper, a draft manuscript describing the results from all studies from the
13 countries in the INTERPHONE Project is being finalized and the pooled analysis is expected
to be published in 2007.

The weight of scientific evidence\(^1\) from the available epidemiological studies indicates no adverse
health effects and this conclusion is strongly supported by results from animal cancer studies;
many of these studies have well-defined RF exposure data useful for risk analysis. There are
37 animal cancer studies in the database and the majority were published in the past 10 years.
These papers have considerably strengthened the RF database because a number of these studies
employed experimental protocols similar to those used by the U.S. National Toxicology Program
to determine the carcinogenic potential of chemical and physical agents. The weight of evidence
of these animal studies, including studies in which animals were exposed daily throughout their
lifetimes, supports the conclusion that RF exposure does not cause or promote tumor formation
\([5–7]\). RF exposure durations have ranged from 2–22 hours per day up to two years, exposure
levels in these studies have ranged up to 4 W/kg, and exposure frequencies have ranged from about
400 to 9000 MHz, including a number of studies at radiofrequencies specific to mobile telephony
(e.g., 900 and 1800 MHz). In addition, the weight of scientific evidence of the animal cancer studies
indicates no effect on survival or body weight at exposure levels less than 4 W/kg, which is regarded
as the exposure threshold for adverse effects in animals. These results provide strong evidence that
RF exposure does not cause life shortening diseases or general toxicity at exposure levels within
ICNIRP limits which are set well below the adverse effect threshold of 4 W/kg \([6]\).

Table 1: Biological and health effect studies of RF exposure in the WHO database.

\(\text{Studies listed on WHO website under citation listings:}\)
\(\text{http://www.who.int/peh-emf/research/database/en/}\)

<table>
<thead>
<tr>
<th>Research Study Type</th>
<th>Ongoing</th>
<th>Reported but not Published</th>
<th>Peer-reviewed Publications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Epidemiology</td>
<td>44</td>
<td>9</td>
<td>233</td>
</tr>
<tr>
<td>Human Studies</td>
<td>64</td>
<td>17</td>
<td>170</td>
</tr>
<tr>
<td>Animal Studies</td>
<td>49</td>
<td>30</td>
<td>722</td>
</tr>
<tr>
<td>Cellular Studies</td>
<td>64</td>
<td>31</td>
<td>401</td>
</tr>
<tr>
<td><strong>Totals</strong></td>
<td><strong>221</strong></td>
<td><strong>87</strong></td>
<td><strong>1526</strong></td>
</tr>
</tbody>
</table>

Table 2: Mobile telephony relevant studies in the WHO database.

\(\text{These studies are listed on WHO website:}\) \(\text{http://www.who.int/peh-emf/research/database/en/}\)

<table>
<thead>
<tr>
<th>Research Study Type</th>
<th>Ongoing</th>
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<th>Peer-reviewed Publications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Epidemiology</td>
<td>38</td>
<td>7</td>
<td>78</td>
</tr>
<tr>
<td>Human Studies</td>
<td>60</td>
<td>16</td>
<td>107</td>
</tr>
<tr>
<td>Animal Studies</td>
<td>43</td>
<td>20</td>
<td>181</td>
</tr>
<tr>
<td>Cellular Studies</td>
<td>55</td>
<td>26</td>
<td>118</td>
</tr>
<tr>
<td><strong>Totals</strong></td>
<td><strong>196</strong></td>
<td><strong>69</strong></td>
<td><strong>484</strong></td>
</tr>
</tbody>
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Some reports have suggested that biological effects are frequency specific and are associated with
low-frequency modulations of the RF signal. The studies in the extensive RF database use a wide
range of frequencies and include many modulations characteristic of mobile telephony and other

\(^1\)Weight of scientific evidence is the outcome of assessing the published information about the biological and health effects
from exposure to RF energy. This process includes evaluation of the quality of test methods, the size and power of the study
designs, the consistency of results across studies, and the biological plausibility of dose-response relationships and statistical
associations (see page 12 in \([9]\) )
signals. The weight of scientific evidence shows no frequency-dependent or modulation-dependent response suggestive of adverse health effects. This statement is supportive of the scientific consensus that all established adverse health effects are thermal effects.

Much of the peer-reviewed literature has been summarized in eleven review papers published in a Special Issue of Bioelectromagnetics in December 2003 [8]. These reviews cover epidemiology, cancer, survival, central nervous system, behavioral and cognitive effects, thermoregulation, ocular effects, auditory responses, teratogenesis, effects on blood cells and functions of the cardiac, endocrine and immune systems and in vitro studies on mammalian cell toxicity, genotoxicity and cellular transformation, i.e., cancer-related changes. All of these reviews are available to the public and can be downloaded from the Wiley Interscience website (http://www3.interscience.wiley.com/cgi-bin/jhome/34135) [Open website, click on “Issues” and then click on Bioelectromagnetics, Volume 24, Supplement 6(S6), December 2003.] The publication of the recently revised IEEE C95.1-2005 RF safety standard [9] includes a comprehensive review of more than 1300 primary peer reviewed papers on RF biological effects. Overall, the reviews published in 2003 in Bioelectromagnetics [8] and the IEEE review [9] support the conclusion that the only adverse effects of RF exposure are thermal effects and the adverse effect threshold level is 4 W/kg, the basis for both the IEEE C95.1-2005 standard [9] and the ICNIRP guidelines [1].

2. THE ICNIRP GUIDELINES

The process for developing an RF exposure guideline requires a review of all available scientific evidence on the subject, including papers describing thermal and non-thermal effects, short-term and long-term exposures, cancer and other biological and health endpoints, and epidemiological and other human studies. The purpose of the review includes identification of all established adverse health effects and identification of the threshold exposure level causing the effect. The RF database available in the 1990’s proved adequate for the development of the human exposure limits recommended in 1998 by ICNIRP [1]. There is broad scientific consensus that RF exposure at high levels can cause adverse health effects due to a significant increase in temperature of body tissues or in the whole body. This consensus provides a reliable baseline for the development of exposure limits that protect all segments of the population from established adverse effects.

The ICNIRP guidelines are based on established adverse effects of RF exposure and the only replicated adverse effects are caused by RF heating (thermal effects). These effects are well-understood and exhibit a clear RF exposure threshold level. Adherence to the ICNIRP exposure guidelines ensures RF exposure levels remain below this tissue heating threshold. The ICNIRP guidelines [1] are recommended by the World Health Organization and have been adopted by more than 35 countries.

Recently, WHO summarized important points in the ICNIRP guidelines concerning the magnitude of safety factors and the protection provided to people of all ages as follows: “The ICNIRP guidelines were developed to limit human exposure to electromagnetic fields (EMF) under conditions of maximum absorption of the fields, which rarely occurs, and the limits incorporate large safety factors to protect workers and even larger safety factors to protect the general public, including children. Thus, the limits in the ICNIRP guidelines are highly protective and are based on all the available scientific evidence” [10].

3. EXPERT REVIEWS

Many national and international expert groups have evaluated the evidence on the potential health and biological effects of RF fields and have been consistent in their conclusions that RF exposures within the ICNIRP limits pose no known health risks. This section is a compilation of the conclusions of expert groups over the past 6 years regarding the ICNIRP guidelines, mobile phones and base stations.

The report by the Independent Expert Group on Mobile Phones [11] in the United Kingdom (UK), commonly know as the Stewart Commission, concluded that “the balance of evidence to date suggests that exposures to RF radiation below NRPB and ICNIRP [International Commission on Non-Ionising Radiation Protection] guidelines do not cause adverse health effects to the general population.”

In Germany, the Commission on Radiological Protection (SSK) [12] issued the following statement: “the SSK concludes that even after assessing the recent scientific literature, there are no new scientific findings with respect to proven adverse impact on health that give rise to doubts
regarding the scientific assessment underlying the protective concepts of ICNIRP or the European Council Recommendation.”

The French Environmental Health and Safety Agency (AFSSE) [13] concluded that “the general analysis of current scientific data on exposure to base station waves shows no health risk linked to mobile phone base stations.”

With specific reference to health aspects of third generation (3G) phones, the Australian Communications Authority (ACA) [14] concluded: “The weight of national and international scientific opinion is that there is no substantiated evidence that exposure to low level radiofrequency EME causes adverse health effects. This view has been backed by every major review panel . . .”

The independent UK Advisory Group on Non-Ionising Radiation (AGNIR) [15] examined recent experimental and epidemiological evidence for health effects due to exposure to RF transmissions, including those associated with mobile telephone handsets and base stations. This review focused on the scientific data made available since the publication of the IEGMP report in 2000 mentioned above. In their 2004 report, the AGNIR concluded: “In aggregate the research published since the IEGMP report does not give cause for concern. The weight of evidence now available does not suggest that there are adverse health effects from exposures to RF fields below guideline levels, but the published research on RF exposures and health has limitations, and mobile phones have only been in widespread use for a relatively short time.”

Also in 2004, the Electromagnetic Fields Committee of the Health Council of the Netherlands (HCN) [16] expressed its support for the ICNIRP limits and concluded that “no health problems can be expected to occur as a direct result of exposure to those fields. Furthermore, the Committee feels that there are no health-based reasons for limiting the use of mobile phones by children.”

The 2004 review by the UK National Radiological Protection Board (NRPB) [17] was an update of both the above mentioned AGNIR review and the May 2000 report from the IEGMP (as known as the Stewart Report). The NRPB advice stated: “Since then, the widespread development in the use of mobile phones world-wide has not been accompanied by associated clearly established increases in adverse health effects. Within the UK, there is a lack of hard information showing that the mobile phone systems in use are damaging to health. It is important to emphasis this crucial point.”

In response to the NRPB report, the US Food and Drug Administration (FDA) [18] released the following statement: “FDA agrees with the NRPB on its conclusions that there is ‘no hard evidence of adverse health effects on the general public’ from exposure to radiofrequency energy while using wireless communication devices . . . With regards to the safety and use of cell phones by children, the scientific evidence does not show a danger to users of wireless communication devices including children.”

More recently, WHO issued a clarification statement on children and mobile phones reading in part as follows: “In 2000 WHO issued a fact sheet (#193) on Mobile Phones and their Base Stations. In the section under ‘Precautionary measures’ it states ‘Present scientific evidence does not indicate the need for any special precautions for the use of mobile phones. If individuals are concerned, they might choose to limit their own or their children’s RF exposure by limiting the length of calls, or by using ‘hands-free’ devices to keep mobile phones away from the head and body. Not only is the information provided in this WHO fact sheet still valid, but the precautionary measures suggested are still those recommended by the International EMF Project. For further information readers are referred to: http://www.who.int/emf” [10].

At its annual symposium on Cell Phones and Cancer, the European Cancer Prevention Organization [19] developed a consensus statement including the conclusion that “The European Cancer Prevention Organization states that, in 2005 there is insufficient contemporary proof with regard to increased cancer risk to change mobile phoning habits.”

In summary, the current website of the World Health Organization [3,10] has the following statements:

“Despite extensive research, to date there is no evidence to conclude that exposure to low level electromagnetic fields is harmful to human health.”

“To date, all expert reviews on the health effects of exposure to RF fields have reached the same conclusion: There have been no adverse health consequences established from exposure to RF fields at levels below the international guidelines on exposure limits published by the International Commission on Non-Ionizing Radiation Protection (ICNIRP, 1998).”
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