Mobile telephones

An evaluation of health effects

Gezondheidsraad

Health Council of the Netherlands

Gezondheidsraad **President**

Health Council of the Netherlands

The Minister of Housing, Spatial Planning
and the Environment

Subject	: presentation advisory report Mobile telephones
Your reference	: DGM/SVS/99207094
Our reference	: -2625/EvR/RA/673-R
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Dear Sir,

At your request, in a letter nr DGM/SVS/99207094, I herewith present you an advisory report on health effects of mobile telecommunication systems. It has been drafted by the Electromagnetic Fields Committee of the Health Council of the Netherlands and evaluated by the Standing Committee on Radiation Hygiene. Corresponding to the request for advice I have also presented this report today to the Minister of Health, Welfare and Sport and to the State Secretary of Traffic, Public Works and Water Management. Additionally, I have sent the report to the Minister of Economic Affairs and the State Secretary of Social Affairs and Employment.

On 29 June 2000 the Health Council published the advisory report 'GSM base stations' that was drafted by the Electromagnetic Fields Committee. That report deals with health aspects of the fixed components of networks for mobile telecommunication. In addition to this, the Committee has now drafted the present report that deals with the portable components: the mobile telephones.

Yours sincerely,

(signed)
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to

the Minister of Housing, Spatial Planning and the Environment

the Minister of Health, Welfare and Sport

the Minister of Economic Affairs

the State Secretary of Social Affairs and Employment

the State Secretary of Transport, Public Works and Water Management

No. 2002/01E, The Hague, 28 January 2002

The Health Council of the Netherlands, established in 1902, is an independent scientific advisory body. Its remit is "to advise the government and Parliament on the current level of knowledge with respect to public health issues..." (Section 21, Health Act).

The Health Council receives most requests for advice from the Ministers of Health, Welfare & Sport, Housing, Spatial Planning & the Environment, Social Affairs & Employment, and Agriculture, Nature Preservation & Fisheries. The Council can publish advisory reports on its own initiative. It usually does this in order to ask attention for developments or trends that are thought to be relevant to government policy.

Most Health Council reports are prepared by multidisciplinary committees of Dutch or, sometimes, foreign experts, appointed in a personal capacity. The reports are available to the public.

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Contents

Executive summary

Mobile telecommunication has developed considerably in recent years: to date over half the population of the Netherlands posses a mobile telephone. Nevertheless, concerns also grow, particularly as to whether exposure to electromagnetic fields from antennas and mobile telephones can adversely affect health. In this advisory report, the Electromagnetic Fields Committee of the Health Council of the Netherlands provides, on the basis of the scientific literature, an overview of various aspects that may play a role. The Committee comes to the conclusion that there is at present no reason for concern. However, since mobile telephony leads to widespread electromagnetic field exposure and relatively little knowledge exists on, especially, longterm effects, it indicates areas for further research. In particular, the Committee indicates in what areas research can be conducted in the Netherlands.

Health effects

Biological versus health effects

It is important to distinguish between biological or physiological effects and health effects. If an effect of an electromagnetic field has been demonstrated in experimental research on an isolated biological system, for instance an effect on cultured cells, this does not necessarily imply that exposure to such a field will lead to adverse effects for the health of the organism as a whole. Nor, in the absence of supporting evidence, should effects detected by sensitive measurement methods, such as subtle changes in reaction speed or in the natural pattern of brain waves during sleep in humans, be regarded as harmful to health. The reason for this is that the human body has a great capacity for adequately processing external influences and, if necessary, effectively resisting them (with the aid of the immune system), compensating for them (homeostasis) or successfully adapting to them (specifically with the nervous and the endocrine systems).

Frequency spectrum

Propagation of information by mobile telecommunication systems is usually performed by highly complex high-frequency electromagnetic fields. It is however not correct to assume that clearly discernible and possibly biologically effective low-frequency components are present in the electromagnetic signal of a base station or of a mobile telephone. Low-frequency components can only become manifest upon exposure if a highly specific demodulation of the carrier wave occurs, as in receivers designed for this purpose. There are no reasons to assume that such demodulation mechanisms are available to biological systems.

Temperature changes

The findings of model studies on temperature changes in the head to do not give the Committee grounds to revise the existing recommendations on exposure limits. To give the standards in this frequency range a sounder basis, it is nevertheless deemed necessary to gain a better understanding of the dosimetry of electromagnetic fields. In order to obtain this, additional data are needed on the relationship between temperature, absorbed energy levels, and the type and volume of the tissue in which these parameters are determined.

The Committee recommends to expand model studies previously conducted on this topic in the Netherlands and to perform adequate measurements of temperature in and near the head during mobile telephone use.

Nonspecific symptoms

Various studies have been conducted among mobile telephone users on the occurrence of nonspecific symptoms, such as headache, dizziness and insomnia. This type of symptoms is very general in nature and may have all kinds of causes. On the basis of the presently available data, the Committee believes that the electromagnetic fields generated by mobile telephones cannot be regarded as a cause of such symptoms. They are, nevertheless, even if only a small group of people would be showing such complaints, a relevant problem for those individuals. Therefore, the cause of such symptoms should be sought.

It is in the first instance important to examine whether the nonspecific symptoms are caused by the electromagnetic fields originating from mobile telephones or by other factors. In this respect, also the suggestion raised in the literature could be investigated that symptoms such as dizziness, nausea and headache might result from a unilateral influence on the vestibular system in the middle ear arising from absorption of the telephone's electromagnetic fields.

The Committee recommends that studies be carried out in the Netherlands to determine whether nonspecific symptoms of this kind can arise upon exposure under controlled conditions, both in people who have reported these symptoms and in symptom-free individuals.

Cognitive functions

In a few human volunteer studies, subtle changes have been found in certain cognitive functions, such as memory and reaction speed. Although this suggests an influence from electromagnetic fields on brain activity under certain conditions, the effects involved are extremely small and reversible. The Committee, therefore, does not regard them as harmful to health.

Experiments on laboratory animals provide only equivocal evidence of possible effects on learning behaviour in rodents as a result of exposure to electromagnetic fields at relatively low field strengths. However, the Committee considers experiments of this kind to be less suitable for demonstrating a possible effect of mobile telephones on learning ability in humans, deeming experiments with volunteers to be of considerably greater significance.

The conclusion is, that the available scientific data does not indicate an adverse effect on cognitive abilities, even in people who make frequent use of mobile telephones.

The Committee recommends to conduct research in the Netherlands on the influence of electromagnetic fields on cognitive functions. In particular, this should be carried out with people who have complaints that they attribute to such fields.

Brain activity

Several studies have shown that exposure to a GSM signal during sleep exerts effects on natural brain activity. However, the Committee concludes that the data on this are equivocal. No correlation has been observed with increasing field strength. It is nevertheless striking that, in one of the studies, changes in brain activity during sleep were found following exposure prior to falling asleep.

The Committee feels that, on the basis of these findings, there is no reason to suppose that the effects, in so far as they are real, lead to health problems. It points out that similar effects on brain activity have also been found as a result of caffeine use and natural hormonal fluctuations.

The Committee concludes from the data obtained from research on effects on non-sleeping test subjects – only young, healthy volunteers – that it is basically possible for the electromagnetic field originating from a mobile phone to influence certain brain activities. This influence is present in those parts of the brain closest to the telephone and concerns extremely small changes that are only detectable with sensitive equipment. There is no evidence that the changes recorded persist beyond the period of exposure. No effect has been found on the performance of assigned tasks, nor on the health of the persons tested.

The Committee recommends to study whether individuals with existing brain disorders, such as sleep disturbances, are more vulnerable to electromagnetic-field exposure than healthy individuals. It also considers it important to study the physiological background of the effects on natural brain activity of exposure to a GSM signal during or immediately preceding sleep.

Cancer

Several epidemiological studies, some of which have been conducted on a very large scale, have focused on a possible link between the occurrence of brain tumours and mobile telephone use. In none of these studies has such a link been found for brain tumours in general. However, in some studies a weak association has been observed between the use of a mobile telephone and the occurrence of certain tumours on the side of the head where, as indicated by the subjects, the mobile telephone was normally held. However, this association is not significant and has only been found in studies that had a number of important methodological shortcomings.

These epidemiological findings are substantiated by data from animal experiments. Only in one study an effect has been found, but the experimental design was such that no satisfactory conclusions can be drawn. Two replications of this study are currently being carried out. However, the question arises as to whether the mouse strain used in these studies, which exhibits a high spontaneous incidence of tumours as a result of a genetic mutation, represents a good model for humans.

A major question is whether mobile telephones have been in use for a sufficient period of time to allow any effect on the development of brain tumours to be detected. The use of mobile telephones by large parts of the population has been going on for only a few years. Although in none of the studies a link has been found between usage time and the occurrence of cancer, the number of people in the longest-use category (five years or more) is relatively low. A major international study is currently being conducted under the auspices of the International Agency for Research on Cancer (IARC) to investigate the possible relationship between (digital) mobile telephone use and the occurrence of tumours in the head-neck region. Initial results from that study are not due before 2003.

The Committee recommends that also in the Netherlands studies be performed on possible longterm health effects in users of mobile telephones.

Cardiovascular system

There is no evidence to suggest that electromagnetic fields from mobile telephones have any effect on the cardiovascular system. Exposure to a mobile telephone signal seems to have no influence on natural variations in cardiac rhythm, and research data indicating a possible influence on blood pressure have recently been withdrawn: they proved to be the result of a direct action of the electromagnetic field on the measuring equipment.

Hormones

Studies on volunteers and on animals suggest that GSM fields have no effect on hormone levels.

Blood-brain barrier

A number of studies from the 1970s and 1980s seem to indicate that exposure to electromagnetic fields affects the permeability of the blood-brain barrier. However, recent research has been unable to reproduce these effects. The Committee is of the opinion that there are no scientific grounds to assume the existence of such effects.

Immune system

The Committee considers that there is no convincing evidence that the immune system is affected by electromagnetic fields.

Use by children

It is unlikely from a developmental point of view that major changes in brain sensitivity to electromagnetic fields still occur after the second year of life. The Committee therefore concludes that there is no reason to recommend that mobile telephone use by children should be limited as far as possible.

Precautionary principle

The Committee concludes that the scientific information concerning non-thermal effects discussed in this report provides no reason to apply the precautionary principle and lower the SAR limits for partial body exposure.

Reduction in exposure

The use of a handsfree set generally leads to considerable reduction in the amount of energy absorbed by the head. Under no circumstances will such use result in energy absorption similar to or higher than that experienced by those using mobile telephones without a handsfree set.

The use of covers that partly block the fields emitted by a mobile telephone leads to an increase in the transmitting power of the telephone (as a result of which the shielding effect is in turn partly nullified), and to a reduction in the quality of the mobile network.

The Committee concludes that the use of such protective covers is not useful.

The Committee considers sales promotions for telephone-mounted objects that are claimed to absorb electromagnetic fields to be misleading. Basic physics precludes the possibility of any such absorption effect.

Interference with (medical) equipment

The electromagnetic fields of mobile telephones may interfere with other electronic equipment if this is not adequately protected against these fields. To prevent this interference, such equipment must meet the European electromagnetic compatibility requirements. These requirements prescribe lower field strengths than the health-based exposure limits. Therefore, interference may still occur in an environment with a field strength below these exposure limits. This may occur, for example, if such equipment is located in the direct vicinity of a transmission system or of a mobile phone that is switched on.

The Committee endorses the recommendations of the Netherlands Association for Information- and Communication Technology concerning prohibition of the use of GSM and DECT telephones in the direct vicinity of medical electronic equipment. It stands by its 1997 recommendation that for implanted pacemakers a minimum distance of 15 cm should be maintained to a switched-on mobile telephone.

The Committee urges that no distinction be made between hospital personnel and the public when drafting a set of standards to govern the use of mobile telephones within hospital buildings. The regulations must be the same for everyone and there must also be a means of enforcing compliance.

The Committee recommends that the government sees to an increase in the immunity of medical electronic products, so that no interference problems arise as a result of the normal use of mobile telephones. The government should also encourage a tightening-up of European standards and an extension of the frequency range covered by the latter to at least 10 GHz.

Road safety

The Committee considers the decision of the government to allow only handsfree use of mobile telephones by drivers of motorized vehicles a step in the right direction. It recommends that this decision be extended to all drivers

However, recent research shows that an adverse effect on road safety arises from both non-handsfree and handsfree telephone use. Although there are no direct scientific data on this, the Committee considers that this might be due to the fact that carrying on a conversation via a mobile telephone is felt to be much more compelling than a conversation with a fellow passenger.

The Committee therefore recommends that the government should, by providing advice, encourage lengthy calls and calls requiring close attention in particular to be postponed until the vehicle has been brought to a stop in a suitable location.

Chapter 1

Introduction

Mobile telecommunication has boomed in recent years and has acquired an important place in society. Prompted by these developments, society is radically changing. People can, if they wish, be accessible everywhere and at all times (of course, within the capabilities of the telecommunication networks). The advent of technologies allowing for the high-speed transmission of large amounts of data means that it will soon be possible to exchange not only speech and brief messages but also video and other large data files. This will facilitate the use of mobile videophones and mobile access to the Internet.

1.1 Problems

Despite their acknowledged benefits, all these technological developments nonetheless also cause many people concerns. In particular, one common matter of concern is whether increasing exposure to the electromagnetic fields generated during wireless communication could lead to health problems. An argument regularly put forward in this debate is that man’s electromagnetic environment is rapidly changing, that the human body is not built for this and cannot adapt quickly enough. Consequently, such changes would have adverse implications for body functioning. It is therefore appropriate to determine whether there is any scientific evidence to support this supposition.

1.2 Previous advice

The Health Council of the Netherlands has long been analysing and reporting on scientific developments relating to the effects of electromagnetic-field exposure on the human body. In 1997, the Council issued the advisory report *Radiofrequency electromagnetic fields (300 Hz – 300 GHz)* (HCN97). Based on the level of knowledge at the time, proposals were made in this report concerning exposure limits: electromagnetic field values that should not be exceeded, in order to prevent adverse effects on health. With regard to the low-frequency range, the exposure limits proposed in 1997 were supplemented and partially revised in March 2000 in the advisory report *Electromagnetic fields (0 Hz – 10 MHz)* (HCN00a). However, this did not deal with the frequencies used for mobile telecommunication. As far as radio frequencies are concerned, the limits proposed in 1997 were confirmed in the advisory report *GSM base stations* issued in June 2000 (HCN00b). However, some reservations were made. Firstly, the confirmation applies only to whole-body exposure since that is the situation with GSM base stations (apart from a very limited group of employees who, in order to maintain equipment for example, have to approach the antennas at relatively close distance; as a result, their bodies receive non-uniform exposure). Secondly, it was stated that current exposure limits can only be based on short-term effects. The data for long-term effects does not provide grounds for reducing the exposure limits, not even on a precautionary basis. It was pointed out, however, that clear evidence of long-term effects may yet be obtained at some future date. With this in mind, scientific developments should be closely monitored. The prime reason for this is the large number of people exposed. This means that, should there indeed be long-term effects, these might have an appreciable impact on public health by virtue of this scale. The Electromagnetic Fields Committee (hereinafter referred to as: ‘the Committee’) has therefore been instituted for a relatively long time, provisionally for a period of four years, to continue monitoring these developments and report regularly on them. The make-up of the Committee is set out in Annex B.

1.3 Object of this advisory report

In a letter dated September 1999, the Minister for Housing, Spatial Planning and the Environment and the Minister for Health, Welfare and Sport, also on behalf of the State Secretary for Transport, Public Works and Water Management, asked the Health Council of the Netherlands to update the current level of knowledge as described in the advisory report of 1997 (see Annex A). In this context, it was also requested that an indication be given of the implications of the scientific state-of-the-art for the development and use of mobile telecommunication in society. In the *GSM base stations* advisory report, the Committee provided a first part of the requested update. As specified above, this relates only to whole-body exposure. For a mobile telephone user, exposure is, however, very localized: if the device is used without a handsfree set, only the head and hand are exposed. In the 1997 advisory report, it was concluded on the basis of the scientific data available at that time, that such exposure will in all probability not cause any health problems. However, little information was available at that time that related directly to such an exposure situation. In recent years, many research initiatives have been launched which do directly relate to a possible effect on the head of electromagnetic fields from a mobile telephone. The data now available from that research form the basis for the present report. In this report, the Committee will not restrict itself to the current mobile telephony systems, namely GSM-900 and DCS-1800, but it will also consider future developments, such as UMTS, and portable telephone systems intended for indoor use, such as DECT.

1.4 Criteria for establishing effects

The Committee bases its conclusions regarding the health effects of exposure to electromagnetic fields on an analysis of the scientific literature. It considers the existence of an effect, whether a biological effect or an effect on health, only to be scientifically demonstrated in the event of compliance with the following objective requirements, which encompass the criteria formulated by Hill for epidemiological research (Hil71):

- the research has been published in internationally refereed journals generally acknowledged in the scientific community as being of adequate quality;
- the research is of adequate quality according to prevailing standards in the scientific community;
- the results of the research have proven to be reproducible (in the case of laboratory research) or consistent (in the case of epidemiological research) on the basis of research as referred to under (1) and (2) conducted by other, independent researchers;
- the research result has been substantiated by quantitative analysis, leading to the conclusion that a statistically significant correlation exists between exposure and effect; in the case of epidemiological research, a causal link becomes more plausible as the association becomes stronger;
- the strength of the effect is related to the strength of the stimulus, *i.e.* there is a dose-response relationship; this need not always be the kind of relationship in which a stronger stimulus produces a stronger effect, but may also entail a

resonance effect, in other words the maximum effect is produced by a specific stimulus, while stimuli that are stronger or weaker than this produce a lesser effect.

If one or more of these requirements has not been met, the Committee concludes that it has not been demonstrated that the relevant mode of exposure causes a biological or health effect. With regard to the strength of proof adduced, it is also important whether a hypothesis acceptable to experts exists concerning the way in which the stimulus can cause the effect, i.e. whether there is a plausible biological (or psychological) mechanism. However, the Committee does not consider knowledge of a mechanism a necessary precondition for the identification of a causal link. In the case of weak associations in epidemiological research, however, knowledge of a mechanism is important.

The Committee has based this advisory report on publications issued before December 1, 2001.

1.5 Structure of this report

In Chapter 2, the Committee first provides a brief overview of current exposure limits and the considerations and scientific data underlying them. Chapter 3 deals with mobile telephone technology. In Chapter 4, the Committee then addresses temperature changes in the head as a result of exposure to electromagnetic fields from mobile telephones. In Chapter 5, the Committee presents an overview of scientific literature concerning biological and health effects, particularly with regard to effects in the head. At the end of this chapter the Committee gives special consideration to the exposure of children. Indirect effects on health may result from technical problems in medical equipment (mobile telephones may sometimes cause interference). In the advisory report on GSM base stations, the Committee has already briefly considered this matter. In Chapter 6 of the present advisory report, the Committee explores this issue in more detail. Mobile telephones may also affect health in a very different, indirect fashion, since their use when driving a vehicle adversely affects road safety. In Chapter 7, the Committee examines the relevant scientific findings in more detail. In Chapter 8, it briefly indicates how legislative and regulatory developments in other countries can be followed. Finally, there are five annexes covering the following issues: the request for advise, the composition of the Committee, a list of terms and definitions, an explanation of SAR (Specific Absorption Rate), and background information on the influence of temperature changes on the vestibular system.

Chapter **2**

Exposure limits

Various national and international organisations have made proposals for exposure limits. In 1997, the Health Council of the Netherlands issued the advisory report *Radiofrequency electromagnetic fields (300 Hz - 300 GHz)*, in which limits were proposed for the frequency range in question (HCN97). In 1998, the International Commission on Non-Ionizing Radiation Protection (ICNIRP) issued guidelines for the 0 Hz - 300 GHz frequency range which broadly match the recommendations of the Health Council of the Netherlands (ICN98). Only in the highest frequency range is there a difference. A description of the way in which the limits have been established can be found in the reports indicated. The Committee here gives a short summary of the most important principles.

2.1 Basic restrictions

In their recommendations, both the Health Council of the Netherlands and ICNIRP distinguish between so-called basic restrictions and reference levels (also called derived values). The basic restrictions are maximum values for variables directly relating to a health effect. In the frequency range above around 100 kHz, which covers radio frequencies and thus also the frequencies used for mobile telecommunication, the relevant effect is heat generation. If an organism is exposed to an electromagnetic field, some of the electromagnetic energy is absorbed by the body and converted into heat. In a microwave oven, the same principle is used to heat food or liquids. Excessive heat generated in the body may, however, result in adverse health effects. On the basis of scientific data obtained from laboratory animals and volunteers, it has been established that if the increase in body temperature does not exceed 1°C, this does not lead to health problems even in the case of long-term exposure.

The variable used to express absorbed energy per unit time is the specific absorption rate (SAR), expressed in watts per kg (see Annex D). It is assumed in all the guidelines that, if the average SAR in the body does not exceed 4 W/kg, body temperature does not rise by more than 1°C. As a result of factors such as the extrapolation of experimental animal data to humans, and the existence of human subpopulations who, for various reasons, are more sensitive to heat gain than others (for example young children, frail elderly and sick people), safety margins have been built into the guidelines. A distinction is made between workers and the general population. The term 'workers' does, in this case, not pertain to everyone who works. It refers to healthy adults who, in the course of their professional duties, may be exposed to electromagnetic fields, who are familiar with the risks of such exposure and who know how they should handle these risks. A safety margin of a factor of 10 applies to them, *i.e.* they may be exposed to a maximum SAR of 0.4 W/kg. Everyone else belongs to the general population and is subject to a safety factor of 50. Consequently, the maximum permissible SAR for this group is 0.08 W/kg.

These values pertain to total body exposure. When mobile phones are used only part of the body is exposed: the head, especially the side where the telephone is held, and the hand holding the telephone. With respect to partial body exposure both the Health Council of the Netherlands and ICNIRP deem higher SAR values acceptable. For the general population a SAR of 2 W/kg has been proposed for the head and a value of 4 W/kg for the hand. The corresponding values for workers are a SAR of 10 W/kg for the head and 20 W/kg for the hand. In chapter 4 the Committee elaborates on this subject.

Owing to the differing electromagnetic properties of tissues in the body, local differences in temperature increase will occur. However, as a result of the removal of heat by blood circulation, these are partially nullified. Consequently, a thermal equilibrium will eventually be achieved, where the supply of heat through exposure to the electromagnetic field and the removal of heat through blood circulation and heat transfer to the environment through radiation, convection and sweating are in balance. For this reason, the aforementioned SAR maxima are intended as an average over any 6-minute period. These are the basic restrictions that must be met at all times.

2.2 Reference levels

The measurement of heat absorption is a difficult matter. Particularly if exposure, as is generally the case, does not take place homogeneously throughout the body. From the basic restrictions, in this case the SAR, values have therefore been derived for the electrical and magnetic fields present at the point of exposure, i.e. the undisturbed fields. Annex D, for example, contains details of the relationship between the SAR and electrical field strength. The strengths thus derived for the electrical and magnetic field are called the reference levels. They should be regarded as an aid in determining whether the basic restrictions are met. If the reference levels are not exceeded, this is true also for the basic restriction. If the reference level is exceeded, then it must be checked in some other way, whether or not the basic restriction is met.

The reference levels display a strong frequency dependence, since electromagnetic fields with different frequencies will penetrate the body to different depths and because resonance effects may arise.

Reference levels can only be derived, however, for situations at some distance from the source, in the so-called far field.[a] The exposure of the head and the hand is in the near field. There, the strength of the electric and magnetic field is highly variable. As a result, no general reference levels can be given for that situation and compliance with the basic restrictions has to be done on a case by case basis.

2.3 European recommendations

In 1999, the Council of the European Communities issued recommendations concerning exposure of the general population to electromagnetic fields, adopting the guidelines of ICNIRP (CEC99). The Netherlands government has indicated in the National Antenna Policy that it would like to lay down exposure limits by law and that it will use the European recommendations as the basis for the Dutch regulations (Min00).

[a] The electromagnetic field in the vicinity of a source can be differentiated into the near field and the far field. In the far field, the electrical and magnetic components of the field are perpendicular to each other and to the direction of propagation of the field. Under these conditions, the propagation of energy is called radiation. The field strength decreases proportionally with distance from the source. In the near field, the link between the electrical and magnetic field is more complex than in the far field. The field strengths in the near field are therefore more difficult to calculate than in the far field. They decreases on average more sharply than inversely proportional to the distance from the source.

2.4 Precautionary principle

Citing the precautionary principle, various European countries have laid down lower exposure limits than those recommended by ICNIRP. The reason for this is uncertainty as to the existence of and the possible consequences for health of biological effects unrelated to heat absorption, so-called non-thermal effects. In the request for advice (see Annex A), the members of the Cabinet ask the Health Council of the Netherlands whether, on the basis of such non-thermal effects, there are grounds to set the exposure limits at a lower level than is currently the case. In the advisory report *GSM base stations*, the Committee has indicated that it sees no grounds for this (HCN00b). Although there is some evidence of certain non-thermal biological effects, there is no known or conceivable mechanism by which such effects might result in damage to health. These conclusions relate to total body exposure and therefore not necessarily also to the situation of using a mobile telephone. In Chapter 5 the Committee examines non-thermal effects associated with exposure to electromagnetic fields from mobile telephones in more detail. On the basis these data the Committee concludes with respect to application of the precautionary principle.

Chapter **3**

Technical background

3.1 Network

The basic principle behind wireless communication is that information transfer takes place via electromagnetic waves. Speech can be transmitted by both analogue and digital means. Other information, such as data, is generally transmitted digitally.

Electromagnetic waves are characterised by their frequency, *i.e.* the number of times per second that they alternate from positive to negative, and by their intensity, *i.e.* the field strength. The basic frequency of a signal is called the carrier wave. Information transfer, either analogue or digital, takes place through changes in this carrier wave. These might, for example, be changes in frequency (frequency modulation: FM) or in intensity (amplitude modulation: AM). Such modulation may occur continuously, as with a broadcasting transmitter, or in specific time slots, as with a GSM mobile telephone, which results in a pulsed signal. The way in which the information is transferred (by analogue or digital means) is independent of the type of signal sent by the transmitter.

Insofar as mobile telephony is concerned, wireless transfer is in fact just a small part of the overall process. For the most part, ordinary cable links are used. A mobile telephone communicates via radio waves with the nearest base station. In the base station, the signal is transferred to the fixed network. Some base stations do not have a link of this kind themselves. Instead, they are in contact (via a microwave link) with a base station that does have a link with the fixed network. Each base station has a limited service range, termed a cell. Since a base station can handle only a limited number of calls at the same time, the size of a cell depends on the demand for links. Cells are small in urban areas, and large in rural areas. The advisory report *GSM base stations* examines this in more detail (HCN00b).

3.2 Mobile telephones

Mobile telephones are designed in such a way that they can remain in contact with the nearest base station with the least possible power. Whether this capability is fully used depends on the design of the network. The prime reason for the existence of this facility is to utilise the limited amount of energy in the battery as effectively as possible. In addition, the capacity of the network is thereby increased. The mobile telephone's power regulation means that the strength of the electromagnetic field around the telephone may vary from place to place and over time. Generally speaking, it can be said that the poorer the link, the higher the transmission power needed by the telephone to link to the base station. Conversely, it is also the case that the more antennas there are, the lower the transmission power required by the telephone will be and therefore also the lower the strength of the electromagnetic field at the telephone will be. Under ideal, free-field conditions, mobile telephones have a maximum range of several dozens of kilometres.

Owing to mounting use of GSM telephones, the number of base stations is increasing. Consequently, mobile telephones generally operate at lower power, and exposure for the user will generally decrease.

3.2.1 GSM

Mobile communication according to the GSM (Global System for Mobile communication) standard operates in the 900 MHz and 1800 MHz band. Information, both speech and data, is transmitted digitally. GSM telephones are therefore also designated as ‘digital telephones’, in contrast with ‘analogue telephones’. With the first networks for mobile telephony set up in the Netherlands, such as NMT, a continuous signal was used instead of the pulsed signal described below. Information transfer with this now outmoded technology was carried out by analogue means.

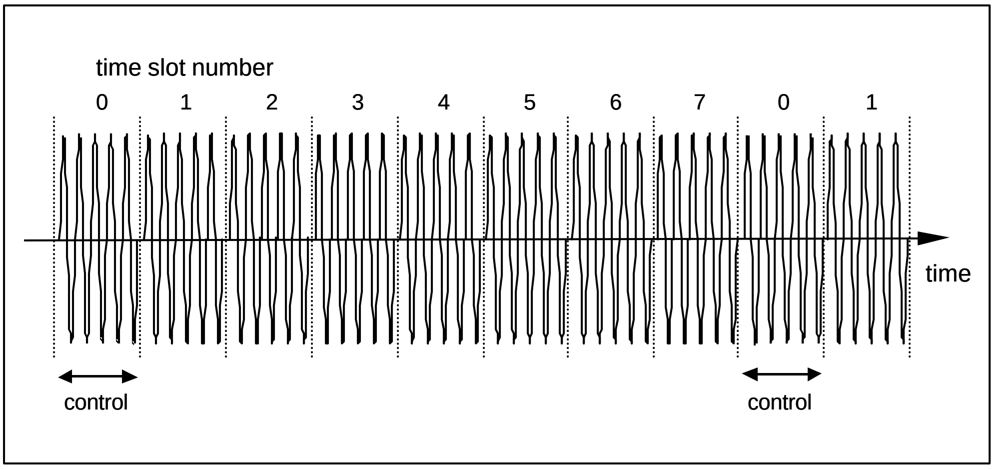
In GSM, Time Division Multiple Access (TDMA) technology is employed, with the signal being divided into 217 information periods (‘frames’) per second. Each frame is in turn subdivided into eight periods (‘time slots’). The first time slot has a regulatory and control function in some cases, and each of the other seven can be used for an individual telephone call. For technical reasons, every 26th frame is not transmitted.

Depending on the expected number of calls that must be simultaneously handled by a base station, one or more channels ('frequencies') are installed at a GSM base station per sector.[a] Each channel is a frequency range with a band width of 200 kHz. One of these channels has a special function in setting up and handling telephone calls. It is a kind of control channel and is always operating at full power and with all time slots completely filled (although information is thus not always transferred in all those time slots).

With the additional channels, it is possible only to transmit in the filled time slots. In addition, the various time slots can be transmitted with different power levels. However, these facilities are not always used. The method most commonly adopted is for the additional channels, just like the control channel, to send out a quasi-continuous signal.

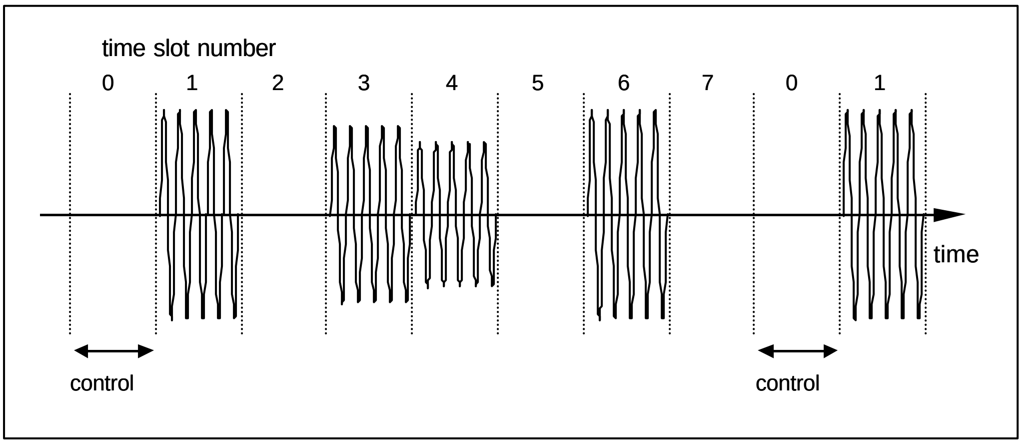
A base station thus involves digital modulation, but not pulsed transmission. However, stepwise changes in the total transmitted power may occur if additional channels are added.

The control channel signal has the following appearance:



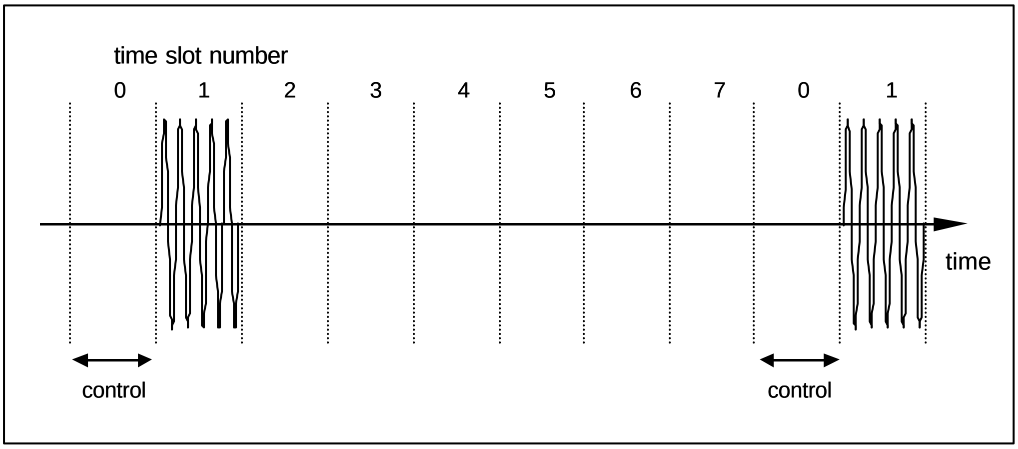
[a] The service range of a base station is subdivided into three roughly equal sectors and therefore also has three antennas pointing in different directions. See the advisory report *GSM base stations* (HCN00b).

For a channel of the base station in which transmission occurs only in the active time slots and the power is simultaneously regulated, the signal may appear as follows:



If the operator does not apply power regulation for the various time slots, the signal in the filled time slots is virtually constant.

For the GSM telephone, the same diagram looks as follows:



Within a frame, the device transmits only during one time slot, with speech being digitised for a period of 4.6 ms – the duration of a frame – and compressed in time to an information pulse of 0.58 ms – the duration of a time slot. As a result, a GSM phone transmits with a pulse frequency of 217 Hz. Owing to the suppression of every 26th frame, there is also extra pulse modulation with a frequency of 217/26 = 8.34 Hz.

Pulse modulation is equivalent to simultaneous modulation of the carrier wave with different frequencies. The result is a system of secondary frequencies around the carrier wave frequency, the side-band frequencies, at distances from the carrier wave that are multiples of 217 Hz and 8.34 Hz. However, the assumption that clearly discernible and possibly biologically effective low-frequency components are present in the electromagnetic signal of a base station or mobile telephone is incorrect. Low-frequency components can only manifest themselves upon exposure if highly specific demodulation of the carrier wave occurs, as in a receiver designed for this purpose. There are no reasons to assume that biological systems have a demodulation mechanism of this kind.

The maximum transmission power of a GSM telephone is 2 W for a GSM-900 device and 1 W for a DCS-1800 device. The effective transmission power is, by application of the time slots, one eighth of this: 0.25 or 0.125 W.

Energy absorption in the body

When a mobile telephone is in use, the antenna of the device is near the user's body, generally near the head. Part of the emitted power is absorbed by the body. The latter is composed of different tissues with widely varying and frequency-dependent electromagnetic characteristics (Gab96, Pey01). The amount of energy that a body can extract from an electromagnetic field is highly dependent on the frequency of the field, the size and dimensions of the body and the tissues in the exposed parts of the body.

Absorption of electromagnetic energy leads to warming of body tissues. Owing to the differing electromagnetic characteristics of the tissues, local differences in temperature gain will arise which are in turn partly cancelled out by heat dissipation through blood circulation. Eventually, thermal equilibrium will be achieved. This means that the supply of heat through exposure to the electromagnetic field and the removal of heat through blood circulation and heat emission to the environment through radiation, convection and sweating are in balance with each other.

Once exposure is stopped, body temperature will gradually return to the pre-exposure level. Calculations and experiments with volunteers show that, in resting individuals, it takes about an hour for the body to return to the starting temperature (NRPB93).

In case of exposure to pulsed fields, the maximum achievable temperature is roughly equal to the temperature that would be caused by exposure to a continuous field with the same average SAR.

Various guidelines and recommendations for exposure limits that have been developed over the last few years provide a maximum SAR for local exposure. In Western European standards, this represents a mean for a volume of 10 g tissue (HCN97, ICN98, REU99), and in the most important US standard a mean for 1 g tissue

(IEEE95). SAR values are known for a number of types of mobile telephone (Nov00). With few exceptions, these do not exceed the standard values at maximum transmission power.

The Committee would point out that the electromagnetic field generated by the antenna of a mobile telephone behaves randomly in the near field (a region within a radius of about 30 cm from the telephone (see footnote in 2.2). Values determined on the basis of measurements and calculations are highly dependent on the defined set-up or configuration. This is because the presence of the head and hand, for example, has a major impact. It is not possible to extrapolate SAR values determined under far-field conditions to a situation in the near field. It is therefore important to have a harmonised standard to unambiguously determine the local SAR in the near field. In Europe, the basic standard EN50361 and product standard EN50360, drawn up by CENELEC, came into force as of 1 October 2001 (CEN01a, CEN01b, EC01). The basic standard regulates which emission requirements products must meet (in this case, the values from the ICNIRP guideline), while the product standard regulates how the emission level must be determined. This represents a major step towards an unambiguous definition of the measurements for determining the SAR values associated with the use of mobile and wireless telephones. There is no simple rule of thumb that can enable results obtained by another measurement procedure to be compared with or extrapolated to values obtained with this new standard.

Significant amounts of electromagnetic energy are only absorbed in the head when making calls on a mobile phone, during which time it is held against the head. This does not occur in any other situation. If the telephone is in use, but is not held to the head (when using a handsfree set, for example) the level of electromagnetic energy absorbed by the body and the region of the body affected will depend on the position of the device relative to the body. When sending or receiving SMS messages, energy absorption is negligible. Composition or reading of a message takes place in standby mode, and sending or receiving a message takes no more than a few seconds. In addition, in this situation the telephone is held at some distance from the body. The concerns expressed in this regard by the British Medical Association in a recent report (BMA01) are therefore unjustified.

If the telephone is on standby, it regularly emits short (1-2 s) pulses for the purpose of position-finding within the network. The intervals between such pulses vary – depending on the network settings – from 20 minutes to several hours. The pulse is initially broadcasted at full power, but the power is then reduced. This reduction will depend on the phone’s position relative to the nearest base station and the setting of that base station. This determines the maximum transmission power of the GSM telephone. If a call takes place, a link is established and the telephone transmits continuously. Here, too, this process takes place initially for a very short time on full power, with the power then being reduced to the minimum level required for a good link. During the call, the telephone transmits as indicated earlier in this chapter.

3.2.2 WAP and GPRS

WAP (Wireless Application Protocol) is a service provided through the standard mobile telephone system and in which data can be retrieved (from the Internet, for example). This can take place via GSM, GPRS or - in due course - UMTS (see below). The power emitted by a mobile telephone using WAP is the same as that emitted during a normal call. However, exposure for a WAP user will be considerably less than if he uses the telephone for a call. After all, users will be viewing information on the device's screen and not holding the device against their head.

GPRS (General Packet Radio System) technology allows users to transmit and receive data with higher speed than with classical GSM-technology. This is achieved by using multiple time slots simultaneously. The average SAR value depends on the number of time slots used. Normal GSM telephones are not designed to use this technology. The dedicated GPRS telephones that will be introduced will have to meet the same requirement as GSM devices, *i.e.* that the SAR introduced in the body does not exceed 2 W/kg. As has been indicated earlier, European guidelines are in force as of October 1, 2001, to determine the SAR in a unequivocal way. They also apply to GPRS telephones.

The GPRS technology is, at the time of drafting of this advisory report, still at the introductory stage.

3.2.3 UMTS

The new system for mobile communication, dubbed UMTS (Universal Mobile Telecommunication System), also known as third generation (3G) mobile telephony, will operate on frequencies around 2 GHz. The individual signal from a mobile UMTS terminal (the device comprises more than just a telephone) will be emitted over a frequencyband of 5 MHz wide. Owing to the nature of the modulation and coding, the signal within that band will look a lot like noise. With UMTS, the information is not transferred by modulations of the carrier wave. If variations in the carrier wave are needed, this will be for network-related reasons.

The maximum power of the mobile terminal will be around 250 mW. Two protocols have been defined. The first protocol applies FDD (Frequency Division Duplex), i.e. the base station and mobile terminal transmit on two different frequencies at the same time. The terminal will transmit continuously during a link, just as with GSM, but in view of the nature of the communication (data, video, internet), this will be in the form of 'bursts' that may vary considerably in length.

The second protocol is Time Division Duplex (TDD). Under this protocol, transmission by the base station and mobile terminal takes place at the same frequency, but not simultaneously. This technology will, however, be used less frequently than FDD.

At the time of drafting this advisory report, it is not yet (publicly) known which protocol is to be used by the various UMTS suppliers. Since the maximum power of UMTS devices is roughly equal to the average power of GSM devices, the field strengths to which UMTS users will be exposed are not expected to differ from those for GSM.

3.3 Wireless telephones

Wireless telephones are intended for use in and around the home, office or company. They have a very low power level and consequently a range of no more than around 300 m. They are intended to communicate with base stations in a house or company. These are not base stations as in mobile telephony, but small units directly connected in-house to the standard telephone network. Unlike mobile phones, portable telephones do not have a dedicated telephone number; the number is that of the fixed link.

3.3.1 Analogue

The well-known older types of wireless telephones for private use employ the CT0 standard. They transmit in the 31 – 40 MHz band. The signal is continuous, with a band width of 25 kHz. The (peak) transmission power of the telephone is 10 mW. The maximum field strength generated by these telephones is therefore much lower than that of a GSM device that has to operate on maximum power.

3.3.2 Digital (DECT)

The modern digital standard for wireless telephones is DECT (Digital Enhanced Cordless Telecommunication). Its range of applications varies from small (private) domestic exchanges to major business exchanges. Like GSM, DECT uses a timedistributed transmission system, which means that the mobile telephones emit short pulses. The system operates at frequencies between 1880 and 1900 MHz and has 10 channels with a 1.728 MHz bandwidth. Within a channel transmission is with 10 ms frames, so with a repetition frequency of 100 Hz. Each frame is divided into 24 time slots. Half of these are used for communication of the base station with the handset, the other half for the reverse connection.

The maximum power of the devices is 250 mW. Since only one time slot is used for each connection, the effective transmitted power is 250/24 = 10.4 mW (rms).

A standard domestic base station uses one channel and can serve up to 8 handsets. The maximum effective transmitted power of a domestic base station therefore is 90 mW. Eight times 10 mW for each time slot used for communication and – in some devices – 10 mW for a time slot permanently used. Larger domestic and business exchanges may have more channels, and therefore more power.

3.4 Bluetooth

Bluetooth is a new system for wireless communication between electronic devices, such as between the computer mouse, keyboard, printer and PC. The range is several metres. The maximum transmission power may be 100 mW, but for most applications it is 1 mW. The frequency used is 2.4 GHz. An important application is a wireless link between a headset/microphone combination and a GSM telephone. This creates a handsfree set in which the SAR in the head is considerably lower (by a factor of 100 to 1000) than with ‘normal’ use of the GSM telephone, since the telephone can be held at some distance from the head, for example in a coat pocket or a bag.

3.5 TETRA

TETRA, which stands for Terrestrial Trunked Radio, is the new standard for mobile radiocommunication to be used by emergency services such as the police, fire and ambulance services. The set-up is similar to that of mobile telephone systems: a network of base stations in contact with portable walkie-talkies or with vehicle-mounted radiotelephones.

TETRA operates in two frequency ranges, 380-395 MHz and 410-425 MHz, and makes use of ‘trunking’ and TDMA (Time Division Multiple Access). Trunking means that all channels are jointly used and that a user is assigned a free channel. In the case of TETRA, TDMA means that each carrier-wave frequency can accommodate 4 calls (‘logic channels’). If high-speed data transfer is required, several logic channels can be assigned. The signal is subdivided into frames and time slots for this purpose, as with

GSM. A frame has a duration of 56.7 ms and is divided into four time slots of 14.2 ms. Thus each of the four simultaneous calls has a duty cycle of 0.25 and a pulse frequency of 17.6 Hz. As with GSM, this only applies to walkie-talkies and radiotelephones. The base stations transmit continuously, *i.e.* all time slots are filled.

The effective power of the walkie-talkies is 0.25 W (max. 1 W) or 0.75 W (maximum power 3 W). No data are available yet to determine whether this equipment meets the SAR limits.

3.6 Reduction in exposure

3.6.1 Handsfree sets

In the first half of the year 2000, various publications appeared concerning a possible increase in the SAR through the use of headsets. With the aid of a headset connected to the mobile telephone (a cable with a microphone and a small loudspeaker to be worn in the ear) it is possible to make calls without holding the telephone against the ear. One of the advantages of the use of a headset is that the user has his or her hands free when telephoning.

By removing the source of electromagnetic energy from the body, it was thought that the amount of energy absorbed in the body would in principle be reduced. However, it is suggested in a publication in *Which?* (Whi00) that the SAR value in the head instead increases on account of conduction of the waves along the cable towards the head.

Prompted by this publication, studies have been conducted in various laboratories. These studies confirm what is revealed by the theoretical analysis set out below for a mobile telephone in combination with a headset. The findings from the *Which?* report are incorrect and are probably based on a measurement error.

Assume that the headset cable is an ideal antenna for 900 or 1800 MHz electromagnetic fields. This ‘headset antenna’ picks up the fields emitted by the mobile telephone. The maximum power P_0 that an ideal antenna can extract from the electromagnetic field is equal to:

$$P_o = \frac{P_{telephone}}{4\pi d^2} \cdot \frac{\lambda^2}{2\pi} \cdot G_T \cdot G_R$$

where $P_{telephone}$ is the maximum transmission power of the mobile telephone, λ is the wavelength of the electromagnetic field, G_T and G_R are the gain factors of the transmitting and receiving antenna and d is the distance between the telephone’s transmitting antenna and the ‘headset antenna’. In practice, G_T and G_R have values between 1 and 2. As an example, take a distance of one wavelength between the transmitting antenna and the cable. This is around 30 cm for 900 MHz, and around 15 cm for 1800 MHz. The formula then indicates that the maximum power available on the 'headset antenna' is only a fraction of what the transmission power may be. With a maximum initial power of 2 W for the GSM telephone, this works out at an available power of around 10 - 40 mW on the headset. (However, the effective power of a GSM device is lower by a factor of 8.)

It can be concluded from the measurement report drawn up by ERA (Ban00), who conducted the measurements for *Which?*, that, instead of local field strength, a high-frequency voltage is measured which is the result of coupling of the measuring antenna with an electrical conductor at a very short distance from the measuring antenna. A measurement set-up of this kind cannot, owing to this undefined coupling, yield reliable results. In a second measurement, ERA shows how the electromagnetic field behaves as a function of distance from the headset. It is apparent from this that, with increasing distance from the headset, the field measured becomes more stable. The coupling between the measuring antenna and the headset apparently decreases and 'real' field strength is measured.

The English company, SARTest Ltd, has performed measurements on mobile telephones in combination with a headset (Man00a, Man00b). These measurements (which in the Committee's view have indeed been performed correctly) show that the use of a headset can substantially reduce the SAR value in the head. The level of reduction is, however, highly dependent on the geometry of the set-up. In the unlikely event of the headset cable being wound around the antenna of the mobile telephone and the end of the cable lying flush against the cheek, directly next to the ear-piece, local measurements reveal a SAR value similar to that for telephoning without a headset.

In the United States, Bit-Babik (Bit01) calculated the SAR in the head and body when using a mobile telephone in combination with a handsfree set.[a] The presence of the body proves to have a major impact: if the telephone and headset are not held close to the body, the SAR in the head is much higher. The length of the headset cable is also important, as certain cable lengths may cause the system to resonate. Nevertheless, a considerable reduction in SAR in the head was achieved, even in the most unfavourable cases, when using a headset.

The Committee's conclusion is that use of a headset generally reduces the SAR substantially and cannot under any circumstances lead to a SAR in the head higher than or similar to that for use of a mobile telephone without a headset.

[a] In the absence of data, the Committee cannot, on the basis of this presentation at a scientific congress, provide an opinion on the quality of the technical design of this study. However, it nevertheless presents the results here as they largely confirm the theoretical expectations.

3.6.2 *Shielding devices*

Various devices are available that, it is claimed by their manufacturers, are capable of reducing exposure to the electromagnetic fields emitted by mobile telephones. These accessories fall into two categories, covers that fit around the telephone and small objects that must be affixed to the telephone itself.

The covers actually afford protection because they contain a metal mesh that partially blocks the electromagnetic fields. However, this will impair the link with the base station, causing the telephone to start transmitting with increasing power. This in turn partly nullifies the effect of the shielding. In general terms, the use of such covers leads to a drop in network quality. The Commission concludes that the employment of these devices is useless.

The effect of objects that must be stuck on a telephone is, according to the manufacturers, based on a sort of ‘absorption’ of the electromagnetic fields. This is impossible, on purely physical grounds. The Committee therefore considers sales promotions for such devices to be misleading.

Chapter 4

Temperature changes

In Chapter 2, the Committee indicated that the exposure limits proposed by the Health Council of the Netherlands (HCN97), ICNIRP (ICN98) and other organisations are based on the prevention of an excessive increase in body temperature. For situations in which only parts of the body are exposed, different exposure limits than for exposure of the whole body have been formulated. This approach is based on the view that an excessive rise in body temperature causes adverse health effects and that, where only certain parts of the body are exposed, the heat generated in those regions can be removed via the unexposed part of the body. As a result, more electromagnetic energy is needed in such a situation in order to arrive at a specific temperature increase. Assuming a maximum acceptable increase of 1°C, the maximum permissible SAR for exposure of just a part of the body is higher than for exposure of the entire body.

In the case of exposure of the head, the Health Council of the Netherlands and ICNIRP have indicated that the permitted SAR is a maximum of 2 W/kg, averaged over an arbitrary volume of 10 g tissue. The American IEEE (IEEE95) gives an SAR limit of 1.6 W/kg over 1 g tissue. These recommendations are based on calculations for exposure of the head in far-field situations. For mobile telephone users, however, a more relevant question is what happens in the case of exposure of the head in the near field, since this is what is actually involved in mobile telephony. It is then important to measure the temperature increase in the various tissues that are exposed to the telephone's electromagnetic fields. On the basis of this information, it can then be determined whether the SAR recommendations must be revised.

An important step towards solving this problem has been taken with a study conducted in the Netherlands by the Utrecht Academic Hospital and the TNO (Netherlands Organisation for Applied Scientific Research) Physical Electronics Laboratory in The Hague (Lee99). This involved a computer model for calculating field strengths in tissue on exposure to an electromagnetic field from a mobile telephone antenna. This was linked to a model that, on the basis of the first model's data, and detailed information about heat dissipation by the circulation, calculates thermoregulation in the various tissues. Calculations have been carried out for a 915 MHz dipole antenna at a distance of 2 cm from the head, with an emitted power of 0.25 W: the maximum effective power of a 900 MHz GSM telephone. It was found that, even with long-term exposure, the temperature increase in areas of skin directly adjacent to the antenna is no more than approximately 0.25°C. The corresponding temperature rise in adjacent brain tissue did not exceed 0.12°C. With increasing distance from the antenna, the temperature increase falls off sharply, and is negligibly small at a distance of several centimetres.

The corresponding SAR values are dependent on the tissue, the volume under consideration and the shape of that volume of tissue. In the standards mentioned above, the tissue volume to be considered is defined as an 'arbitrary shape'. Such a tissue volume may then have a compact form, such as a block form, but can also be for example a thin skin layer. Absorption of electromagnetic energy in a thin layer of this kind may be relatively strong, as a result of which the SAR may exceed the exposure limit. The above-mentioned Utrecht/TNO study reveals the occurrence of SAR maxima of up to 2.28 W/kg (in an arbitrary volume of 1 g). This is therefore considerably higher than the maximum value of 1.6 W/kg laid down by the IEEE for a volume of 1 g tissue. Nevertheless, the temperature rise, as stated, remains limited to no more than 0.25°C. This means that it is not sufficient merely to determine the SAR. Thermoregulation also plays a major role.

The findings from the Utrecht/TNO study have been confirmed by investigations in Japan, the United Kingdom and Italy, in which similar temperature rises were calculated (albeit with less detailed models) (Ber00, Wai00, Wan99). In a recent study in the UK (Par01), the temperature of the skin was measured during a 30-minute telephone call using a mobile telephone. At the side of the head where the telephone was held, the temperature rose by a maximum of 2.3°C. That is considerably more than calculated using the models mentioned above. The Committee suspects a flaw in the measurement methodology, for instance because a direct influence was exerted by the electromagnetic fields of the telephone on the measurement set-up. It was striking that no temperature rise was measured with the telephone switched off, whereas it may be expected that the presence of the telephone and hands would cause the skin temperature to rise. The latter has indeed been found by Gandhi (Gan01). He calculated the maximum temperature rise in the pinna, brain and eye as a result of the presence of a telephone at a temperature of 39°C, as a result of a SAR caused by the telephone of 1.6 W/kg in 1 g of tissue (the ANSI/IEEE limit) and of a SAR of 2.0 W/kg in 10 g tissue (the ICNIRP limit). The temperature rise due to the presence of the telephone was largest in the pinna: 4.5°C. The SAR added a further 0.1-0.2°C. In the brain and eye, the temperature rise as a result of the presence of the telephone was 0.1-0.2°C, and the additional heating produced by the SAR was no more than 0.1°C. Similar figures have been calculated by Bernardi (Ber01).[a] This study showed that the temperature rise caused by the absence of convection (as a result of the presence of a non-functioning GSM telephone) was larger (0.9°C) than that induced by the electromagnetic field (0.01°C).

This information gives the Committee no grounds to revise the existing recommendations for SAR maxima. To ensure a sounder basis for standards, however, the Committee deems it necessary to gain a better understanding of the dosimetry. To this end, more data is required on the relationship between temperature, SAR, tissue type and tissue volume in which these parameters are determined. The Committee therefore recommends an extension of the Utrecht/TNO study (Lee99) and adequate measurements of temperature in and near the head in connection with mobile telephone use.

[a] In the absence of data, the Committee cannot, on the basis of this presentation at a scientific congress, provide an opinion on the quality of the technical design of this study. However, it nevertheless presents the results here as they largely confirm findings from other studies.

Chapter **5**

Health aspects

5.1 Introduction

As a mobile telephone is usually held close to the head when making a call – with the exception of situations in which a handsfree set is used – research on possible health effects mainly focuses on the head. In this advisory report, the Committee therefore concentrates mainly on those studies. An extensive summary of the current level of knowledge has already been provided in the advisory report entitled *Radiofrequency electromagnetic fields (300 Hz – 300 GHz)* (GR 97). Accordingly, in this report, the Committee focuses primarily on studies published after 1997. Relatively limited attention is devoted in this report to *in vivo* studies, and *in vitro* studies are only incidentally discussed. The recent report by the International Expert Group on Mobile Phones from the UK provides a good overview of these studies (IEG00).

Biological versus health effects

In analysing the available data, it is important to distinguish between biological effects and health effects. A biological effect is considered to be a physiological effect that is induced by an external cause and that falls within the natural limits between which processes and functions of a living organism can vary without this leading to adverse health effects. A health effect is the negative consequence for the health of an organism of the inability to sufficiently compensate physiological effects. If an effect has been demonstrated in experimental research on an isolated biological system, for instance an effect on cultured cells, this does not necessarily imply that there will be adverse effects for the health of the organism as a whole. Nor, in the absence of supporting evidence, should effects detected by sensitive measurement methods, such as subtle changes in reaction speed or in the natural pattern of brain waves during sleep in humans, be regarded as harmful to health. The reason for this is that the human body has a great capacity for adequately processing all sort of influences acting on it from outside and, if necessary, effectively resisting them (with the aid of the immune system), compensating for them (homeostasis) or successfully adapting to them physiologically (specifically with the nervous and the endocrine systems).

An example of a biological effect that cannot be regarded as an adverse effect on health is the change brought about by visible light – which is also electromagnetic fields – in the rods and cones in the cells of the retina. These changes lead to electrical signals which are relayed via the optic nerve to the brain, where they are interpreted, allowing individuals to see their environment. One of the most important sensory observations in man is thus brought about by virtue of the fact that electromagnetic fields induce biological effects in the body.

5.2 General health problems and symptoms

Various publications report symptoms that are ascribed to frequent use of a mobile telephone. In Australia, Hocking (Hoc98) assembled a group of forty people with symptoms via a media appeal. These individuals were interviewed over the telephone. The symptoms ranged from heat sensation, headache, dizziness and nausea to visual problems. They sometimes began directly at the start of a telephone call, sometimes later. The symptoms usually vanished within an hour, but sometimes persisted for longer. Because of its design, the study does not show how frequently such symptoms occur and whether there is indeed a correlation with exposure to electromagnetic fields from mobile telephones. However, the type of symptoms matches those in people who have registered in the Netherlands with the Monitoring Network for Environmental Health. This organisation has a database of several hundreds of such registrations. The Committee would like to point out that nonspecific symptoms of this type are associated with a number of ‘syndromes’. The advisory report *Local environmental health concerns* published by the Health Council of the Netherlands examines this in greater detail (HCN01).

A later, more structured study of 17,000 individuals in Sweden and Norway who use mobile telephones on an occupational basis found symptoms similar to those reported by Hocking (Oft00, San01). However, also this study involved the subjective reporting of symptoms and the study was not conducted under controlled conditions, which limits the scientific value of the data. Precisely because subjective symptoms are involved, it is quite conceivable that, given the non-experimental set-up of the study, these have been wrongly ascribed to the use of a mobile telephone. Therefore, on the basis of this study no conclusions can be drawn about the possible existence of a causal link.

Around 31% of the Norwegian callers and 13% of the Swedish callers had occasionally experienced at least one of the symptoms.[a] This occurred relatively more frequently in users of an NMT telephone than in those calling with a GSM unit. There was a clear relationship with the mean length of calls and the number of calls, but no correction was carried out for age or duration of telephone use. In addition, a link also appeared to exist between symptoms ascribed to mobile telephones and symptoms associated with the use of a computer monitor (apart from symptoms of heat sensation). Around 4% of those investigated had consulted a doctor in connection with the symptoms and 45% had themselves taken measures to reduce the symptoms. These steps usually involved a reduction in call time, alternating the side of the head on which the telephone is held or the use of a handsfree set. The investigators conclude that their subjects genuinely experienced the symptoms, but that the findings do not necessarily indicate that they pose a serious health problem.

The Committee, however, feels that people with complaints experience them as a health problem. This justifies research on the cause of these symptoms. It is then of prime importance to determine whether they are caused by the electromagnetic fields produced by mobile telephones. The Continuous Survey of Living Conditions (POLS) conducted by the CBS (Statistics Netherlands) shows that symptoms such as headache, fatigue and dizziness are very common among the population. In 1999, 26% of a representative random sample of the Dutch population reported headache, 31% reported fatigue and 10% reported dizziness (CBS99). The Committee considers that a study should be undertaken in the Netherlands to determine whether symptoms of this kind also occur in connection with electromagnetic field exposure under controlled conditions (provocation studies), both in people who have reported symptoms and in symptom-free individuals.

[a] The Committee doubts the representativeness and thus the direct comparability of the random samples in both countries. The authors indicate that, in the Norwegian group, a higher percentage of symptoms occurred in those willing to participate in the trial (responders) than in the non-responders (some of whom were later interviewed in a non-response analysis). There was no such difference in the Swedish group. In addition, there were differences in age distribution and mobile telephone use between the Norwegian and Swedish groups.

The scientific literature contains just one publication concerning a provocation study of this kind. In two separate experiments, Koivisto (Koi01) exposed a total of 96 volunteers (of whom 85 were in possession of a mobile telephone) to a signal from a GSM telephone, half for one hour and the other half for 30 minutes. Directly before, halfway through and directly after exposure, a record was made of subjective symptoms such as headache, dizziness and fatigue. In this group of healthy volunteers, who suffered no symptoms before the start of the experiment, exposure did not affect the occurrence of the symptoms.

Chia (Chi00) investigated the occurrence of symptoms related to the use of a digital mobile telephone in 808 inhabitants of a district in Singapore. The study was conducted by means of interviews, using questionnaires. It was presented as a study of headache symptoms, which included questions about other symptoms relating to brain function. Last of all, there was a series of questions about mobile telephone use. In mobile telephone users (defined as those using a mobile telephone on average once a day), headache occurred significantly more frequently than in the control group. Furthermore, there was a trend for more symptoms to be associated with longer calls. For all other symptoms investigated, no link with mobile telephoning was found. Use of a handsfree set was related to reduced incidence of headache symptoms.

The Commission points out that this study has a non-experimental set-up and that the percentage of participants is low (45% of those approached). Furthermore, no sharp distinction was made between users of a mobile telephone and the control group. All this limits the value of the results.

Cox & Luxton (Cox00) report on an unspecified number of mobile telephone users in England with nonspecific symptoms. They suggest that symptoms such as dizziness, nausea and headache might result from unilateral stimulation on the vestibular organ in the middle ear by the telephone's electromagnetic fields. The Committee finds this an interesting idea and considers that further research is warranted. Apart from that, the literature contains no data on direct or indirect stimulation of the organ of balance (or its individual components) by electromagnetic fields (see Annex E). However, it is known that temperature differences can stimulate the vestibular organ. If this occurs unilaterally, symptoms associated with motion sickness may arise, such as dizziness and nausea (Annex E). This effect is observed in experiments with unilateral cooling of the vestibular organ. Although an increase of the temperature also stimulates the vestibular organ, it is not clear whether this leads to the same extent to observable symptoms. Also the minimum increase in temperature leading to stimulation is not known.

The Committee concludes that, based on these studies of general health problems and symptoms, no conclusions can be drawn concerning a causal link with mobile telephone usage. The prime reasons for this are the non-experimental set-up of the studies, the generally high percentages of non-participation and a frequent lack of understanding of the population characteristics of non-participants. None of the studies, whether alone or *in toto*, meets the criteria for establishing effects as laid down by the Committee in section 1.4. In addition, the health effects investigated are also very general in nature and could be due to all sorts of causes.

5.3 Neurological effects

Various studies have been carried out to determine whether exposure to electromagnetic fields from a mobile telephone can influence certain brain functions. Such studies always involve short-term exposure and short-tern effects.

5.3.1 Cognitive functions

Preece (Pre99) studied cognitive functions such as (short-term) memory and reaction speed in healthy volunteers who were exposed to 915 MHz fields from a simulated GSM telephone. The telephone was secured in the usual position and emitted either no signal, or a continuous 915 MHz signal, or a 217 Hz-modulated 915 MHz field. The latter matches the GSM signal. After two practice sessions, the volunteers were tested under the three test conditions, which were applied in a random sequence. The sessions involved completing a series of 15 different computerised tests. An extended analysis of all the variables indicated that only when the continuous signal was applied did a small but significant increase occur in one of the 15 tests, a measurement of reaction speed.

Since the effect found does not occur with the GSM signal, but only with the continuous electromagnetic field, the Committee considers it to be of negligible significance for current mobile telephony. In general terms, however, if the effect is genuine (rather than a random false positive), this indicates that electromagnetic fields might have a direct influence on brain activity. This would then be greater with a continuous field than with a pulsed signal. An alternative is the thermal load, which is eight times higher with continuous field than with a pulsed one. In Chapter 4, the Committee indicated that the temperature rise in the brain as a result of exposure to a GSM signal is no more than 0.12°C. The temperature rise for a continuous signal would then be maximally around 1°C, which might affect neuronal impulse conduction.

Koivisto (Koi00) conducted a similar study on 48 healthy adult volunteers. A series of 12 different tests for reaction time was performed, using a mobile telephone in the usual position. This emitted a 905 MHz, 217 Hz-pulsed GSM signal. Testing was carried out with and without a signal. In two of the tests, a slight increase in reaction speed was recorded, and a small reduction in calculation speed in another test. However, the statistical processing of the data raises certain doubts as to the value of this finding. The Committee takes the view that it is incorrect to exclude tests from the analysis which are more than two standard deviations from a volunteer's mean. Furthermore, no information is provided on the number of cases involved, which makes it impossible to check the reliability of the conclusions. Another striking feature is that the results are not in accordance with those recorded by Preece.

Krause (Kra00) investigated the influence of exposure to a 905 MHz, 217 Hz-pulsed GSM signal on electrical activity in the brain during a memory test. The EEG was subdivided into 4 frequency ranges: 4-6 Hz, 6-8 Hz, 8-10 Hz and 10-12 Hz. Sets of four words were presented and, two seconds later, subjects were asked whether a fifth word fitted in the sequence. In all frequency ranges, changes were observed in brain activity as a function of time, but only in the second part of the test, i.e. during the recall phase. At 4-6 Hz, this change was a reduction in activity, while in the other frequency ranges the change observed was first an increase and then a decrease. According to the authors, all this indicates a slight acceleration in performance of the mental task.

In Hong Kong, Lee (Lee01) compared two groups of students, one of which used mobile telephones while the other did not. In one of the three tests conducted on attention and concentration, the telephone users scored better than their peers without telephones. The authors speculate that this might be explained by an effect on the brain by the telephone's electromagnetic fields, but also by an intrinsic difference between the two groups (which otherwise matched closely on various social and intelligence criteria). However, this was a study with a non-experimental set-up. The Committee has already indicated in section 5.2 that such studies have limited evidential value for a cause-effect relation.

The Committee concludes that it seems possible that electromagnetic fields might influence brain activity under certain circumstances. However, only slight and reversible biological effects are involved which might even be regarded as beneficial for the most part. They should certainly not be regarded as effects that are harmful to health.

Various studies have been conducted on the influence of exposure to pulsed radio-frequency electromagnetic fields on the learning behaviour of laboratory animals. In a number of these, an effect has been found only at SAR values associated with an increase in body temperature of about 1°C (see IEG00). In two studies conducted by Lai, however, an effect was found at a much lower SAR values.

Exposure of rats to 2.45 GHz in 2 µs pulses, 500 per second, with a SAR of 0.6 W/kg, for 45 minutes a day on 10 consecutive days, led to daily increases in the number of errors made in a food search test (Lai94). Exposure for 20 minutes a day to the same regime resulted in a decrease in the number of errors during the first two days. However, there was no effect when viewed over the entire test period (Lai89).

Exposure to the same field pattern, but doubling the value of the SAR to 1.2 W/kg, for 2 x 60 minutes on three consecutive days, led to a decrease in the efficiency of search behaviour. The test used in this case involved the location of an underwater platform (Wan00). It has been suggested that the energy per pulse, calculated at 2.4 mJ/kg, would be high enough to enable the animals to 'hear' the electromagnetic fields (HCN97, IEG00). If true, this would undermine the analysis of this experiment.

Sienkiewicz (Sie00) investigated food searching behaviour in mice, using a test similar to that used by Lai (Lai89, Lai94) but with a much lower SAR (0.05 W/kg). The mice were exposed to a mobile telephone signal of 900 MHz, 576 µs pulse, 217 pulses per second (217 Hz), for 45 minutes a day over a period of 10 days. No effect was observed.

The Committee concludes that these experiments provide no clear picture of a possible effect of exposure to pulsed electromagnetic fields on the learning behaviour of rodents, at relatively low SAR values . The most representative experiment for the purposes of comparison with mobile telephone users, that by Sienkewicz (Sie00), does not reveal any effect. Nevertheless, the Committee considers experiments of this kind to be unsuitable for demonstrating an effect from mobile telephoning on the learning capacity of humans. Experiments with volunteers, as described earlier, are much more appropriate for this purpose.

The Committee’s conclusion is that the available data does not indicate that cognitive capacities are adversely affected, even when a mobile telephone is frequently used. However, there are still many questions and uncertainties, and therefore the Committee makes proposals in this advisory report for further research.

5.3.2 *Sleep*

At the universities of Mainz and Zürich, research is being conducted on the effects on sleep and brain activity during sleep of exposure to electromagnetic fields from GSM telephones.

In Mainz, sleeping healthy volunteers were exposed to a 0.5 W/m^2 strong electromagnetic field from a GSM telephone (Man96). After one night of habituation, two experimental nights followed in which exposure took place randomly during the first or second night. The time elapsing before the volunteers fell asleep was considerably shorter during exposure than during the control night. In addition, during exposure, the total period of REM (Rapid Eye Movement) sleep was shorter, while the intensity of natural brain activity during REM sleep increased. After exposure, the test subjects felt no less or better rested, but felt calmer and more energetic the next day.

In a follow-up study with the same design, a power density of 0.2 W/m^2 was applied. An antenna was used for this purpose, which enabled a more homogenous field to be achieved at head level (Wag98). The SAR was calculated as 0.3 W/kg on the vertex, and a maximum of 0.6 W/kg at the back of the neck. Under these conditions, there was no appreciable difference between the exposure night and the control night in terms of time taken to fall asleep, nor was there a difference in the total length of REM sleep or in brain activity.

In a second follow-up study, 20 volunteers were exposed to a power density of 50 W/m^2, equivalent to a maximum SAR of 1.8 W/kg (Wag00). The design used was the same as in the previous study (Wag98), except that the test subjects now underwent two test sessions, with a minimum of one week in between. In this study, no difference between the exposure night and control night was found for any of the parameters studied. The authors put forward the possible explanation that, in the first study (Man96), in which the most pronounced effects were found, the electromagnetic field was linearly polarised, whereas circular polarisation was applied in the follow-up studies. The Committee considers that, by virtue of this and other differences, the studies cannot be properly compared, but should be assessed separately. So, only in the first study an effect was found, which to date has not been reproduced.

Borbély (Bor99) exposed 24 healthy volunteers in the sleep laboratory to a 900 MHz pseudo-GSM signal. The main difference from the signal from a mobile telephone was the duty cycle, which was 87.5% instead of the 12.5% used in telephones (which means that seven time slots were used instead of one). After one habituation night, the test subjects were studied for two nights: one without and one with exposure. In the latter case, the source was alternately switched on and off, at intervals of 15 minutes. The period of nocturnal awakening compared with the habituation night varied according to the sequence of the exposure night and control night. Those exposed during the first night woke up less often, and that remained so during the following control night. In the other group, waking during the first (control) night increased, and decreased during the exposure night (to the first group's level). Exposure thus seems to have a sleep-promoting effect, but the unexplained large increase in awakenings of the second group during the control night precludes a proper analysis of the effect. During the exposure night, minor differences in the EEG spectrum during the non-REM parts of the sleep were observed, independent of the exposure sequence.

A second study by the Zürich group focused on the effects on sleep of exposure before falling sleep (Hub00). Exposure to a GSM signal was carried out on the left or right side of the head, with a mean SAR in the respective half of the brain of 0.14 W/kg, for 30 minutes. The volunteers were deemed to be sleeping 10 minutes later. These experiments took place in the morning, after the volunteers had slept for only four hours the previous night. The controls followed the same sleep regime, but were not exposed. Exposure had no impact on the time taken to fall asleep, the length of the various sleep stages or the extent to which the volunteers felt rested after their sleep. The only effects were changes in the EEG spectrum during the first 30 minutes of non-REM sleep. The conclusion is that exposure for half an hour to an electromagnetic field corresponding to a GSM signal induces physiological changes in the brain which persist for at least half an hour and lead to measurable changes in the EEG. There were, however, no effects on health. Similar changes in the EEG spectrum to those found in both experiments also occur as a result of caffeine use, hormonal fluctuations during pregnancy and during the menstrual cycle (Bru94, Dri96, Lan95).

The Committee concludes that the data relating to effects on the brain during sleep are ambiguous. Although effects on the EEG pattern have been observed, this was during the non-REM phases in the case of the studies conducted in Mainz, while the effects in the studies in Zürich conversely occurred during the REM phases. No correlation with increasing field strength was found. The time-lag effect found in the study by Huber is striking. This should be investigated further.

The Committee also concludes that, on the basis of these findings, there is no reason to suppose that the effects lead to health problems. It points out that similar effects have also been found as a result of caffeine consumption and natural hormonal fluctuations. However, all the studies have been conducted with young healthy volunteers. It should be determined whether people with existing sleep-related or other disorders might be more sensitive.

5.3.3 Brain activity during waking

Studies of brain activity in non-sleeping volunteers do not yield a clear picture either.

Röschke and Mann (Rös97) exposed volunteers to the electromagnetic field from a GSM telephone located 40 cm from the vertex. They incorrectly considered this as corresponding to normal use. In fact, this involves exposure in the far field. The field strength at 40 cm was 0.5 W/cm^2, i.e. equal to that in their first sleep experiment (Man96) in which effects were detected. During exposure, which lasted 3.5 minutes (simulating a telephone call) no changes in the EEG were detected.

Eulitz (Eul98) investigated the EEGs of test subjects during their response to an acoustic signal. A GSM telephone was attached to the head in the usual position and could be remotely activated without the test subjects noticing. The peak transmission power was 2.8 W, with the effective transmission power thus being 0.35 W. Exposure had no measurable impact on mean EEG. Only in a specific frequency band (18.75 - 31.25 Hz) were slight anomalies measurable. These mainly occurred in the brain hemisphere nearest to the telephone.

Freude (Fre00) used the same experimental design to measure specific aspects of brain activity during the performance of certain reaction tests. One of the tasks was aimed at measuring so-called slow brain potentials, activities which precede the performance of controlled movements and which are connected with the processing of information by the brain. Exposure led to a slight reduction in the strength of these slow brain potentials, particularly in parts of the brain nearest to the telephone. Nevertheless, exposure was not found to have any impact on performance of the three tasks.

The Committee concludes from this data that electromagnetic fields from mobile telephones could conceivably exert an influence on certain brain activities. This particularly concerns those parts of the brain closest to the telephone, and the changes in question are so subtle that they can only be measured using sensitive equipment. There is no evidence that the changes measured persist after exposure comes to an end. These changes had no impact either on the performance of assigned tasks or on the test subjects’ health. It would be interesting to investigate the extent to which these effects occur in association with other factors, as indicated above for changes in EEG during sleep.

5.4 Cancer

For some time there has been a debate about whether exposure to radio-frequency electromagnetic fields is associated with an elevated risk of developing cancer. In recent years, this debate has focused on a possible impact on health from the use of mobile telephones. This was sparked after the publicity in 1993 regarding the claim by an inhabitant of Florida that his wife had developed a brain tumour as a result of her frequent use of a mobile telephone. It subsequently emerged that there was surprisingly little scientific information on this particular mode of exposure. Data available at the time related only to far-field situations (for example, living or working in the vicinity of a radio and television transmitter or radar installation). However, nothing specific was known about regular exposure in the near field, as is the case with mobile telephones. This was true not only of long-term effects, such as cancer, but also of short-term effects, which the Committee has discussed in the preceding sections.

Since concerns are increasingly being expressed by society concerning the safety of mobile telephones, research has been initiated in many places around the world. In the United States, the telecommunications industry has invested around 27 million dollars in a research programme. This programme was launched in 1994, led by an independent organisation specially established for this purpose, Wireless Technology Research (Car00).

5.4.1 *Brain tumours*

As stated, concerns about the safety of mobile telephones initially focused on the question of whether the electromagnetic fields emitted by the antenna could cause the development of brain tumours or promote their growth. Over the last few years, various epidemiological studies have been published investigating whether a link exists between mobile telephone use and the incidence of brain tumours. Animal experiments have also been conducted.

Hardell (Har99) conducted a case-control study on 209 patients with brain tumours and 425 controls. Taking all the brain tumours together, no link was found between mobile telephone use and the occurrence of brain tumours. This was true both of users of analogue telephones and those who used a digital (GSM) telephone. In one subcategory of patients with a tumour on the side of the brain, the tumours appeared to occur more frequently on the side of the head where the telephone was usually held. This link was, however, not significant and was only found in analogue telephone users.

The Committee would point out in this regard that it is not certain whether people's recollection about the side of the head against which they hold the telephone is accurate enough. It also considers it likely that people do not always hold the telephone on the same side of the head, but alternate this. In addition, patients might report on this in a biased way if the object of the research were known. Research on this so-called laterality can better be conducted in a cohort study. In this way, the side of the head to which the telephone is preferably held can be recorded before a brain tumour arises, and thus also without having to trust users' recollections. The Committee considers that, without more accurate and reliable data on laterality, no conclusion can be reached concerning possible links.

From 1994 to 1998, Muscat (Mus00) conducted a case-control study on 469 brain tumour patients and 422 controls. The telephones used were mainly analogue models. No difference in overall tumour incidence was found between subjects using the telephone ‘ever’, ’infrequent’ or ‘frequent’. Nor was there link between the length of use and the occurrence of brain tumours. The mean length of mobile telephone use was 2.8 years for patients and 2.7 years for the controls. For tumours in the cerebrum, there was a weak, non-significant association between the brain hemisphere where the tumour was located and the side on which the telephone was usually held. However, for the subcategory of tumours in the temporal lobe (which is located in the temporal region of the head and thus closest to the telephone), the relationship was exactly the reverse. Relatively more tumours were to found to occur on the opposite side of the head from that on which the telephone was held. However, in view of the small numbers of tumours involved, this could simply be due to chance. With regard to the various histological types, only in the case of neuroepithelial tumours was a non-significantly increased relative risk found (RR = 2.1; 95% confidence interval 0.9 - 4.7).

In a larger case-control study of similar design, Inskip (Ins01) collected data from 782 patients and 799 controls over the same period, 1994-1998, as in the study by Muscat. In this study, too, no link was found between use of a mobile telephone (surmised by the authors to be mainly of the analogue type) and the occurrence of brain tumours. This was true both of the total number of tumours and of the various individual subtypes. With regard to neuroepithelial tumours, a relative risk of 0.5 (95% confidence interval 0.1 - 2.0) was found. There was no association between the location of the tumour and the side of the head on which the telephone was normally held, nor was there an elevated risk for those using the telephone for more than one hour a day or for those who had been regularly using it for 5 years or more (2.6% and 3.3% respectively of the total number of those studied).

The most recent study in this series is a cohort study in Denmark. Johansson (Joh01) monitored a group of more then 420,000 mobile telephone users from 1982 to 1995. Data on the occurrence of tumours was obtained from national cancer records. In this group, the probability of developing a brain tumour did not differ from that of the Danish population as a whole. No correlation was found with mean call time, duration of telephone use, age at start of use, or telephone type (analogue or digital). This applied both to brain tumours in general and to each of the various subtypes. However. most people had not been using mobile telephones that long. Only seven per cent had had a subscription for more than two years.

The Committee would like to make a number of comments on this data. Firstly, it is debatable whether results for analogue telephone users can be extrapolated to digital telephone users. The study by Johansen does not, however, indicate that there are differences between the two groups. In addition, a major question is whether the period over which the telephones were used was indeed long enough to produce any observable impact on the development of brain tumours. It is only since few years that the use of mobile telephones has become really widespread. Inskip analysed the data according to the year in which people began using their mobile telephones. The classification ran from before 1990 to 1995-1998. In no instance was there a link between duration of use and relative risk. Johansen also found no link between the time that had passed since subjects first started to use their mobile telephone (the longest use category being five years or more) and the occurrence of tumours. In both studies, however, the number of people in the longest use category is relatively low. A major international study is currently being conducted under the auspices of the International Agency for Research on Cancer (IARC) to examine the possible relationship between (digital) mobile telephone use and the occurrence of tumours in the head and neck region (Car99). The first results from this study are not due until 2003.

The above epidemiological studies found no link between exposure to electromagnetic fields from mobile telephones and the occurrence of brain tumours. This finding is substantiated by data from laboratory animal trials.

In the course of a two-year study, Adey (Ade99, Ade00) exposed rats to electromagnetic fields with a signal form of the kind in use in mobile telephony in the US. The animals were exposed for a period of 4 hours a day, 5 days a week. The SAR in the brain was 1.1 - 1.6 W/kg. No effect was found on the occurrence of spontaneous and chemically induced brain tumours.

In another 2-year study, Zook (Zoo01) exposed rats to a mobile telephone signal for 6 hours a day, 5 days a week. The SAR in the animals' brains was 1 W/kg. This study also failed to find any effect on chemically induced tumours.

Higashikubo (Hig99) studied the effect of two different American mobile telephone signals on inoculated 9L brain tumours. Exposure resulted in an SAR of approximately 0.75 W/kg in the brain and took place for 4 hours a day, 5 days a week, from 4 weeks before until 150 days after inoculation. No effect was found.

Salford (Sal93) exposed rats to a 915 MHz, FM-modulated field for 2 - 3 weeks (7 hours a day, 5 days a week). The maximum SAR in the brain was 8.3 W/kg. No effect was found on brain tumours that had been inoculated five days before the start of this exposure.

The studies by Lai (Lai95, Lai96) deserves a separate mention in this context. On exposing rats to a continuous or pulsed 2450 MHz field for 2 hours, resulting in a SAR of 0.5 or 2.0 W/kg in the brain, the author found an increase in the number of breaks in the DNA in brain tissue compared with non-exposed rats. This finding is often cited as an argument to support the view that radiofrequency electromagnetic fields may cause cancer.

Others have unsuccessfully attempted to reproduce these findings (Mal97, Mal98). It has been suggested that the method used for sacrificing the animals might have caused artefacts (Mal98), while the technique used by Lai for detecting DNA breaks is put forward as having actually caused them (Mal97, Mal98 Vija00).

The Committee deems it highly likely that Lai's findings are due to deficiencies in the experimental procedures.

5.4.2 *Other forms of cancer*

As indicated above, research on the possible impact of mobile telephony on the development of cancer has mainly focussed on brain tumours. Other forms of cancer have been investigated in only two epidemiological studies which, because of their suboptimal design, are of only limited evidential interest.

Dreyer (Dre99) investigated mortality among mobile telephone users. Two groups were distinguished: portable analogue telephone users and users of a (fixed) car telephone. With the aid of information supplied by the telephone companies, information was collected on calling behaviour and this was linked to the National Death Index, which also contains data on cause of death. No differences in death between the two groups were found in terms of cancer in general, brain tumours, leukaemia and cardiovascular diseases. Nor was there an effect from mean call time (median 0.8 minutes a day versus 5.0 minutes a day) or period of use (median 1.6 years versus 3.8 years). The most important limitations of this study are the short follow-up period and the small number of deaths diagnosed as brain tumours or leukaemia (6 and 15 respectively out of a total of 765).

Employees of mobile telephone manufacturers may, during their work, be exposed to radiofrequency electromagnetic fields from the equipment they make. Morgan (Mor00) investigated mortality as a result of brain tumours, lymphomas, leukaemia and various other diseases in the Motorola workforce. Exposure was estimated on the basis of job description. Neither for the investigated population as a whole nor for subgroups with an estimated relatively high exposure level did the mortality pattern for each of the causes investigated differ from that of control groups.

Of more interest in this respect is laboratory animal research.

Chagnaud (Cha99) exposed rats to a 900 MHz GSM signal for 2 hours a day over a two-week period, with a SAR of 0.075 or 0.27 W/kg averaged over the body. This treatment had no effect on the development of mammary tumours induced by benzo(a)pyrene.

Hepatic tumours may be induced in a rat by injecting diethyl nitrosourea, followed by removal of part of the liver. Using this technique, Imaida (Ima98a, Ima98b) investigated the effects of exposing the liver to the 930 MHz or 1.5 GHz type fields used in Japan for mobile telephony. The animals were exposed for 1.5 hours a day, 5 days a week over a 6-week period, and the SAR in the liver did not exceed 2 W/kg. Exposure had no influence on carcinogenesis.

Using a mouse strain that has been genetically modified to spontaneously develop lymphomas, Repacholi (Rep97) studied the effect of exposure to a 900 MHz GSM signal. Exposure took place for 30 minutes a day over an 18-month period. The overall effect of the treatment was a doubling of the number of tumours. The dosimetry of this study is, however, somewhat problematic: the mean SAR varied from 0.13 to 4.2 W/kg since the animals were able to move about freely through their cage. Consequently, a possible dose-effect relation cannot be established. The study is currently being repeated in two independent laboratories, under better defined experimental conditions.

Various authors have investigated the effect on tumour growth of exposure to electromagnetic fields with frequencies other than those used in mobile telephony (Cho92, Fre98a, Fre98b, San88, Tol97, Wu94). In all cases, long-term exposure to low fields strengths was involved, and no effects were found.

5.4.3 *Conclusions*

The Committee concludes that the results of the epidemiological studies yield no evidence of the existence of a correlation between mobile telephone use and the occurrence of brain tumours or other forms of cancer in the relatively short term. Animals studies support this conclusion. Only in the study by Repacholi (Rep97) has an effect been found. As stated, the design of that study did not permit clear conclusions to be drawn. It is also doubtful whether a mouse strain exhibiting a high spontaneous incidence of tumours as a result of genetic mutation is in fact a good model for humans.

In this report, the Committee does not deal in detail with any *in vitro* research on possible induction of cancer. It considers that no evidence has emerged from such research of a possible influence of exposure to electromagnetic fields on the occurrence or development of cancer. For a recent summary of current developments, see the report by the IEGMP (IEG00).

The Committee points out that tumours in humans often become manifest only after a latency period of a few years up to several decades. Digital mobile telephones, such as GSMs, have been in widespread use for only a few years. The Committee therefore takes the view that further research is needed, both epidemiological studies and research on laboratory animals. The international study to investigate a correlation between mobile telephone use and the occurrence of tumours in the head and neck region, which is currently being conducted under the auspices of the IARC (Car99), is an important project that will provide greater understanding in several years' time.

5.5 Other effects

5.5.1 Cardiovascular system

Mann investigated the influence of exposure to the electromagnetic field of a mobile telephone on natural heart rate variability during sleep (Man98). The design of the study was the same as that used to determine the effects on brain activity during sleep (see 5.3.2). The maximum field strength was 0.5 W/m^2. Such exposure proved to have no influence on natural heart rate variability.

One study that is often cited by people attributing all kinds of symptoms to electromagnetic fields is that in which Braune found an influence on blood pressure (Bra98). This study has been criticized to be of limited evidential value (Rei98), due to the small number of ten test subjects. However, the same authors have recently reported that their results are due to a direct influence of the electromagnetic field on the measuring equipment and, hence, do not indicate a physiological effect (MWN01).

The Committee concludes that no evidence exists of effects on the cardiovascular system.

5.5.2 *Melatonin and other hormones*

Mann (Man98) exposed healthy volunteers during sleep to a 900 MHz GSM signal with a power density of 0.2 W/m^2 (see 5.3.2). Every 20 minutes, blood was taken and concentrations of growth hormone, cortisol, luteinising hormone and melatonin were determined. Only a change in cortisol level was found. This increased slightly in the first hour of exposure, but fell back again to control values. The authors regard this as an adaptation of the body to the signal.

Radon (Rad01) determined the concentration of various hormones, including melatonin and cortisol, in the saliva of test subjects. These were exposed to a GSM signal with a power density of 1 W/m^2 for four hours, resulting in a maximum SAR of 0.025 W/kg in the head. Owing to diurnal variations in hormone levels, exposure took place both during the day and at night. For none of the hormones investigated did exposure have an influence on their concentration in saliva.

De Sèze (DeS99) investigated the effect of exposure to electromagnetic fields from GSM telephones on the melatonin level in blood. Test subjects were exposed to the fields from a 900 MHz or 1800 MHz telephone operating on maximum power. This exposure lasted for 2 hours a day, five days a week over a four-week period. The maximum SAR at the side of the head where the telephone was held was 0.1 - 0.3 W/kg. Blood was taken four times over 24 hours at intervals of 1 - 3 hours, before, during and after the exposure period. At none of these measurement points an anomaly in daily variations in melatonin level was found.

The studies conducted with laboratory animals do not reveal any clear effects for GSM fields on hormone levels.

Vollrath (Vol97) found no effect in rats and hamsters on melatonin levels following exposure for between 15 minutes and 6 hours to 900 MHz fields. The SAR in the rats was 0.06 - 0.36 W/kg, while in the hamsters it was 0.04 W/kg .

Heikkinen (Hei99) exposed rats to 900 MHz fields from an analogue telephone for 1.5 hours a day, 5 days a week over a 17-month period. The SAR was 1.5 W/kg (continuous field) or 0.35 W/kg (pulsed field). This exposure had no effect on melatonin levels in the blood.

In a study on the effects of exposure to electromagnetic fields from mobile telephones on the development of hepatic tumours (see 5.4.2), Imaida (Ima98a, Ima98b) exposed rats to 929 MHz with an SAR of 0.58 - 0.80 W/kg or 1439 MHz with an SAR of 0.45 - 0.68 W/kg. Exposure was for 90 minutes a day, 5 days a week over a 6-week period. In the exposed animals, corticosterone, adrenocorticotrope hormone and melatonin levels were elevated relative to the values for sham exposed animals. This was, however, not always the case relative to the values obtained in untreated controls. In addition, there was a difference of a factor of two between the melatonin values in both experiments.

The Committee's conclusion is that there is no clear evidence that exposure to electromagnetic fields from mobile telephones has any effect on hormone levels.

5.5.3 Blood-brain barrier

The blood-brain barrier is a layer between the blood vessel endothelium and brain tissue that is virtually impenetrable to high molecular weight substances, such as proteins. Leakage of such substances may give rise to undesirable effects in the brain. It is therefore important that the blood-brain barrier remain intact. A number of studies from the 1970s and 1980s seem to indicate that exposure to pulsed electromagnetic fields affects the permeability of the blood-brain barrier to saccharides (Alb79, Alb81, Osc77). These effects have not, however, been reproduced in more recent studies (Gru82, Lin80, Mer78, Pre79, War82, War85).

Using histological techniques, some recent Swedish studies have shown that in rats exposed to 915 MHz electromagnetic fields for 2 - 960 minutes, leakage of the protein albumin through the blood-brain barrier occurs more frequently than in control animals (Per97, Sal94). This phenomenon occurs even at extremely low SAR values of around 1 mW/kg and arises more frequently on exposure to a continuous field than with exposure to a pulse-modulated field. However, there is no clear dose-effect relation. The authors argue that, since their detection method is extremely sensitive, the very small effects involved are unlikely to result in damage to health. This conclusion is endorsed by Fritze who, in similar research following exposure for 4 hours only at an SAR of 7.5 W/kg, found significantly greater albumin leakage (Fri97). With exposure to 1439 MHz fields for a much longer period, 2 - 4 weeks, and an SAR of 2 W/kg, Tsurita found no induction of albumin leakage through the blood-brain barrier (Tsu00).

The Committee concludes that, since the effects initially found for exposure to electromagnetic fields on the blood-brain barrier could not be reproduced, such effects have not been demonstrated.

5.5.4 Immune system

Only very limited scientific data exist for possible effects of electromagnetic fields on the operation of the immune system. In a recent study, Bosculo (Bos01) compared women living in the vicinity of radio and television transmitters (mean electrical field strength 4.3 ± 1.4 V/m) with a control group (mean electrical field strength < 1.8 V/m). In the 'exposed' group, certain types of cells of the immune system were reduced in number compared with the control group. However, the authors put forward the alternative explanation that the modification in immunecompetent cells may also be brought about via the nervous system. It is unclear whether this is a direct consequence of the effect of the electromagnetic fields, or a psychosomatic effect caused by living close to transmitters. The possible implications for health are also unknown.

The study by Radon (Rad01) cited in section 5.5.2 also examined the effect on the immune system of exposing the head to a GSM signal. No effect was detected in this study.

Tuschl (Tus99) investigated immune parameters in the blood of physiotherapists working with diathermy equipment (which involves exposure to field strengths that often exceeded the exposure limits) and found no anomalies.

The Committee considers that, based on this data, there is no convincing evidence that electromagnetic fields exert an effect on the immune system.

5.6 Difference between adults and children

Following recommendations from the International Expert Group on Mobile Phones (IEGMP) (IEG00), the UK government recently published a brochure recommending that children up to the age of about 16 should use mobile telephones as little as possible. The IEGMP suspects that, since they are still developing, children are more sensitive to influences from electromagnetic fields. The supporting argument provided is that children's brain tissue is more conductive than that of adults, since it has a higher water content and ion concentrations. This argument merits a brief discussion of the early development of the human head and brain.

In neonates, the head accounts for about a quarter of physical height. In adults, the corresponding proportion is around 10%. Growth of the head primarily takes place during the first ten years of life. During puberty, the rest of the body grows rapidly, causing the head-body ratio to decrease. The circumference of the head of a one-year-old infant is approximately 84% of that in adults. The corresponding percentage for a 7-year-old is 93-95% (Pra88). This growth mainly takes place in the skull and brain.

Structures such as the internal parts of the auditory organ and the eyes do not grow after birth (Eis76). The thickness of the cranial bones increases in a virtually linear fashion during the first twelve years after birth, with growth then decelerating sharply before coming to a stop at around 18 years of age (Koe95). The water and ion level in the cranial bones, and thus conductivity, decreases during this period. As a result, and on account of growth in thickness, the barrier function of the cranial bones increases.

During the first year of life, brain growth is the result of an increase both in the number of brain cells, and in their weight (Fei78). After this time, only the weight of the cells increases. Myelination of the brain chiefly occurs in the first two years of life (Hol86, Kna95). This means that there is a reduction in the ion concentrations (and thus electrical conductivity) of the brain during early development, but that there is subsequently very little change.

A recent publication describes measured changes in the dielectric properties of various tissues in the rat, from birth up to an age of 70 days (Pey01). The conductivity of both cerebral tissue and the cranium decreases continuously over that period. How and whether these data can be extrapolated to humans is unclear.

In a model-based study of exposure to a mobile telephone antenna, Schönborn (Sch98) calculated the SAR for three different models of the head based on MRI scans, namely for an adult, a 3-year-old and a 7-year-old child. These calculations showed that no difference exists between these models in terms of absorption of electromagnetic fields. Given the somewhat smaller dimensions of the children's heads, the mean quantity of absorbed energy per unit volume only is somewhat higher than for an adult. However, the calculations use the same dielectric parameters for all ages. The effect of using an age-dependent magnitude for these parameters is unknown, assuming that they undergo significant changes between the age of 3 and adulthood. The Committee expects that such effect falls within the uncertainty of the present model calculations (Nik00).

Taking all this into account, the Committee feels that there is no reason to recommend that children should restrict the use of mobile telephones as much as possible.

5.7 Precautionary Principle

The Committee finds no reason in the scientific data concerning non-thermal effects presented in this chapter to apply the precautionary principle and lower the SAR limits for partial body exposure.

Chapter **6**

Interference with medical equipment

Equipment containing electronic components is increasingly being used in health care. This concerns equipment used in hospitals or at home for the monitoring or treatment of patients, such as heart monitors, respirators, dialysis units and infusion pumps, and implantable medical aids such as pacemakers and insulin pumps. It also concerns other kinds of medical aids such as electric wheelchairs, lifts and height-adjustable beds. It is essential that such equipment continue to function normally under all circumstances. Failure to do so might have adverse repercussions for patients’ health, particularly where such equipment has a life-supporting function. The Committee therefore discusses here the possible functional impairment of such equipment by electromagnetic fields.

6.1 Directives and standards

Electromagnetic compatibility (EMC) is the capacity or property of an electrical or electronic device to function satisfactory in its electromagnetic environment without adding inadmissible interference signals to that environment (IEC89). In other words, equipment must not cause interference and should itself be sufficiently insensitive (immune) to interference. To have some degree of certainty that the immunity requirement is met, EMC Directive 89/336/EEC of the European Community came into force in 1992 (CEC89).[a] Under the terms of this Directive, the manufacturer is responsible for ensuring and demonstrating that his equipment is sufficiently immune. EMC Directive 89/336/EEC is what is known as a 'horizontal' (general) Directive. Other Directives may apply to specific groups of equipment, such as medical devices (93/42/EEC) and active implantable medical devices (90/385/EEC) (CEC90, CEC93).

With regard to medical devices, a harmonised EMC standard of 3 V/m for the 26 MHz - 1 GHz frequency range has been drawn up in conformity with the Directive in question (IEC93).[b] Recently this standard has been raised to 10 V/m and the frequency range expanded up to 2.5 GHz (IEC01).

In relation to implantable medical devices, European Directive 90/385/EEC lays down essential requirements concerning immunity. These requirements have been further worked out in technical standards stipulating the minimum field strengths that such devices must withstand. These minimum field strengths are higher than the field strength in the general immunity requirement for medical devices referred to above. They are also higher than the health-based exposure limits, such as those of the Health Council of the Netherlands and ICNIRP (HCN97, ICN98). Therefore, if these health-based standards are met, it is unlikely that interference will arise in the medical implants concerned. These technical standards do not, however, lay down requirements for frequencies above 1 GHz, while that part of the electromagnetic spectrum is increasingly being used, for instance by DCS-1800 and UMTS. It is therefore desirable that the frequency range to which the standard applies is expanded to higher frequencies.

6.2 Interference resulting from mobile telephones

In 1995, the trade association VIFKA Telecommunicatie[c] issued a report concluding that mobile telephones may interfere with medical equipment used in hospitals (VIF95). This was based on the results of measurements conducted by TNO. The report therefore recommends maintaining a distance of at least 1.5 m between a telephone in operation (even one in standby mode) and sensitive medical equipment in hospitals. The Health Council of the Netherlands endorsed this recommendation in its advisory report *Radiofrequency electromagnetic fields (300 Hz - 30 GHz)* (HCN97). Most hospitals in the Netherlands have adopted the recommendation and generally apply it in

a European Directives are compulsory and should be implemented in national legislation.

b Such standards are voluntary in nature and serve as an aid in determining whether the essential requirements specified in the Directives have been met.

c VIFKA Telecommunicatie was later restructured into the Telecommunications branch of the Dutch Association for Information and Communication Technology (V-ICTN) and is now, as ICT Telecom, part of Nederland-ICT.

the form of a blanket ban on mobile telephones in hospitals. The implementation of this ban is, however, confined to the use of prohibitory signs and/or messages at entrances to the hospital building.The Committee is unaware of any actual monitoring and supervision of this ban on mobile phone use. The Committee is similarly unaware of any cases in which a mobile telephone in use within hospital walls has led to interference with sensitive medical equipment. It might well be possible, however, that actual events of this kind would not necessarily be connected to the presence of a mobile telephone and therefore not reported to the responsible authorities.

There is an increasing need to provide personnel in hospitals with mobile telecommunication equipment. The Committee is aware of the fact that, in some cases, GSM devices are being used for this purpose. In principle, this need not lead to problems, provided that the minimum distance of 1.5 m from sensitive equipment is observed. The Committee urges, however, that no distinction be made between hospital personnel and the public when drafting rules to govern the use of mobile telephones within hospital buildings. The regulations must be the same for everyone and there must also be a means of enforcing compliance.

Recently, an extensive study has been conducted by TNO to investigate the effects of electromagnetic fields on GSM and DECT telephones on a range of medical devices used outside hospitals (Hen00). This study revealed that the operation of a considerable percentage of such devices may be influenced by a GSM or DECT telephone in operation. This prompted V-ICTN to recommend avoiding the use of GSM and DECT telephones in the immediate vicinity of such equipment (VIC00). The Committee endorses these recommendations. In the case of GSM telephones, these recommendations mean that a distance of at least 1.5 m must generally be maintained between the telephone and the device unless the device is known to be insensitive to interference. In the case of DECT telephones, it is recommended that these should not be kept in very close proximity to medical equipment. For a number of categories of equipment, the recommendations are specified in yet greater detail. Thus, a distance of ‘a few dozen centimetres’ is sufficient for blood glucose meters and insulin pens. The same applies to electric wheelchairs and scooters. Where interference with these conveyances did occur, this was when the telephone was held at a very short distance (a few centimetres) from the wheelchair’s electronics. The mobile telephones of passers-by will, according to the report, not interfere with electric wheelchairs and scooters. Users are, however, advised for safety's sake to keep their telephone in a jacket inside pocket. The Committee can also endorse the suggestion that wheelchairs or scooters be switched off before using a mobile telephone, not so much because of possible interference problems but for the sake of traffic safety (see Chapter 7).

In its 1997advisory report, the Health Council of the Netherlands recommends maintaining a minimum distance of 15 centimetres between a switched-on mobile telephone and an implanted pacemaker. Since some patients may still have pacemakers that do not meet the stricter immunity requirements in force since 1995, the Committee stands by this advice.

Hearing aids may also experience interference from mobile telephones. A study conducted among patients with hearing aids that make use of bone conduction of sound (bone-anchored hearing aids) shows that 11 out of 13 patients using a digital mobile telephone experience irritating background noise (buzzing) (Kom00). There were no other effects, such as dizziness. The Committee considers it important for such nuisance to be prevented. It is possible that a handsfree set may provide a solution for users of hearing aids that are sensitive to interference.

6.3 Recommendations

At the moment, it is theoretically possible for an environment with a field strength below the health-based exposure limits to impair the satisfactory operation of medical equipment conforming to the EMC standards. This may, for instance, occur if such equipment is located in the direct vicinity of a transmitter or switched-on portable telephone. The Committee therefore recommends that the government takes care that the immunity of medical electronic products is increased, so that no interference problems arise in connection with normal use of mobile telephones. In addition, the government must promote the tightening-up of European standards, and extension of the frequency range they cover to a minimum of 10 GHz.

Chapter 7

Road safety

The boom that has occurred in the use of mobile telephones in recent years is also evident with road-users. As this could have an adverse effect on road safety, mobile telephoning in vehicles without using a handsfree set is prohibited in a number of European countries and North American states. The Dutch government, too, has decided to introduce such a ban.

Various studies investigating the influence of mobile telephoning on road behaviour have been published. A distinction can be made between studies conducted in a simulator and those carried out in road traffic. The simulator studies sometimes give a rosier picture than the other studies. This might be due to the fact that the test subjects are aware of the fact that they are in an artificial situation in which mistakes do not lead to actual accidents, material damage or personal injury (Nat99). The studies conducted on the road indicate that driving behaviour is adversely affected by mobile telephone use. This is partly the result of handling the device. Where a number is manually searched or keyed in, attention is diverted from traffic and one hand is unavailable for controlling the vehicle. This situation largely corresponds to operating a radio, cassette or CD player. Although this seems to result in a reduction in attention, this may partly be compensated via - unconscious - precautions such as reducing speed and maintaining a greater distance from the vehicle in front. There is less scope for controlling the vehicle while talking to someone on the phone if the conversation is being conducted without using a handsfree set. This is because the telephone is held in one hand or wedged with the shoulder against the head. This leads to a reduction in ability to react quickly to road situations (Bro91). An analysis of mobile telephone use before and during road accidents revealed that there was no difference between the percentage of handsfree and non-handsfree users involved in these accidents (Red97). This indicates that a reduced ability to control the vehicle is not the most important factor in the reduction in road safety associated with mobile telephone use. A more important factor seems to be the reduction in attention associated with conducting the call itself (Hla99, Lam99, Str01). Although no direct scientific information exists on this, the Committee considers that this might arise from the fact that conducting a mobile telephone call is felt to be more compelling than a conversation with a fellow-passenger. This might be due to the fact that a passenger also observes the road situation, as a result of which it is easier to interrupt the conversation early on if the driver's attention is needed for the situation on the road.

The Committee feeld the government's decision to allow only handsfree calling when driving a motor vehicle a move in the right direction. It recommends that this regulation is extended to all drivers. However, the Committee feels that this measure only partly reduces the problem of decreasing attention. It therefore also recommends that the government encourage people (via the provision of information, for example) to postpone lengthy calls and calls demanding close attention until the vehicle has been brought to a stop in a suitable place.

Chapter 8

Approach in other countries

In many countries, legislation laying down exposure limits is in force or under development. Any summary of this that the Committee might give here is no more than a snapshot. It therefore points out that the World Health Organization has developed an initiative to publish the current state of affairs via a dynamic information system. This information will be available on the website of World Health Organization's International EMF Project (http://www.who.int/peh-emf), from the beginning of 2002.

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Annexes

Annex A

The request for advise

In September 1999, the President of the Health Council of the Netherlands received the following request in a letter bearing the reference DGM/SVS/99207094:

In January 1997, the Health Council of the Netherlands issued an advisory report on the health effects of 300 Hz - 300 GHz radiofrequency electromagnetic fields. In this advisory report, the Health Council concludes, among other things, that available data do not indicate that mobile telephone use has adverse effects on health.

Since then, the use of mobile telephony has really boomed, and certain sections of the population have become concerned about the possibility of adverse health effects. This concerns the use of mobile telephones as well as antenna facilities of the kind that are frequently installed on residential buildings. This concern is partly prompted by various studies and reports on them in the media that supposedly indicate possible adverse health effects from electromagnetic fields through the use of mobile telephones and the associated antenna facilities.

In this connection, we would ask you, on behalf of the State Secretary for Transport, Water Management and Public Works, to provide in the near future a summary of the scientific literature of relevance to mobile telephony that has been published since your 1997 advisory report, and of the conclusions and recommendations the Health Council of the Netherlands arrives at on this basis. Of particular importance in this regard is the question of the extent to which non-thermal effects may, on the basis of current understanding, have an effect on health. Another important aspect is the extent to which, from the scientific point of view, there are grounds to adopt more stringent standards on the basis of the precautionary principle than on the strength of known thermal effects.

In addition, we would ask you, in the light of section VI of the Council Recommendation on the limitation of exposure of the general public to electromagnetic fields (see Annex), to provide a summary of recent relevant scientific literature that has been published since the publication of your advisory report on the health effects of radiofrequency electromagnetic fields in general. Would you also indicate in this connection what conclusions you draw from this research and what, in the view of the Health Council of the Netherlands, are the most important gaps in our current knowledge. Studies currently being conducted should also be included in this. I also look forward to receiving your recommendations in this regard.

Yours faithfully,

The Minister for Housing, Spatial Planning and the Environment,
J.P. Pronk

The Minister for Health, Welfare and Sport,
Dr E. Borst-Eilers

Annex **B**

The Electromagnetic Fields Committee

- Dr EW Roubos, c*hairman*
  Professor of Zoology, neurobiologist; Catholic University of Nijmegen
- Dr LM van Aernsbergen, *advisor*
  physicist; Ministry of Housing, Spatial Planning and the Environment, The Hague
- Dr G Brussaard
  Professor of Radiocommunication; Technical University of Eindhoven
- Dr J Havenaar
  psychiatrist; Utrecht University Medical Centre
- FBJ Koops
  biologist; Arnhem
- Dr FE van Leeuwen
  Professor of Cancer Epidemiology; Free University of Amsterdam,
  epidemiologist; Netherlands Cancer Institute, Amsterdam
- Dr HK Leonhard, *advisor*
  physicist; Ministry of Transport, Public Works and Water Management,
  Groningen
- Dr GC van Rhoon
  physicist; Erasmus Medical Centre, Rotterdam
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- DHJ van de Weerdt, physician
  specialist in environmental medicine; Municipal Health Service, Zwolle
- Dr APM Zwamborn
  Professor of Electromagnetic Effects; Technical University of Eindhoven, physicist; Netherlands Organization for Applied Scientific Research (TNO), The Hague
- Dr E van Rongen, *secretary*
  radiobiologist; Health Council of the Netherlands, The Hague

Annex **C**

Terms and definitions

When a term and its definition only appear on a single place in this report, it is not repeated in this list.

Quantities and units

Hz	hertz: unit of frequency; 1 Hz equals 1 cycle per second
kHz	kilohertz = 10^3 Hz
MHz	megahertz = 10^6 Hz
GHz	gigahertz = 10^9 Hz
J	joule: unit of electrical energy (1 J = 1 V· A· s = 1 W/s)
W	watt: unit of power (1 W = 1 J/s)
mW	milliwatt = 10^{-3} W
W/kg	watt per kilogram, unit to express the SAR
W/m^2	watt per square metre: unit of power density
°C	degree celcius: unit of temperature
s	second: unit of time
ms	millisecond = 10^{-3} s
g	gram, unit of weight
kg	kilogram = 10^3 g
m	metre: unit of length

cm centimetre = 10^{-2} m

Electromagnetic concepts

Amplitude
The maximum value of an electromagnetic wave.

Carrier wave
The main frequency of an electromagnetic signal, that can transfer information by means of variations in frequency (FM) or in amplitude (AM).

Dielectric properties
Properties of an object that detemine the way an electric or magnetic field acts upon the object.

Dosimetry
The technique to determine the amount of electromagnetic radiation absorbed in the body.

Far field
The space at some distance from a source where the electric and magnetic components of the field are perpendicular to each other and to the direction of propagation of the field. Under these condition the propagation of energy is dubbed ‘radiation’. The field strength is inversely proportional to the distance to the source.

Frequency
The number of oscillations per second. The unit is hertz (Hz).

Gain factor
The number indicating the increase in concentration of the electromagnetic field by an antenna, compared to a simple dipole antenna.

Near field
The space in the direct vicinity of a source where the relation between the electric and magnetic field are more complex than in the far field. It is therefore difficult to calculate the field strengths in the near field. On average, they decrease stronger than inversely proportional to the distance to the source.

Permeability
The magnetic density of a medium. The unit is henrys per metre (H/m).

Polarisation
The preferential direction of an electric field vector. A distinction is made between vertical polarisation, horizontal polarisation and mixed types.

Rms

Root mean square: the calculated mean or effective value of a periodically varying function. The r.m.s. value of an electric field with field strength *E(t)* and oscillation period *T* (=1/frequenty) is calculated as follows:

$$E_{rms} = \left[(1/T) \int_{t}^{t+T} E(t)^2 \, dt \right]^{0,5}$$

SAR

Specific Absorption Rate: the extent to which energy is being absorbed per unit mass per unit of time; the unit in which it is expressed is watts per kilogram (W/kg) (see annex D).

Other concepts

Analogue

A signal is called analogue when its magnitude is continuously varying with time.

Association

In epidemiology a connection established on the basis of statistical calculations in the sense that, in individuals exhibiting a certain clinical picture, certain environmental factors appear more frequently than in individual without that picture. The existence of an association does not constitute proof of a causal link, but may well prompt further research.

Basic restrictions

Health-based exposure limits that relate to certain electromagnetic phenomena that may lead to health impairment in the human body. For static fields these limits are the electric and magnetic field strengths, for alternating fields up to around 10 MHz, they are the electrical current that is induced in the body, and for alternating fields upwards of about 100 kHz they are the conversion that takes place in the body from electromagnetic energy into heat. Between 100 kHz and 10 MHz, both the current density and the generation of heat are important.

Blood-brain barrier

A hydrophobic layer, constituted by tightly packed cells, between the lumen of brain bloodvessels and neuronal brain tissue that is almost or completely impermeable for most, and especially large, molecules.

Cardiovascular system

The heart and bloodvessels.

Case-control study

Epidemiological research which takes the disease as its starting point. Using a group of patients selected according to certain criteria ('cases'), a control group is formed comprising individuals who correspond as closely as possible to the study group with regard to a number of relevant characteristics. Researchers then investigate which factors the 'cases' and the controls have been exposed to in the past. A higher incidence of a given exposure factor in the 'cases' than in the controls can be indicative of a possible causal factor.

CENELEC

The European Committee for Electrotechnical Standardization.

Cognitive functions

Processes that take place in the brain during perception, information-processing, learning, thinking and problem-solving.

Cohort study

Epidemiological research which takes exposure as its starting point. For a given exposure factor, a group of exposed individuals and an equivalent control group of non-exposed individuals are formed. In both groups, the occurrence of diseases is observed over a period of time. More frequent occurrence of a specific disease in the exposed group can be an indication of a causal link with the selected exposure factor.

DCS-1800

Digital Communication System: a standard for mobile telephony operating in a frequency band around 1800 MHz.

DECT

Digital Enhanced Cordless Telecommunication: a standard for wireless telephony.

Demodulation

Reconstruction of the original signal after transmission of that signal in modulated form.

Diathermy equipment

Equipment used in physiotherapy to generate warmth inside the body by means of radiofrequent electromagnetic fields.

Digital

A signal is called digital when it can only assume discrete values (for instance on / off).

Dose-respons relationship

An increase in effect upon increasing exposure to a given factor.

EEG

Electroencephalogram: the registration of differences in electrical charge inside the brain, measured by electrodes on the skin of the head.

Electromagnetic compatibility (EMC)

The property of an electrical or electronic apparatus to function satisfactorily in its electromagnetic environment without introducing unacceptable interference signals to that environment.

Epidemiological research

Investigation of the occurrence of diseases in connection with the occurrence of factors suspected of having a certain relationship with those diseases. The aim is to obtain evidence regarding the possible causes of the diseases. Epidemiology is an observational, and not an experimental, science. It is not possible to draw definite conclusions about a causal link based on the data from epidemiological research.

Exposure limits

Health-based values of specific parameters related to the strength of the electromagnetic field to which people may be maximally exposed. A difference is made between basic restrictions and reference levels.

Frame

Transfer of information by digital mobile communication systems is not continuous, but occurs in discrete packages of data. For that purpose the signal is divided into several periods called ‘frames’. In GSM-systems the signal is divided into 217 frames per second, each of which consequently has a duration of 4.6 ms. Every frame is subdivided into 8 time slots of 0.58 ms each.

GSM

Global System for Mobile communication: a standard protocol for mobile telecommunication. In Europe it is often used for mobile telephony in general.

GSM-900

Global System for Mobile communication: a standard protocol for mobile telecommunication operating in a frequency band around 900 MHz.

GSM base station

A GSM base station is a construction designed for the transfer of information between a mobile telephone and a network for mobile or land-based telephony. A base station consists of an antenna, a supporting structure for the antenna and a equipment cabinet.

Handsfree set

A device enabeling to carry on a conversation using a mobile telephone without holding the device in the hand.

Homeostasis

The ability of a living organism to maintain a constant internal equilibrium.

IARC

The International Agency for the Research on Cancer, an agency of the WHO.

ICNIRP

The International Commission on Non-Ionizing Radiation Protection.

IEGMP

The International Expert Group on Mobile Phones from the UK.

Immunity

Insensitivity; in this report: for electromagnetic interference.

Immune system

The natural defence system of a living organism.

Incidence

The number of new cases of a disease that occur during a certain period of time within a certain area.

In vivo research

Experimental research in cultured cells or tissues.

In vitro research

Experimental research in intact organisms, such as experimental animals.

Laterality

In some epidemiological studies discussed in this report the indication for the alledged observation that tumours occur more frequently on the side of the head where the telephone is said to be preferentially held.

Leukaemia

Cancer of the blood cells, uncontrolled growth of early-stage white blood cells.

Long-term effect

Biological effect that only manifests itself some time after exposure.

Lymphomas

Tumours of the lymphoid glands.

Melatonine

A hormone produced by the pineal gland in the brain, which plays a role in the circadian rhythm. It can also function as a free-radical scavenger. Radicals are highly reactive molecules which can damage other molecules, such as DNA. Such damage can be a first step in the process of cancer development.

MRI

Magnetic Resonance Imaging. A diagnostic technique that uses non-ionising electromagnetic fields to produce an image of the interior structures of living organisms.

Mutation

A permanent alteration in the DNA.

Neuro-epithelial tumors

Undifferentiated tumours of nervous tissue in the brain.

NMT

Nordic Mobile Telephone: an presently obsolete standard for mobile telephony with analogue transfer of information.

Nystagmus

Involuntary, rhytmic movements of the eye ball occurring after stimulation of the vestibular system.

Operator

A company operating a mobile telephony network and selling space for the transfer of information through that network.

Pacemaker

An electronic device that can regulate cardiac activity. It is usually implanted in the body.

Precautionary principle

The notion that measures can be taken to limit a certain activity or exposure, even when it has not been fully established that the activity or exposure constitutes a health hazard.

Reference levels

Values for the strength of the undisturbed electric and magnetic field which are derived from the basic restrictions and which serve to establish whether the basic restrictions are being satisfied. Measurement of the quantities that underlie the basic restrictions is not easy (whereas the electric and magnetic field strength is easily measured).

REM

Rapid Eye Movement: a phase in the natural sleeping cycle caracterized by rapid movements of the eye ball.

Short-term effect

Biological effect that occurs during or shortly after exposure.

Statistically significant effect:

An effect that, based on scientific calculation, is unlikely to be entirely attributable to chance.

Thermal effects

Biological effects caused by development of heat.

Time slot

The periods in which a frame is devided.

UMTS

Universal Mobile Telecommunication System, a new protocol for mobile telecommunication, also called 3rd generation (3G) mobile telephony.

Annex **D**

SAR

SAR

Atoms, molecules and ions in tissue may follow the variations in time of an external electrical field, for example owing to the presence of internal electric dipoles. If this happens, some of the energy of the electromagnetic field is converted into heat. The extent to which such conversion takes place is dependent on an electromagnetic property of tissue, namely its conductivity s (SI unit: siemens per meter, S/m). The Specific Absorption Rate (SAR) has been introduced to quantify heat generation in a medium. This is the rate of energy absorption per unit of mass and per unit of time, expressed in watts per kilogram (W/kg) (one watt equals one joule per second).

The SAR is defined as the derivation, as a function of time, of the energy W absorbed by a mass m in a volume V of density r (in kg/m^3):

$$SAR = \frac{d}{dt}\frac{dW}{dm} = \frac{d}{dt}\left(\frac{dW}{r\,dV}\right) \text{ (W/kg).}$$

In the case of sinusoidal fields, the SAR may also be expressed as a function of electrical field strength:

$$SAR = \frac{d}{dt}\frac{s\left|E_{rms}\right|^2}{r} \quad \text{(W/kg).}$$

Here E_{rms} is the 'root mean square' (rms) value for the electrical field strength in the body, s the electrical conductivity of tissue and r the density of tissue. In practice, this is the formula most commonly used for determining the SAR since electrical field strength is easy to measure.

The SAR can also be determined by measuring temperature increase:

$$SAR = c\left(\frac{dT}{dt}\right) \text{ (W/kg)},$$

where c stands for the specific heat of tissue. The SAR is thus directly proportional to the rate of temperature change (dT/dt).

Annex **E**

Effects of unilateral stimulation of the vestibular system

Cox & Luxton (Cox00) suggest that symptoms such as dizziness, nausea and headache may result from unilateral stimulation of the vestibular system by the electromagnetic fields from a mobile telephone. Not everyone suffers from such symptoms, however. This is thought to be due to a large degree of inter-individual variation in the orientation of the semicircular canals in the vestibular system.

Two explanations can be given for such a phenomenon:

- direct unilateral stimulation of the endolymph and/or the hair cells in the semicircular canals is generated by the electromagnetic fields. No studies investigating stimulation of the vestibular system by electromagnetic fields have been found in the literature. Such a phenomenon is thus purely hypothetical;
- a thermal effect is involved in which the vestibular system is unilaterally warmed.

When disturbance of equilibrium is examined, the sensitivity of the vestibular system can be studied by alternate flushing of the auditory canal with warm (44°C) and cold (30°C) water. The nystagmus induced by this procedure provides indications on the functioning of the vestibular system. It is also known that temperature differences may lead to unilateral stimulation of the vestibular system, giving rise to symptoms associated with motion sickness, such as dizziness and nausea. In experimental research on frogs, it has been found that the semicircular canals are activated by temperatures differences, and particularly by cooling (Suz97, Suz98). This has also been found in experimental research on humans: unilateral cooling of the vestibular system leads to symptoms of dizziness (Ern99, Tak96). This is a symptom familiar to GPs. It is why they perform ear irrigations with water at body temperature.

The effect of cooling seems to be much greater than the effect of warming on the vestibular system (Cui97). It is unclear whether unilateral warming produces more or less severe symptoms of motion sickness than unilateral cooling. Research mainly focuses on cooling of the vestibular system. The temperature threshold for generating a nystagmus has been studied in connection with cooling (Ita94). A stream of air, gradually falling in temperature, was blown into the ears of human volunteers. On cooling (from 37°C) by 0.01°C/s (1°C per 100 seconds), a nystagmus arose at 34.2°C after 263 seconds. On cooling by 0.05°C/s, a nystagmus was found at 33.1°C after 120 seconds. The faster the temperature drop, the lower the temperature at which a nystagmus occurred. Above all, with rapid temperature drops (0.1 – 0.2°C/s), symptoms such as nausea and dizziness were experienced. Stimulation of the vestibular system thus occurs with a temperature drop of at least several degrees Celsius. Research on a nystagmus threshold after warming of the vestibular system has not been found in the literature.

It is unclear whether the use of a mobile telephone leads to warming of the vestibular system. A certain level of heat transfer is needed for this. Possibilities include heat conduction via bone, convection via air in the middle ear and via thermal radiation. Cox & Luxton suggest convection, but several investigators think that thermal radiation is the most important factor here (Fel91, Pau99).