ICNIRP Statement

HEALTH ISSUES RELATED TO THE USE OF HAND-HELD RADIOTELEPHONES AND BASE TRANSMITTERS

International Commission on Non-Ionizing Radiation Protection*

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INTRODUCTION

THIS STATEMENT from the International Commission on Non-Ionizing Radiation Protection (ICNIRP) addresses the health issues related to the radiofrequency radiation emissions from hand-held radiotelephones and base transmitters.

ICNIRP has previously reviewed the published data on adverse health effects of exposure to radiofrequency radiation. This review was published by the World Health Organisation (WHO) (UNEP/WHO/IRPA 1993) and, together with further review of more recent scientific publications, forms the basis for this statement.

"Guidelines on limits of exposure to radiofrequency electromagnetic fields in the frequency range 100 kHz to 300 GHz" was published in 1988 by the predecessor of ICNIRP, the International Non-Ionizing Radiation Committee (INIRC) of the International Radiation Protection Association (IRPA). These guidelines included limits for both whole and partial body exposure in terms of specific absorption rate (SAR) and were intended to prevent the effects of whole body or localized heating. SAR is the power absorbed per unit mass (watt per kilogram, W kg^{-1}). The guidelines were not intended to apply to low power radio transceivers whose radiated power is less than 7 W.

Since the publication of these guidelines there has been a significant increase in the use of hand-held radiotelephones, together with an extension of the coverage of reception areas with more fixed base transmitters, often sited in residential areas. This has led to concerns being expressed about risks to health, and in particular about cancer, from the emissions of such telephones and their base stations. The adequacy of current protection limits has also been questioned.

Following the extensive review of the health effects of RF exposure conducted in conjunction with WHO (UNEP/WHO/IRPA 1993), ICNIRP is formulating guidelines on exposure limits.

The frequency range of emissions of most hand-held radiotelephones is from about 800 MHz to 2 GHz. However, it is likely that further technological developments will lead to the use of higher frequencies.

TECHNICAL CHARACTERISTICS

Hand-held radiotelephone systems involve communication between mobile handsets and fixed base transmitters that provide coverage of specific areas (cells). In the mid 1980's a first generation of analogue radiotelephone systems was introduced using frequencies less than 1 GHz. In the absence of a global standard different systems have appeared. Analogue systems are in widespread use throughout the world and are expected to remain in existence until early in the next century when gradual replacement by digital systems will be complete.

Digital systems are based upon the harmonized European standard known as GSM, named after the Group Spéciale Mobile, which originally drafted its specification. The initial frequency allocation for GSM is adjacent to that of the analogue system to allow the frequency spectrum to be gradually transferred as demand shifts from analogue to digital. A further set of digital communications systems, known as Personal Communication Network (PCN), is based on the GSM standard. One such system is known as DCS1800 and operates within a band of frequencies spread around 1.8 GHz. Each 25 kHz channel of the analogue system carries one call; however, the digital systems use the Time Division Multiple Access (TDMA) scheme to carry up to eight calls per 200 kHz channel.

Packets of information, known as bursts, are transmitted to and from each mobile base station in the appropriate time slots. An important feature of mobile communication systems is adaptive power control. This

*At the 8th International Congress of the International Radiation Protection Association (Montreal, 18–22 May, 1992), the IRPA established a new independent scientific organization, the International Commission on Non-Ionizing Radiation Protection (ICNIRP), as a continuation of the former IRPA/International Non-Ionizing Radiation Committee (IRPA/INIRC). The functions of the Commission are to investigate non-ionizing radiation (NIR) hazards, develop international guidelines on limiting exposure to NIR and to deal with all aspects of NIR protection. During the preparation of this statement, the composition of the Commission was as follows: M. H. Repacholi, Chairman (Australia), M. Grandolfo, Vice-chairman (Italy), A. Ahlbom (Sweden), U. Bergqvist (Sweden), J. H. Bernhardt (Germany), J. P. Césarini (France), L. A. Court (France), A. F. McKinlay (UK), D. H. Sliney (USA), J. A. J. Stolwijk (USA), M. L. Swicord (USA), L. D. Szabo (Hungary), T. S. Tenforde (USA), H. P. Jammet, Chairman-emeritus (France), R. Matthes, Scientific Secretary (Germany). ICNIRP Secretariat, c/o Dipl.-Ing. R. Matthes, Bundesamt für Strahlenschutz, Institut für Strahlenhygiene, Ingolstädter Landstraße 1, D-85764 Oberschleißheim, Germany.

0017-9078/96/$3.00/0

is used to ensure that communications are carried out with an adequate signal to noise ratio but not with unnecessarily high power which would interfere with calls in adjacent signal areas and thus reduce the capacity of the network. For the purpose of exposure calculations, it is necessary to assume that the radiated power is equal to the maximum possible, although this is never likely to be the case.

Handsets are small compact transceivers which are normally held against the head while a call is made. Their signal radiating and receiving structure is normally a monopole antenna, or occasionally a sleeve dipole antenna, mounted on a metal box. The head of the user is in the near field of the source because the distance from the antenna to the head is a few centimeters, which is of the same order of magnitude as the wavelength of the emitted radiation.

Base station transmitting antennas are formed from vertical arrays of collinear dipoles that are phased to give a very narrow vertical beamwidth, typically between 7 and 10 degrees. The arrays are often mounted in corner reflectors to give sector antennas with horizontal beamwidths of between 60 and 120 degrees. The antennas are most often mounted on buildings or on free standing towers at least 15 m high.

DOSIMETRY

For frequencies between 800 MHz and 2 GHz, established interactions with biological tissues are related to the rate of energy deposition per unit mass. The dosimetric quantity commonly used is specific absorption rate (SAR) expressed in the unit watt per kilogram (W kg^{-1}).

The antennas of hand-held radiotelephones presently in operation or under development operate near the head. Thus, localized RF exposure occurs within the head.

Base station transmitting antennas are a source of whole body exposure of people close to them. Typically, for base stations, the exposure distances from the transmitting antennas are greater than $2D^2/\lambda$, where D is the largest dimension of the antenna, and λ is the wavelength of the field. Under these conditions, the electric and magnetic field components vary inversely with distance from the antenna and the power density varies inversely as the square of the distance. This region is called the radiating far field. Under such exposure conditions, demonstration of compliance with basic limits of exposure can be made by comparison of the measured or calculated power density or electric or magnetic field strength with derived limits of power density or field strength.

In the case of hand-held radiotelephones, however, the exposure distance for the user is less than $2D^2/\lambda$, and the RF field contains significant reactive components that interact strongly with objects and with people. This may result in a localised pattern of absorption produced from the resulting anisotropic field. Demonstration of compliance with basic limits, which are formulated in terms of SAR, can be achieved through coupled head-antenna calculations of the spatial deposition of energy in the head, complemented by measurements of energy deposition in appropriate anatomical phantoms and comparison with recommended localized SAR basic limits.

Power absorption from the antenna of a hand-held radiotelephone is very inhomogeneous (Balzano et al. 1978a, b; Chatterjee et al. 1985; Fleming and Joyner 1992; Dimbylow 1993; Dimbylow and Mann 1994). SAR values in the head depend on the radiated power, frequency, antenna design, its position with respect to the head, and the mode of operation (duty cycle). The location of the antenna feed point in relation to the head is particularly important. Both calculations and experimental studies in tissue-equivalent phantoms have revealed that existing basic limits may be significantly exceeded when using a portable radio or radiotelephone emitting 7 W (e.g., Cleveland and Athey 1989; Kuster and Balzano 1992; Dimbylow 1993). Cleveland and Athey (1989) showed that portable radio transceivers would be capable of exceeding a local SAR of 8 W kg^{-1} averaged over 1 g mass of tissue (IEEE localized SAR limit, IEEE 1992), if the transceiver had an output power of 7 W and a 100% duty cycle. During normal use and typical powers of 1 to 2 W, 8 W kg^{-1} would not be exceeded. However, Dimbylow and Mann (1994), assuming an antenna to an adult head (eye) separation of 2 cm, have calculated that for a power of 7 W (100% duty cycle) the peak SAR in the head will be 33 W kg^{-1} averaged over 1 g mass for 900 MHz radiation and 54 W kg^{-1} for 1.8 GHz radiation. This implies that the IEEE basic limit of 8 W kg^{-1} averaged over 1 g mass will be exceeded for duty cycle weighted powers greater than 1.7 W for 900 MHz radiation and 1.0 W for 1.8 GHz radiation.

BIOLOGICAL EFFECTS

The scientific literature on the biological effects of RF fields (including microwaves) has been reviewed extensively (Saunders et al. 1991; NRPB 1992, 1993; UNEP/WHO/IRPA 1993). Although most data do not relate specifically to hand-held radiotelephone use, they do provide information relevant to a health risk assessment. In order to address questions raised by prolonged exposure to modulated radiofrequency transmission, or specific end points such as cancer, it is necessary to collect information from a wide range of experiments carried out on different biological systems exposed under various conditions. The relevance of these data to the exposure of people may, however, be limited due to differences in the coupling of the fields to the exposed objects and differences in the responses of different biological systems compared with those of humans.

Most of the established biological effects of exposure to RF fields are consistent with responses to induced heating, resulting in rises in tissue or body temperature of greater than 1°C (UNEP/WHO/IRPA 1993). Most studies examined end points other than cancer; many examined physiological and thermoregulatory responses, effects on behavior and on the induction of lens opacities (cataracts) and adverse reproductive outcome following acute exposure to relatively high levels of RF fields. Very few studies are relevant to the evaluation of RF exposure on the development of cancer in humans.

Cancer-related studies

The scientific evidence indicates that exposure to RF fields is not mutagenic and is therefore unlikely to act as an initiator of carcinogenesis (IEEE 1992; NRPB 1992; Cridland 1993; UNEP/WHO/IRPA 1993). For example, a number of *in vitro* studies have reported a lack of RF-induced DNA damage (e.g., Hamrick 1973); positive effects have been attributed to the presence of Cu^+ ions (Sagripanti et al. 1987). A lack of effect of RF exposure has also been reported on mutation frequency in yeast (Dardalhon et al. 1981, 1985) and mouse leukaemia cells (Meltz et al. 1989) and on chromosome aberration frequency in human lymphocytes (Lloyd et al. 1984, 1986). In two rodent studies, there is the suggestion that RF fields may affect DNA directly (Sarkar et al. 1994; Lai and Singh 1995). When mice were exposed to 2.45 GHz fields at 10 W m^{-2} (SAR 1.18 W kg^{-1}) for 2 h d^{-1} for 120, 150, and 200 d, there was an indication of structural genomic rearrangement in brain and testes cells (Sarkar et al. 1994). Lai and Singh (1995) reported that rats exposed to pulsed (2 μs duration pulses, 500 pulses per second) or continuous wave (cw) 2.45 GHz fields with SARs of 0.6 or 1.2 W kg^{-1} for 2 h increased the number of single strand breaks in brain DNA. Both these papers produced quantitative data subject to sources of inter-trial variation and experimental error such as incomplete DNA digestion (Sarkar et al. 1994) or unusually high levels of background DNA fragmentation (Lai and Singh 1995). These experiments should be replicated before the results can be used in any health risk assessment, especially given the weight of evidence suggesting the RF fields are not genotoxic. Further, in animal studies, most well conducted investigations report a lack of clastogenic effect in the somatic or germ cells of exposed animals (UNEP/WHO/IRPA 1993).

Other studies have examined the possibility that RF radiation may influence tumor promotion through increases in the rate of cell proliferation via effects mediated through changes in proliferative signalling pathways, leading to enhanced transcription and DNA synthesis (Cridland 1993; Sienkiewicz et al. 1993). Ion fluxes through the cell membrane constitute important signaling mechanisms. A number of reports suggest that RF radiation may be capable of affecting ion fluxes via effects on ion pumps such as Na^+K^+-ATPase in human red blood cells exposed to RF and microwave radiation (Allis and Sinha-Robinson 1987; Liu et al. 1990). Athermal effects on gross transcription, as measured by incorporation of the specific RNA precursor ^{3}H-uridine, have been reported following the exposure of glioma cells to RF and microwave radiation (Cleary et al. 1990a). Similar effects on cellular proliferation, assayed as the incorporation of the specific DNA precursor ^{3}H-thymidine, were also reported following exposure of human lymphocytes (Cleary et al. 1990b) or glioma cells (Cleary et al. 1990a). Both transcription and proliferation were elevated at an SAR of 25 W kg^{-1} but appeared to be unchanged or even depressed at higher SARs. RF exposure has also been reported to induce the activity of ornithine decarboxylase (ODC), an enzyme, levels of which are often elevated during cell growth and tumor promotion. The exposure of mouse fibroblasts to amplitude-modulated microwaves at an SAR of 3 W kg^{-1} increased ODC activity (Krause et al. 1990) but to a much lower level than treatment with a chemical promoter. In addition, changes in the level of this enzyme are not necessarily indicative of cell promotion (NRPB 1993).

Assays of cell transformation are used to detect changes consistent with tumorigenesis but do not provide information on the nature of the damage giving rise to the change. An increased rate of *in vitro* transformation has been reported (Balcer-Kubiczek and Harrison 1985 1989, 1991) in a chromosomally abnormal cell line. Enhanced transformation rates were found in C3H10$T_{1/2}$ cells exposed to combined amplitude-modulated microwaves (4.4 W kg^{-1}) and x rays followed by treatment with the chemical promoter TPA, compared with cells exposed only to x rays and TPA (Balcer-Kubiczek and Harrison 1985). Similar levels of enhanced transformation rates were found after exposure to microwaves and/or x rays (1.5 Gy), followed by treatment with the promoter (Balcer-Kubiczek and Harrison 1989). However, there are inconsistencies between these two studies. In the first study, microwave exposure resulted in a 50% reduction in plating efficiency, while in the second no such effect was observed. Further, although the data from the second study were consistent with an additive effect of microwaves and x rays when followed by TPA treatment, unlike the first study this effect was not statistically significant. More recently Balcer-Kubiczek and Harrison (1991) reported that exposure to microwaves at SARs between 0.1 and 4.4 W kg^{-1} followed by TPA treatment resulted in a dose dependent induction of transformation; in addition, microwave exposure slightly enhanced the effects of x irradiation and TPA on transformation rate. The result of these studies of C3H10$T_{1/2}$ cells are important but their results in respect of carcinogenesis *in vivo* are not clear; C3H10$T_{1/2}$ cells are chromosomally highly abnormal, and their response to proliferative stimuli may be atypical. In addition, transformation studies tend to be susceptible to a variety of experimental confounding factors (NRPB 1992).

Most cancer studies using animal models have sought evidence of an effect on spontaneous or natural cancer rates, enhancement of effects of known carcinogens, or effects on growth of implanted tumors (NRPB 1993; UNEP/WHO/IRPA 1993), but have provided only equivocal evidence for an effect on tumor incidence. Chronic microwave exposure of mice at 2–8 W kg^{-1} resulted in an SAR dependent increase in the progression or development of spontaneous (mammary) or chemically induced (skin) tumors (Szmigielski et al. 1982; Szudzinski et al. 1982). A further study showed that exposure at 4–5 W kg^{-1} followed by the application of a sub-carcinogenic dose of a chemical carcinogen to the skin, a procedure repeated daily, eventually resulted in a threefold increase in skin tumors (Szmigielski et al. 1988). However, at the higher exposures indirect temperature mediated effects cannot be excluded.

An extensive investigation on rats chronically exposed from 2 up to 27 mo of age to low-level pulsed microwaves at SARs up to 0.4 W kg^{-1} reported that no single type of malignant tumor was enhanced (Guy et al. 1985; Chou et al. 1992). Overall the incidence of primary malignancies was similar to that reported elsewhere in rats of this type. If the incidence of primary malignant lesions was pooled without regard to site or cause of death, however, the exposed group had a significantly higher incidence compared with the control group. Also, primary malignancies occurred earlier in the exposed group compared with the sham exposed group. While interesting, these data do not provide clear evidence of an increase in tumor incidence as result of microwave exposure. The incidence of benign tumors did not appear enhanced in the exposed group compared with the controls, nor was any particular type of neoplasm in the exposed group significantly elevated compared with the values reported in stock rats of this strain.

In contrast to these reports, studies in which cancer cells are injected into animals have reported a lack of effect of exposure to cw and pulsed RF radiation on tumor progression (Santini et al. 1988; Salford et al. 1993). In particular, the progression of melanoma in mice was unaffected by daily exposure to pulsed or cw microwave radiation following subcutaneous implantation (Santini et al. 1988), and the progression of brain tumors in rats was not affected by cw or pulsed microwave radiation following the injection of tumor cells into the brain (Salford et al. 1993).

Most of the experiments described above were conducted using RF fields at frequencies and modulations different from those characteristic of hand-held radiotelephones. Taken overall, the evidence suggests that RF exposure is not mutagenic and is therefore unlikely to initiate cancers. The evidence for a co-carcinogenic effect or an effect on tumor promotion or progression is not substantive. However, these few studies are sufficiently indicative to merit further investigation.

Amplitude-modulated RF and microwave effects

Exposure to very low levels of amplitude-modulated RF radiation, too low to involve heating, has been reported by several groups to alter the electrical activity of the brain in cats and rabbits, to alter the activity of the enzyme ODC, levels of which may be elevated during tumor promotion, and to affect calcium ion mobility in brain tissue *in vivo* and *in vitro* (NRPB 1993; UNEP/WHO/IRPA 1993). Effective SARs *in vitro* were less than 0.01 W kg^{-1} occurring within "modulation frequency windows" (usually between 1 and 100 Hz) and sometimes within "power density windows." These changes in calcium ion mobility have not been easy to corroborate. These data challenge the conventional assumption that the likelihood or severity of an effect increases as some function of "dose;" however they are not sufficiently well established nor are their implications for human health sufficiently well understood to provide a basis for restricting human exposure.

Pulsed radiation

Exposure to very intense pulsed microwave radiation has been reported to suppress the startle response and evoke body movements in conscious mice (NRPB 1993; Sienkiewicz et al. 1993; UNEP/WHO/IRPA 1993). Specific energy absorptions were 200 mJ kg^{-1} (for 1 μs pulses) and 200 J kg^{-1} (for 10 μs pulses) for suppression of the startle response and evoked body movement, respectively. The mechanism for these effects is not well established. In addition, people with normal hearing have perceived pulse-modulated RF radiation of frequencies between about 200 MHz and 6.5 GHz, the so-called microwave hearing effect. The sound has been variously described as a buzzing, clicking, hissing or popping sound, depending on modulation characteristics (NCRP 1986; NRPB 1993; UNEP/WHO/IRPA 1993). Prolonged or repeated exposure may be stressful. It seems most likely that the sound results from the absorption of the incident energy. The perception threshold for pulses shorter than 30 μs depends on the energy density per pulse and has been estimated as about 400 mJ m^{-2} at 2.45 GHz, corresponding to an estimated peak specific energy absorption in the head of about 16 mJ kg^{-1}. However, a reduction in ambient noise has been reported to reduce this to about 280 mJ m^{-2}. These potentially stressful and harmful effects should be avoided.

Some studies suggest that the retina, iris, and corneal endothelium of the primate eye are susceptible to low-level microwave radiation, particularly to pulsed radiation (NRPB 1993; Sienkiewicz et al. 1993; UNEP/WHO/IRPA 1993). Various degenerative changes, particularly in the light sensitive cells in the retina, have been reported; specific energies per pulse (10 μs pulses at 100 pulses per second) were 26 mJ kg^{-1} and even as low as 2.6 mJ kg^{-1} after the application of a drug used in the treatment of glaucoma. Exposure to low levels of pulsed or cw microwave radiation have been reported to affect neurotransmitter metabolism and the concentration of receptors involved in stress and anxiety responses in different parts of the brain (NRPB 1993; Sienkiewicz et al. 1993; UNEP/WHO/IRPA 1993). For pulsed radiation, the threshold specific energy per pulse was approximately equal to the microwave auditory threshold. However, these studies could not be replicated (Kamimura et al. 1994).

Thermal considerations

Thermally mediated effects of RF fields have been studied in animals, including primates. These data suggest effects that will probably occur in humans subjected to whole body or localized heating sufficient to increase tissue temperatures by greater than 1°C. They include the induction of opacities of the lens of the eye, possible effects on development and male fertility, various physiological and thermoregulatory responses to heat, and a decreased ability to perform mental tasks as body temperature increases. Similar effects have been reported in people subject to heat stress, for example while working in hot environments or by fever. These various effects are well established and form the biological basis for restricting occupational and public exposure to radiofrequency fields. In contrast, non-thermal effects are not well established and currently do not form a scientifically acceptable basis for restricting human exposure for frequencies used by hand-held radiotelephones and base stations.

For limiting temperature increases in parts of the body, the restrictions on localized SAR are appropriate. For head exposure to RF fields from hand-held radiotelephones, ICNIRP recommends that an averaging mass of 10 g is used. This is because of the very inhomogeneous spatial distribution of energy absorbed inside the head, together with concerns about possible localized heating of the eye and other parts of the head with equivalent mass. A calculation of temperature increase for a realistic finite element model of the eye (Scott 1988) has yielded a maximum rise of about 1°C from the absorption of 10 W kg^{-1} throughout the eye.

HUMAN HEALTH STUDIES

Many epidemiological studies have addressed possible links between exposure to RF radiation and excess risk of cancer. There are difficulties in the design, execution, and interpretation of these studies, particularly with respect to the identification of study populations with substantial RF exposure and retrospective assessment of such exposure.

A large scale study of radar workers (Robinette et al. 1980) involving over 40,000 people exposed for 2 y and followed up for 20 y failed to identify an increased incidence of illness or mortality associated with exposure. Lillienfeld et al. (1978) studied 1,800 employees and 3,000 dependents of the United States embassy in Moscow who were exposed to low level RF radiation in the embassy. They did not find significant adverse health effects in that population. Szmigielski et al. (1988) reported an increased risk of cancer in military personnel. However, the results of this study are difficult to interpret because neither the size of the population nor the exposure levels are clearly stated.

Review groups evaluating the state of knowledge about possible links between RF exposure and excess risk of cancer have concluded that there is no clear evidence for this (IEEE 1992; NRPB 1992; UNEP/WHO/IRPA 1993). The United Kingdom NRPB Advisory Group on Non-ionising Radiation concluded that there is no firm quantitative evidence of a carcinogenic hazard from electromagnetic field exposures for the general public and workers in the electrical, electronics, and telecommunications industries (NRPB 1992).

INTERNATIONAL GUIDELINES FOR LIMITING EXPOSURE

International guidelines for limiting exposure to electromagnetic fields in the frequency range 100 kHz to 300 GHz have been published (IRPA/INIRC 1988). These are intended to provide a safe, healthy working or living environment from exposure to radiofrequency fields under all normal conditions.

Basic limits of exposure in terms of whole body and localized SAR are provided together with derived power density and electric and magnetic field strengths limits. Limits for whole body exposure are provided for both occupational (0.4 W kg^{-1}) and for general public exposure (0.08 W kg^{-1}). In the frequency range appropriate to hand-held radiotelephones, the localized SAR limit for occupational exposure of the head is 10 W kg^{-1} averaged over any 100 g mass of tissue. However, no localized SAR limit is provided for equivalent exposure of the general public.

While ICNIRP is formulating comprehensive guidelines on exposure limits, the basic limits for localized exposure have been agreed upon. ICNIRP recommends a localized SAR limit of 10 W kg^{-1} averaged over any 10 g mass of tissue in the head for occupational exposures and 2 W kg^{-1} averaged over any 10 g mass of tissue in the head for general public exposure.

ASSESSMENT OF HEALTH RISKS

From dosimetry studies (Dimbylow and Mann 1994; Meier et al. 1995), the ICNIRP localized SAR limit for occupational exposure of 10 W kg^{-1} averaged over any 10 g mass of tissue is not likely to be exceeded under normal use conditions for handsets with duty cycle weighted powers less than 3.2 W for 900 MHz radiation and 2.2 W for 1.8 GHz radiation, and the limit for general public exposure will not be exceeded under normal use conditions for handsets with duty cycle weighted powers less than 0.6 W for 900 MHz fields and 0.4 W for 1.8 GHz fields. These calculated values (Dimbylow and Mann 1994) are based on an antenna to head separation of 1.4 cm that is the transmitter case in contact with the head and the assumption that all the available power from the handset is radiated. In practice, because of the electrical characteristics of antennas, the power radiated will be less than the available power. The energy deposition occurs mainly in the superficial tissues of the head, particularly the skin and underlying muscle, with little penetration inside the skull.

ELECTROMAGNETIC INTERFERENCE

It is recognized that, under certain circumstances, RF emissions from hand-held radiotelephones can cause interference with the function of some electrical and electronic equipment (for example, with hearing aids). Of concern is the problem of interference with electromedical equipment, especially life support devices.

It is recommended, therefore, that the use of radiotelephones is restricted to areas where such interference effects are unlikely to occur (e.g., well away from hospital intensive care departments and similar locations). Manufacturers of electrical equipment are encouraged to design and manufacture equipment that is insensitive to RF interference.

CONCLUSIONS

Following a critical review of the scientific literature ICNIRP has reached the following conclusions:

1. The results of published epidemiological studies do not form a basis for health hazard assessments of exposure to RF fields, and neither can they be used for setting quantitative restrictions on human exposure. They do not provide a basis for hazard assessments in relation to the use of hand-held radiotelephones and base transmitters.
2. Data from laboratory studies relevant to cancer do not provide a basis for limiting exposure to the fields associated with the use of hand-held radiotelephones and base transmitters.
3. Limits for human exposure to the fields associated with the use of hand-held radiotelephones and base transmitters should be those of the INIRC (IRPA/INIRC 1988) for whole body average SAR and those of ICNIRP for localized SAR set out in this document.
4. There is no substantive evidence that adverse health effects, including cancer, can occur in people exposed to levels at or below the limits on whole body average SAR recommended by INIRC (IRPA/INIRC 1988) or at or below the ICNIRP limits for localized SAR set out in this document.
5. At the frequencies and power levels involved in the use of hand-held radiotelephones there will be no concern about shocks and burns.
6. The localized SARs in the head associated with the use of hand-held radiotelephones must be assessed for each frequency and configuration used.
7. For hand-held radiotelephones used in occupational situations, ICNIRP recommends that the localized SAR in the head be limited to 10 W kg^{-1} averaged over any 10 g mass of tissue in the head (0.1 W absorbed in any 10 g mass of tissue in the head).
8. For hand-held radiotelephones used by the general public, ICNIRP recommends that the localized SAR in the head be limited to 2 W kg^{-1} averaged over any 10 g mass of tissue in the head (0.02 W absorbed in any 10 g mass of tissue in the head).
9. The use of radiotelephones should be restricted to areas where interference effects are unlikely to occur (for example, well away from hospital intensive care departments and similar locations). Manufacturers of electrical equipment are encouraged to design and manufacture equipment that is insensitive to RF interference.

Acknowledgements—The support received by the ICNIRP from the IRPA, the World Health Organization, the United Nations Environment Programme, the International Labour Office, and the European Commission is gratefully acknowledged.

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