Hoofdstuk **1**

Introduction

1.1 Background

Public concern over possible harmful effects of exposure to electromagnetic fields has increased substantially in recent years. This is due in part to the upsurge in mobile telephony. The Health Council is therefore often confronted with questions on this subject, both from the general public and from government and Parliament. On 6 March 2000 the President of the Council therefore set up the Electromagnetic Fields Committee. The Committee was initially established for a period of four years, but its mandate has subsequently been extended by two years at a time and currently runs to the end of 2007.

The task of the the Committee is to regularly report on scientific developments in the area of electromagnetic fields, as it does in this Annual Update 2006. On an *ad hoc* basis, it will also take a closer look at key scientific developments. The membership of the Committee is given in Annex A.

1.2 Function of the Annual Update

This Annual Update deals with two subjects: UMTS and DECT. It is the fourth time that that the Committee uses this format to report on important scientific developments in this way. Previous Annual Updates were published in May 2001[17], January 2004[19] and November 2005.[21]

In the Annual Updates the Committee briefly indicates which advisory reports it has published in the period under review and comments on topics that have received attention in the scientific press and the general media during that period. These may be issues that have been addressed in a previous advisory report but have been cast in a new light in recent publications. They may also be topics on which the Committee is preparing an advisory report and, in the light of reports in the media, a provisional standpoint is needed.

1.3 Organisation of this Annual Update

Chapter 2 of this Annual Update begins with a brief discussion of the advisory report containing research proposals that the Committee published in May 2006. In chapter 3 the Committee discusses the scientific knowledge concerning possible effects of exposure to UMTS (Universal Mobile Telecommunications System) signals. Chapter 4 is devoted to a discussion of this kind of knowledge with regard to DECT (Digital Enhanced Cordless Telecommunications).

Hoofdstuk **2**

New research recommendations

At the request of the government, and as suggested by the Health Council, a research programme on Electromagnetic Fields and Health was established in the Netherlands in 2006 by the Organisation for Health Research and Development (ZonMw). The State Secretary of Housing, Spatial Planning and the Environment has asked the Health Council to indicate what issues might be addressed in this programme, also in the light of the research efforts in other countries.

The Committee published an advisory report on this topic on 30 May 2006, in which it makes proposals for studies in the areas of epidemiology, social-science research, experimental research in humans and in animals, research with cell cultures, and activities aimed at characterising exposure, both at micro and macro level.[22]

The Committee has taken into account the expertise that is available in the Netherlands and the research recommendations made by the World Health Organization (WHO).

The Committee's proposals have have been guiding in the drafting of the research programme Electromagnetic Fields and Health.[53]

Hoofdstuk **3**

Research on possible effects of UMTS

What is known on the possible health impact of exposure to UMTS signals? In this chapter the Committee discusses a Swiss follow-up study into the possible influence of such signals. It has been performed after a 2003 study of the Netherlands Organization for Applied Scientific Research TNO seemed to indicate an effect on well-being. In the following the design and results of both studies are compared and their power is considered. Results of other studies are also discussed. The chapter starts with some short background information on UMTS.

3.1 Technical information

There are different types of wireless telecommunication systems in use. GSM and DECT systems utilise a non-continuous signal (see the advisory report *Mobile telephones: an evaluation of health effects*[18] and chapter 4 of this Annual Update, respectively), which involves transmitting the information from different users in successive "time slots". These are called TDMA (Time Division Multiple Access) systems.

UMTS, on the other hand, works according to the CDMA (Code Division Multiple Access) system, whereby the information from different users is transmitted simultaneously and encoded in a unique manner for each user. UMTS signals do not display the characteristic low-frequency pulses that are caused by the time slots in GSM and DECT systems. Low-frequency variations in signal strength may well occur as a result of the continuous signal-strength adjustment that is required for an optimal connection.[39] With the available frequency bandwidth and capacity of the network, far more information can be transmitted much faster with UMTS than with GSM.

3.2 Comparison of the Netherlands and Swiss studies

3.2.1 History

The TNO study

In September 2003 TNO (the Netherlands Organisation for Applied Scientific Research) published the results of a study on the effects of exposure to electromagnetic fields originating from GSM and UMTS antennae on cognitive functions and well-being in human subjects.[55] The researchers found a statistically significant relationship between exposure to a UMTS base-station signal and a decline in a measure for well-being. Changes in various cognitive functions were also measured, both on exposure to GSM signals and on exposure to a UMTS signal. The picture that emerged was inconclusive, however.

Public concern

The findings with regard to the impact of exposure to a UMTS signal on well-being have attracted particular attention both in the Netherlands and in many other countries and led to growing concern over possible health effects of living in the vicinity of a UMTS antenna.

Improved analysis in a Health Council advisory report

The Health Council published an advisory report on the TNO study in June 2004.[20] This included an improved analysis of the data that the researchers had performed at the request of the Council.

That reanalysis led to a revision of the conclusions concerning the effects on cognitive functions. It was now only possible to identify a significant difference between actual and sham exposure for one combination of study group, type of exposure and cognitive test.

The conclusions regarding the effects on well-being remained the same even after the analysis had been revised. In both of the groups investigated in the study – a group of people who had various non-specific symptoms that they ascribed to living near GSM antennas and a group of people without these problems – a statistically significant difference was discovered between the measurements associated with UMTS exposure and sham exposure, pointing to a decline in well-being following UMTS exposure.

The Health Council concluded, however, that the instrument that had been used in order to quantify well-being – a specific questionnaire – was possibly not ideally suited to this purpose. This questionnaire stemmed from a study of long-term effects on well-being in people using certain anti-hypertension drugs and had not been tested as an instrument for measuring the short-term effects of exposure to electromagnetic fields that were investigated by TNO.

In the advisory report, the Council recommends having the TNO study repeated by other research groups in order to see whether the results are reproducible. The aim would then be to improve on the weak points from the TNO study. The Council found it particularly important that a questionnaire that had been validated for a study of this kind should be used to assess well-being.

Follow-up studies

Studies have been initiated in several countries – Switzerland, Denmark, Japan and the UK – which can be regarded wholly or partly as a replication of the TNO study. The Swiss study has meanwhile been completed and published.[43] Below the Committee gives a brief description and assessment of this Swiss study and a comparison with the TNO study, together with an opinion on the current level of knowledge with regard to UMTS and health.

3.2.2 Differences and similarities

Broadly speaking, the design of the Swiss study was the same as that of the TNO study. Under closely controlled laboratory conditions, study participants were exposed to electromagnetic fields of the type and strength that can occur in the living environment. The researchers investigated whether this exposure had an impact on well-being and on cognitive functioning.

Just like the TNO study, the Swiss study was aimed exclusively at effects that manifest themselves in the short term, i.e. during or directly after exposure. The design of the study was double-blind, i.e. neither the study participants nor the researchers knew during the study who had been exposed to what.

The design differed from that of the TNO study in several points of detail, however. This was partly on account of the need expressed by the Health Council to modify various points that had been identified as needing improvement. In the following several differences and similarities are being discussed.

Study participants

Two groups of subjects were investigated in each of the studies.

In the TNO study, one group consisted of people with symptoms that they ascribed to exposure to electromagnetic fields, while the second group comprised individuals without symptoms of this kind.

In the Swiss study, one group consisted of people who considered themselves to be sensitive to electromagnetic fields, either because they believed they could perceive these fields or because they had symptoms that they ascribed to exposure to these fields. The second group consisted of people who did not regard themselves as "electro-sensitive".

Number of study participants

A point of concern in the TNO study was the number of participants, therefore the Swiss study comprised more people. For the purposes of this study, a calculation was made of the minimum number of people required in order to be able to observe a given difference in outcome. To increase the statistical robustness of the study, however, it was considered advisable to include more study participants. In the TNO study, both groups (people with and without symptoms) in each exposure category (GSM or UMTS) consisted of 24 people. In the Swiss study the "sensitive" group comprised 33 subjects and the "non-sensitive" group 84 subjects.

Inclusion and exclusion criteria

A further difference between the two studies lay in the inclusion and exclusion criteria. Whereas the TNO study included people aged between 18 and 75 years, the age range in the Swiss study was 20-60 years. The following were excluded from the TNO study: people who had suffered brain injury, had epilepsy or claustrophobia, had undergone treatment for psychological problems in the six months prior to the study or had used psychoactive drugs in the two weeks preceding the study, and people with a pacemaker or a hearing aid.

On the basis of an extensive telephone interview, the Swiss study excluded those who had in the past suffered head injuries or a neurological or psychiatric illness, regular users of narcotics or psychoactive drugs in the six months prior to the study, people with a pacemaker, a hearing aid or a hearing implant, and also smokers, people with various symptoms as a result of chronic illness, pregnant women, people with sleep disorders, people with an average alcohol consumption of more than 10 drinks per week, or consumption of caffeine-containing beverages that resulted in an intake of more than 450 mg caffeine per day (which is approximately three cups of coffee). Also excluded were people who did shift work and those who had made a long-haul flight (across more than three time-zones) in the month preceding the experiment.

As a result of this, the composition of the groups in the Swiss study was more homogeneous than in the TNO study. The two groups in the Swiss study are also comparable in terms of their age and gender profile.

Exposure

The participants in the TNO study were each exposed to two of the following three types of signal: GSM 900 MHz, GSM 1800 MHz and 2100 MHz UMTS, with each combination occurring equally often. Because both groups consisted of 36 people, each signal type was used on 24 study participants. In addition, each participant also underwent a sham exposure ("placebo"). The effective field strength to which the study participants were exposed was 0.7 V/m for the two GSM signals and 1 V/m for UMTS.

Apart from the sham exposure, the Swiss study only used exposure to a UMTS signal, but in two different strengths: 1 V/m and 10 V/m. The form of the signal was the same as that of the UMTS signal used by TNO. All study participants were subjected to the three exposures.

Time intervals

In the TNO study, all of the activities involving a particular individual took place during a single half-day session. The exposure sessions lasted as long as was necessary in order to complete the cognitive function tests (about 20-25 minutes). The time interval between two successive sessions was also around 20-25 minutes, such that each session began 45 minutes after the start of the previous session.

The Swiss researchers felt that such relatively short intervals between successive sessions resulted in a considerable chance of carry-over effects, which means that at the beginning of a session the effects induced by the previous session have not completely disappeared and consequently are of influence on the measurements. In the Swiss study, the exposures therefore took place at one-week intervals and at around the same time of the day for each participant. Each exposure session lasted 45 minutes.

Questionnaires

The questionnaire used in the TNO study was a shortened and adapted version of one that had been developed for a study on antihypertensive drugs, in which effects were measured over periods of several months.[3] The validity of the TNO questionnaire for research into short-term effects of exposure to electromagnetic fields has not been verified. This was considered in some detail by the Committee in its evaluation of the TNO study.[20]

The TNO questionnaire was also used in the Swiss study (in order to allow for a comparison with the TNO study). Several other questionnaires were also used. A short questionnaire on current disposition was used as the measuring instrument. This comprised six items, each consisting of two choices: tense/calm, apprehensive/unperturbed, worried/unconcerned, anxious/relaxed, sceptical/trusting, uneasy/comfortable.[38] This questionnaire has been validated with a view to measuring short-term changes in well-being. It was used before and after each exposure session, and hence it was possible to measure changes that occurred during the session. Another questionnaire was drawn up especially for this study in order to identify factors that might influence well-being: length and quality of sleep the previous night, colds, amounts of alcohol, caffeine and medication consumed on the day of the session, (pre)menstrual complaints and stressful events. These factors were then taken into account when analysing the data. The participants were also asked to indicate what field strength they thought they had been exposed to by scoring them on a scale that ran from 0 (not exposed) to 100 (very heavily exposed). This questionnaire and the TNO questionnaire were completed after each session.

One week before the first (training) session and one week after the final exposure session, the participants completed a detailed questionnaire on the subject of well-being.[12] This list was developed and validated with a view to measuring changes over a prolonged period. It has been used in this study to determine whether participation in the study as such had a direct impact on well-being.

In figure 1 the chronological order of the different elements of both studies is shown.

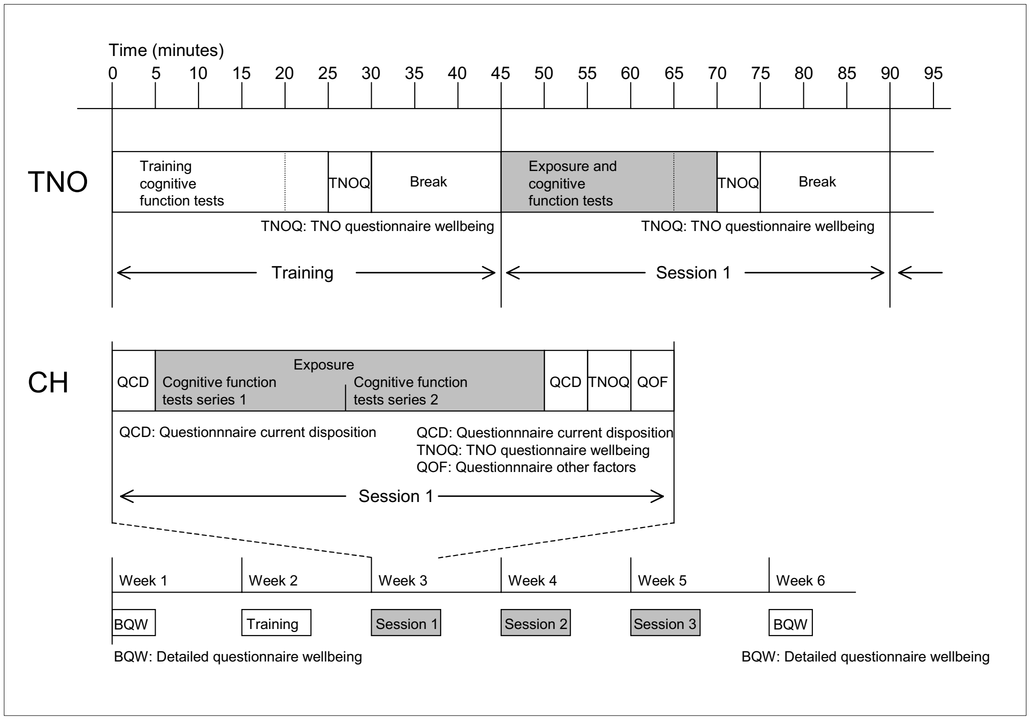

Figure 1 Chronological order of the different elements of the TNO and Swiss studies. The top two bars employ the same scale (minutes), while the bottom bar is a weekly scale. In the TNO study, all sessions were conducted sequentially within a single half-day session. Exposure periods are shaded.

Cognitive function tests

In the TNO study, cognitive functions were tested using the Taskomat test battery developed by TNO. This consists of five different computerised memory and reaction tests (reaction time, memory comparison, visual selective attention, dual tasking and filtering of irrelevant information).[2] The series of tests was run once in each exposure session.

The Swiss study used only the visual selective attention test from this series, together with two reaction tests – a simple reaction-time test and a two-choice reaction-time test [28,40,41] – and a memory test (the N-back test).[27] The series of tests was run twice in each exposure session.

Statistical analysis

The data in the TNO study were analysed using an ANOVA (ANalysis Of VAriance) procedure.* This included the following variables: exposure (sham, GSM900, GSM1800 or UMTS), group (with symptoms or without symptoms), session (first, second or third), sequence (there were 18 different possible sequences), subject within sequence (36 people in the group with symptoms, 36 people in the group without symptoms), timing of the procedure (morning or afternoon). Because ANOVAs are predicated on the assumption that the residuals are normally distributed and this was not always the case, non-parametric analyses were also performed – where applicable – with the Wilcoxon (Mann-Whitney U-test), rank-sign or median test (Cochran-Mantel-Haenszel test).

The statistical analysis for each of the two groups in the Swiss study was performed separately using linear mixed models. These models are preferable to an ANOVA since they take account of the intrinsic correlation among repeated observations in the same participant. The variables included here are: exposure (sham, 1 V/m or 10 V/m) and time (week 1, 2 or 3). An additional variable included in the analysis of cognitive functions is the test series for each exposure session (series 1 or 2). Furthermore, the reliability of the models was tested by adjusting for potential confounders (age, gender, body weight, caffeine intake, medication, (pre)menstrual complaints, sleep quality and colds). For purely statistical reasons, highly discrepant results (more or less than 4 x the median deviation) were not included in the analysis of the test results for reaction speed. This did not happen in the TNO study, where all results were included in the analysis. For a number of cognitive function tests in the Swiss study, the residuals were found not to be normally distributed. In these cases, a non-parametric test was performed (the Wilcoxon rank-sign test). In the analysis of the cognitive function tests, an adjustment was made for multiple comparisons.[50]

The relationship between the perceived strength of the electromagnetic field and its actual strength was tested using the Spearman rank correlation test. The number of positive and negative correlations was tested with a sign test. The same procedures were performed in order to investigate the association between the perceived field strength and well-being.

* An ANOVA is a statistical procedure designed to determine whether there are differences between the means of the relevant values for the groups under investigation. This is accomplished by ascertaining whether the variation between the groups is comparable to the variation within the groups. For each individual, the individual value of a given parameter can be defined as the sum of the mean value for the group, the variation within the group and an individual component (“residual”). An ANOVA can only be performed if the residuals are normally distributed.

3.3 Assessment of the results of the Swiss study

3.3.1 Well-being

The outcomes of the scores from the questionnaires (the questionnaire on current disposition and the TNO questionnaire) do not reveal any differences between sham exposure and exposure to 1 V/m or 10 V/m. This applies both to the absolute scores measured after each exposure session and to the difference in scores as measured before and after each session with the questionnaire on current disposition.

The score for the perceived field strength also does not show any difference between the three exposure modalities: there is no association between the actual and perceived exposure. Regardless of the actual exposure, however, there is an association between the perceived exposure and well-being: the higher the perceived exposure, the greater the decline in well-being. This can be explained in two ways. If the study participants thought they had been exposed, this had an adverse effect on their well-being, or if they were not feeling well then this could lead them to think that they must have been exposed. This association between perceived exposure and well-being was identified in both groups. It is therefore not dependent on whether or not people regarded themselves as being “electro-sensitive”.

Regardless of the exposure, the questionnaire scores were higher (indicating reduced well-being) in the “sensitive” group than in the “non-sensitive” group. That is a logical consequence of the fact that some of the “sensitive” subjects already had symptoms – which does not, of course, mean that those symptoms were caused by exposure to electromagnetic fields. In the TNO study too, the questionnaire score in the group with symptoms was higher – regardless of the exposure – than that in the control group.

The analysis of the questionnaires that explored the impact on well-being of participation in the study did not bring to light any differences in the “sensitive” group as far as the scores for health and satisfaction are concerned. In the “non-sensitive” group, the score for health was significantly lower after the study than before (pointing to better health), but the score for satisfaction was unchanged.

The conclusion is that in none of the two groups participation in the study *per se* had a negative influece on well-being.

3.3.2 *Cognitive functions*

Initial results

a. Reaction speed

Exposure was not found to affect the reaction speed in the simple reaction-time test, the N-back test and the visual selective attention test in either of the two groups. In the "sensitive" group, the speed in the two-choice reaction-time test was lower in the second series of tests than in the first series for sham exposure and exposure to 1 V/m (two series of tests were used per exposure session), but not in the case of 10 V/m. In the "non-sensitive" group, the reaction speed decreased within each of the three exposure modalities. The conclusion is that exposure had no impact on the two-choice reaction-time test.

b. Accuracy

The exposure modality was not found to affect the accuracy with which the tests were performed in either of the two groups. Only in the case of the "non-sensitive" subjects was the accuracy in the 1-back test less with 1 V/m than with sham-exposure, and less with 10 V/m than with 1 V/m.

Results after correction

Adjustment for confounding factors did not result in any change in the results outlined above.

This was different when a correction for multiple comparisons was applied. As in the TNO study, several variables were used in the Swiss study on cognitive functions both for exposure (three different field strengths) and for the measured effects (different cognitive functions). In fact, therefore, several questions were addressed. An adjustment should be made for this fact when conducting a statistical analysis on the data in order to prevent statistically significant results from being found by chance.*

After the adjustment for multiple comparisons had been made (allowing for a correlation factor of 0.39), all of the aforementioned differences in the cognitive function tests were found to be no longer significant.

3.3.3 *Assessment of the power*

Participants

Generally, the Swiss study has been well designed and executed. Most of the improvements recommended by the Health Council have been heeded.[42]

The number of study participants is larger than in the TNO study and this increases the statistical robustness. On the other hand, however, the composition of the "sensitive" group differs from the TNO study. Whereas in the TNO study these were all people with symptoms that they ascribed to exposure to electromagnetic fields, the Swiss study also included people who considered themselves to be "electro-sensitive" but did not necessarily had symptoms. It is impossible to assess what impact this has had on the outcome of the study, since no effects were identified in either the "sensitive" or "non-sensitive" groups.

Another difference lies in the more stringent inclusion and exclusion criteria that were applied in the Swiss study. On the one hand these lead to a stricter selection than in the TNO study, but on the other hand they reduce the impact of potential confounding factors and result in more homogeneous groups than in the TNO study and this too enhances the study's statistical robustness.

Exposure

As far as the exposure of the study participants to a UMTS signal is concerned, the two studies are readily comparable. The form of signal used in the Swiss study is the same as the one in the TNO study, as is the field strength of 1 V/m. According to the Swiss researchers, the field in the place where the subjects are tested is somewhat more uniform and reproducible than in the TNO study, but it is unlikely that this had an impact on the outcome. The Swiss researchers' deci-

* It is common for a study to look at the effect of exposure in terms of a number of possible outcomes. When this is done, there is always the possibility that pure chance will produce statistically significant results. The more possible outcomes are investigated, the greater the likelihood of such false-positive findings. An adjustment should therefore be made in such cases for multiple comparisons. The correction is made to the α, the figure that represents the acceptable risk of a false-positive result. Ordinarily, α is 0.05, corresponding to a one-in-twenty chance of incorrectly rejecting the null hypothesis. As the number of comparisons made increases, so a smaller value has to be used, so that the risk of incorrectly rejecting the null hypothesis is reduced for any one outcome, but remains the same (0.05) for all outcomes together. The number of comparisons made in a study dictates the size of the adjustment. However, it is sometimes the case that the parameters under study are not entirely independent of one another, due to the existence of certain correlations. Under such circumstances, the correlations need to be identified and allowance made in the multiple-comparisons adjustment factor. This is then reduced, resulting in a smaller reduction in the α value than where no allowance has been made for correlations.

sion to opt for additional exposure to a ten times higher field strength of 10 V/m furthermore afforded the opportunity to assess an exposure-effect relationship. No such relationship was identified, however. There was no effect at the higher field strength either, thereby reinforcing the conclusion that there are no effects at 1 V/m. It is a pity that the Swiss study did not also include exposure to a GSM signal as this would have further enhanced comparability with the TNO study.

A difference between the two studies lies in the time intervals between the successive sessions: 45 minutes in the case of TNO and 1 week in the Swiss study. It is possible that carry-over effects occurred in the TNO study, but an adjustment was made for this when analysing the data. In the Swiss study, on the other hand, variations in health and mood may have arisen over the period in which the subjects made their four weekly visits to the laboratory. The brief questionnaire on current disposition was, however, completed before and after each session and the change in the score was used as a measure of changes in well-being. With this approach, it is not possible for any changes in health and mood over the four weeks in which the exposures took place to play a significant role.

The absolute scores from the measurements performed after each session were also presented, both with the brief questionnaire on current disposition and with the TNO questionnaire. The spread in these values is smaller than the spread in the differences, which indicates that long-term variations in health and mood did not play a major role.

Questionnaires

An important question that arose during the analysis of the TNO study was whether the questionnaire that had been used was an effective measuring instrument. This question was considered at length in the Health Council advisory report on the TNO study. Although the TNO questionnaire was also included in the Swiss study, this was not done with the intention of testing the validity of this questionnaire, but in order to allow for a comparison with the TNO study. The Swiss researchers point out that the two questionnaires explore different aspects of well-being. The outcomes of the Swiss study are therefore of no assistance in assessing the suitability of the TNO questionnaire. The only conclusion that can be drawn is that the results from the two questionnaires in the Swiss study are similar and that this gives no reason to cast doubt on the value of the TNO questionnaire. A direct comparison with the results from the TNO study is not possible, however, since the Swiss data have been analysed in a different way (as an exposure-effect relationship).

Cognitive function tests

As in the TNO study, statistically significant changes have, in some cases, been found in the analysis of the effects on cognitive functions. Moreover, it was not possible to discern any obvious pattern (or, in this case, exposure-effect relationship) – as in the TNO study. In the Swiss study, there was no longer found to be any significant effect after adjustment for multiple comparisons.

The cognitive function tests used in the two studies are different, with one exception. Each test undoubtedly provides an insight into one aspect of cognition, but no conclusions can be drawn on the question of whether the tests used in the Swiss study are more effective than those used by TNO, or vice versa. All of the tests have been validated and also used in other studies. The absence of any effect makes it impossible to establish the value of the tests in these studies.

Statistical analysis

Generally speaking, the Swiss researchers have carefully performed the statistical analyses.[42] However, the Committee has reservations about the exclusion of highly discrepant results from the tests on reaction speed. The Committee feels that it is not correct to exclude such results in this case.

The exclusion of discrepant data can be useful and necessary when dealing with subjective data (when, for example, the participant is required to provide certain information). In the case of the reaction speed tests, however, we are dealing with objectively measured data. The only reasons for excluding discrepant values in such a case are technical problems or if the study participants were to react wrongly (e.g. too slowly) on purpose.

The Swiss researchers have not indicated the possible reason for the discrepant data. They do, however, state in a response to questions from the Committee that the percentage of measurements excluded across all study participants ranged from 3.7 to 6.5%. This, they maintain, makes it most unlikely that the exclusions could have influenced the final outcome – i.e. that there is no effect on cognitive functions. The Committee endorses this assumption, but would rather it had been supported with analyses of all the data (i.e. without excluding the discrepant values).

It is not possible to make a direct comparison between these results from the Swiss study and the TNO findings. In the TNO study, a comparison was consistently made between sham and actual exposure for each exposure modality. In the Swiss study, this was not done separately for the two levels of exposure; instead, an exposure-effect relationship was assessed.

3.3.4 *Conclusions*

No effect on well-being and cognitive functions

The final conclusion from the Swiss study is that exposure to a UMTS signal with a field strength of up to 10 V/m for 45 minutes does not result in an effect on well-being or on cognitive functions.

Thus the results of the TNO study were not confirmed in this study and no effect was identified even at a field strength ten times higher than the 1 V/m used by TNO. This raises two questions: how are these differences to be explained and which results should be considered more important?

Let us start by answering the second question. The results of the Swiss study are more robust for a number of reasons. First and foremost, both studies were properly designed and executed. However, being the first study of its type, the TNO study was necessarily of an exploratory nature. The Swiss study built upon the knowledge that had been acquired by TNO. The analysis of the TNO data and the further evaluation of the study by the Health Council highlighted a number of weaknesses, which were also discussed in the Health Council advisory report. Wherever possible, those weaknesses were rectified in the design of the Swiss study. All things considered, this means that the results of the Swiss study have greater robustness than the TNO findings and that, based on the knowledge now available, the conclusion to be drawn must be that the exposures studied seem not have any effect on well-being or cognitive functions.

At this point in time it is not possible to give an unequivocal explanation of the differences between the TNO study and the Swiss study. It is possible that TNO's findings with regard to effects on well-being are due to chance. However, the fact that this effect was identified in both groups under investigation would tend to suggest otherwise. Another possible explanation is that there was a systematic flaw somewhere in the procedure, though there is no evidence of this at present. In the Health Council's advisory report on the TNO study it was suggested that the questionnaire might possibly not have been an effective measuring instrument – and this remains a possibility. Although no difference was found in the Swiss study between the results of the brief questionnaire on current disposition and the TNO questionnaire, it is not possible to establish the validity of the TNO questionnaire with these data. Another possibility is that the statistical analysis used by TNO was inadequate. This was also discussed in some detail in the Health Council report and, according to the TNO researchers, the analytical models that were used were suitable and correctly applied. It would, however, be useful to undertake a further analysis of the TNO data using the models from the Swiss study.

No differences between "sensitive" and "non-sensitive" participants

A second important conclusion is that no differences have been identified between the reactions of the "sensitive" and "non-sensitive" individuals. Thus this study does not support the notion that such a thing as "electro-sensitivity" actually exists. This corresponds to the outcome of a recent review on this subject.[44]

It is certainly worth noting that there is a connection between well-being and the degree of perceived exposure. There are two possible explanations for this. If the study participants thought they had been exposed, this had an adverse effect on their well-being, or if they were not feeling too good this might lead them to think that they must have been exposed. This association between perceived exposure and well-being was identified in both groups and is therefore makes no difference whether or not people considered themselves to be "electro-sensitive".

3.4 Assessment of other research

As UMTS is a new technology, very little research has been done as yet into biological or health effects of exposure to this particular form of signal. The TNO study was the first study to investigate exposure to UMTS.[55] With the exception of the Swiss study, only two papers have been published about effects of UMTS signals since that publication.

3.4.1 Study on possible effects on visual perception

Set-up

Schmid *et al.* investigated what effect a UMTS signal such as that generated by a mobile telephone had on parameters relating to visual perception in volunteers.[46] The exposure came from an antenna positioned on the left side of the head. This resulted in exposure of the head only – as opposed to the situation in the TNO and Swiss studies, where the study participants were subjected to whole-body exposure.

The average SAR in the brain in the Schmid study at the highest signal strength was 370 mW/kg (averaged over 10 g tissue), with a minimum of 160 mW/kg and a maximum of 840 mW/kg. The low signal strength was a factor of

10 lower. The maximum SAR in 10 g brain tissue as calculated in the TNO study was 0.078 mW/kg, whereas in the Swiss study an average value of 0.045 ± 0.013 mW/kg was calculated at 1 V/m and 4.5 ± 1.3 mW/kg at 10 V/m. The exposure of the brain in the Schmid *et al.* study was therefore higher than in the TNO and Swiss studies. The composition of the signal in the Schmid study also differed from that in the TNO and Swiss studies. The signal chosen by Schmid is representative of a call made with a UMTS telephone[39], whereas the signal in the other two studies typifies that of a UMTS base station without active calls.[43]

Each of the 58 study participants was offered four different visual perception tests under three different sets of conditions: sham exposure or exposure to either a high or a low signal strength. The sequence of exposure modality was randomised and the tests were always offered in the same order. It is not clear how long each series of tests lasted and how long the interval was between successive test series. The entire procedure took place within a period of 3.5 hours.

Results

A visual selective attention test was also used in the TNO and Swiss studies. In the TNO report[55], a significant result was reported for this test for both groups of study participants, but in the multiple comparison-adjusted analysis that is presented in the Health Council advisory report[20] these results are no longer significant. In the Swiss study, no effect on visual attention was discovered at either level of exposure. Also Schmid *et al.* did not identify a significant difference between sham exposure and exposure to a low or high signal strength in any of the tests. In other words, no effect was identified on visual perceptiveness after local exposure of the head to UMTS signals that resulted in the brain absorbing at least four times more energy than in the TNO and Swiss studies.

3.4.2 Study into possible effects on the blood-brain barrier

Franke *et al.* investigated the effect of exposure to a UMTS signal on an *in vitro* model of the blood-brain barrier, consisting of primary microvascular endothelial cell cultures derived from porcine brain tissue.[9] These cells were exposed for 84 hours at an average field strength that ranged from 3.4-34 V/m (maximum SAR: 1.8 W/kg). The signal was of the same type as that used in the study by Schmid *et al.*[39]

Exposure to a UMTS signal did not result in any changes in the permeability of this blood-brain barrier model.

3.5 Conclusions

Experimental studies do not show effects with short-term exposure

The research in Switzerland, which set out to repeat the TNO study using an improved design, did not confirm the TNO findings. As the Swiss study built on the experience gathered by the TNO researchers, its design was better and more comprehensive and consequently its results have more weight than those of the TNO study.

Based on the results of these studies, there is, for the time being, no reason to suppose that there would be any negative effects on health during or immediately after 45 minutes exposure to a UMTS signal. The only evidence of such effects comes from the TNO study and was not substantiated in the study that was performed in Switzerland with an improved design.

Similarly, the Swiss research did not show that exposure had any effect on well-being over the six-week study period. Whether any effects emerged thereafter was not investigated either in this or in the TNO study.

These two studies are currently the only available sources of information as far as effects on well-being are concerned. Other replication studies are currently under way in various locations worldwide. They have been started later than the Swiss study and their results are not expected in the near future. The results of these studies will provide more insight into whether UMTS exposure can result in short term health effects.

The findings from the TNO and Swiss studies as regards the absence of an effect on cognitive functions are borne out by the Schmid *et al.* study as far as visual perception is concerned.

Only indirect data on long-term exposure

In the TNO and Swiss studies short-term exposure has been investigated. Consequently these studies do not provide any information about possible effects of prolonged or continuous exposure of the type that occurs in everyday life as a result of the presence of UMTS antennas in the living or working environment. Such situations cannot be investigated in the laboratory either. No research has been conducted to date, however, on the effects of prolonged exposure to electromagnetic fields of whatever sources on well-being.

Although research has been performed into the occurrence of such diseases as cancer in relation to prolonged exposure to electromagnetic fields, exposure to

UMTS signals has not been addressed. This type of research is only possible if exposure has taken place over a prolonged period and the UMTS technology has been in place only for a relatively short period of time.

Until more time has elapsed, we must rely on information about long-term effects from research on exposure to other sources, such as radio and television transmitters. In the 2005 Annual Update, the Health Council provided a comprehensive overview of that research and concluded that at the basis of current scientific knowledge no long-term effects can be identified as a result of prolonged exposure to radiofrequency electromagnetic fields.[21] There is no reason to suppose that the situation is any different with regard to UMTS.

Hoofdstuk 4

Research on possible effects of DECT

It is becoming increasingly common for people who claim to suffer from health problems as a result of exposure to electromagnetic fields to identify DECT cordless indoor telephone systems as an additional source of these problems alongside the GSM and UMTS mobile telecommunications systems. In particular, this might be due to the fact that a DECT base station continuously emits a pulsed signal. One sometimes hears (incorrect) references to “100 very sharp pulses per second”.

In this chapter the Committee discusses the scientific knowledge regarding health effects of exposure to DECT signals. The chapter sets off with some short background information on DECT.

4.1 Technical information

DECT (Digital Enhanced Cordless Telecommunication) is a modern digital standard for wireless telecommunications. As far as telephony is concerned, its area of application ranges from small domestic exchanges to large business exchanges. However, there are also DECT baby monitors and DECT headsets on the market.

A domestic exchange usually consists of a base station that is connected via a cable to the landline telephone network and either one or several telephone handsets. Wireless communication takes place exclusively between the telephones and the accompanying base station. Via the base station, it is also possible to make a call from one handset to the other, which does not involve connecting to the landline telephone network.

Like GSM, DECT uses a time-divided transmission system. For the domestic exchanges, this means that the mobile telephones and the base stations do not transmit with a continuous signal, but in short pulses. The system operates at frequencies between 1880 MHz and 1900 MHz and there are 10 frequency channels with a bandwidth of 1.728 MHz. One frequency channel is always used per connection. DECT equipment transmits in “frames” of 10 milliseconds (ms), i.e. 100 frames per second, meaning that the pulse frequency is 100 hertz (Hz). If several channels are in use simultaneously (for several connections), the pulse frequency changes.

Each frame is subdivided into 24 time slots, half of which are used for communication from the base station to the handset (downlink*)*, and the other half for the reverse connection (uplink) – see figure 2. One time slot is used per connection. Since a frame is 10 ms long, the length of each time slot is 10 ms / 24 = 417 µs. 368 µs of this is used for the actual transmission, but no transmission takes place during the remaining 49 µs in order to prevent overlap of successive time slots. Thus transmission does not occur in the form of discrete pulses but via small packets of information.

The maximum power output of both the telephones and the domestic base stations is 250 mW. Because only one 10 ms time slot is used per connection, only 368 µs of which is actually transmitted, the maximum effective transmitted power of a telephone is 250 x 0.368 / 10 = 9.65 mW. A standard domestic base station can support a maximum of 8 handsets at any one time. In the majority of devices, one time slot is permanently in use for the transmission of a “beacon signal” 83 µs long, thus producing a power output of 250 x 0.083 / 10 = 2.1 mW. The effective transmitted power of a standard domestic base station therefore ranges from a minimum of 2.1 mW to a maximum of 79.3 mW (8 times 9.65 mW per time slot in which communication is taking place plus 2.1 mW for the beacon signal). Larger domestic and business exchanges can accommodate more channels, and therefore a greater power output.

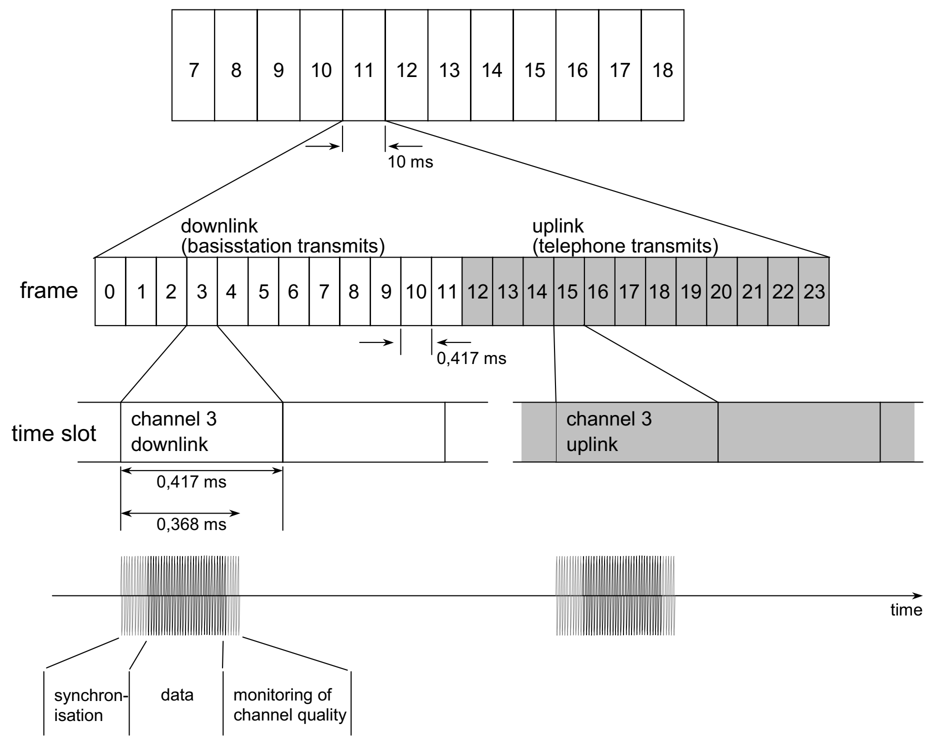

Figure 2 Schematic representation of a DECT signal using a single frequency channel (Source: adapted from Schmid *et al.* [45]).

4.2 Field strength measurements and calculations

Measurements have been performed on base stations and telephones for two types of DECT systems by Schmid *et al.*[45] and on three types of DECT base stations by Kühn *et al.*[30] Schmid *et al.* carried out the measurements for the situation in which a call was made via the base station by two telephones, i.e. two time slots were in use for the call information and one slot for the beacon signal. The Kühn *et al.* measurements were conducted with a single telephone connected plus the beacon signal.[30] These measurements show that a relatively high field strength arises within a very short distance (a few centimetres) of a base station while a call is being made, which approaches or even slightly exceeds the reference values specified by ICNIRP [26] (59.6–59.9 V/m)*. These measurements were performed in the near field** of the antenna, however, and the ICNIRP reference values cannot be applied in that situation as they relate to the far field. The field strength decreases sharply with increasing distance, and at a normal distance from the user (where the far-field situation applies) it is usually less than 1 V/m. Table 1 gives an overview of the measured values, taken from a graph in Kühn[30] and from Table 7.3 in Schmid.[45] These data have been converted for the use of a single telephone in order to allow for comparison with the Kühn data. The effective transmitted power of the base station is then 9.65 mW (call) + 2.1 mW (beacon) = 11.75 mW.

Table 1 Mean values of the field strength and power density for a DECT base station connected to a single telephone, based on field-strength measurements performed on 5 types of base station

Distance (cm)	Electrical field strength (V/m)[a]	Power density (W/m^2)
5	15–20[b]	[c]
10	3.5–8[b]	[c]
20	1.5–2.2	0.006–0.013
30	1.1–1.7	0.0032–0.0077
40	0.7–1.2	0.0013–0.0038
50	0.6–1.0	0.00095–0.0027
100	0.3–0.4	0.00024–0.00074
300	0.2	0.00011

[a] ICNIRP reference values: 59.6–59.9 V/m.
[b] Measurements in the near field; comparison with reference values not relevant.
[c] Measurements in the near field; power density cannot be calculated.

* The exposure limits proposed by ICNIRP distinguish between two types of limits.[26] The actual exposure limits are termed "basic restrictions". These are values for variables that relate directly to processes that can lead to adverse health effects in an exposed individual. For the radio frequencies used by DECT systems, the Specific Absorption Rate (SAR) has been defined as the basic restriction. The relevant biological effect is tissue heating. The SAR is a measure of the speed at which electromagnetic energy is absorbed into the body and is therefore a measure of the conversion of this energy into heat and therefore of the heating effect. In practice, the SAR is difficult to measure directly and therefore the so-called reference levels have been derived from the basic restrictions. These are values for the electrical and magnetic field that is present at the site of the exposure in the absence of the exposed object. These field strengths are relatively easy to measure. The reference levels are an aid to determining whether the actual exposure limits, the basic restrictions, are being complied with.

** 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. On average, they decrease more sharply than inversely proportional to the distance from the source.

Because there is a linear correlation between the power density and the effective transmitted power, one can calculate what the power density and the corresponding electrical field strength are for the stand-by situation whereby only the beacon signal is transmitted. The power density is then multiplied by a factor of 2.1 / 11.75 = 0.179.

Table 2 Mean values of the field strength and power density in a DECT base station in stand-by mode, calculated from the data in Table 1.

Distance (cm)	Electrical field strength (V/m)	Power density (W/m^2)
5	6.3–8.4[a]	
10	1.5–3.4[a]	
20	0.63–0.92	0.0011–0.0023
30	0.47–0.72	0.00058–0.0014
40	0.30–0.51	0.00023–0.00068
50	0.25–0.42	0.00017–0.00048
100	0.13–0.17	0.000043–0.000076
300	0.08	0.000019

[a] Extrapolated.

Based on the available technical specifications concerning DECT baby monitors, it appears that these continuously exchange signals between the baby unit and the parent unit. No data are available with regard to the resultant field strength or the field strength generated when sounds are being transmitted.

4.3 Attenuation

DECT signals are, to some extent, attenuated by all kinds of materials, with floors and walls made from reinforced concrete being particularly effective in this respect. A number of examples are included in the table below.

Table 3 Attenuation of the field strength of DECT signals by different materials.

Material	Attenuation (dB)	Attenuation (%)
Glass	2	21
Wall	3-17	29–86
Floor	14-55	80–99.8

A DECT base station that is located against the wall between two dwellings also gives rise to an electromagnetic field in the adjoining dwelling. The strength of this field depends on the attenuating effect of the wall, and this will vary according to the structure of the building. In the case of a wall made of reinforced concrete, the attenuation of the field strength is more than 80%. Due to the thickness of the wall, the minimum distance between someone in the adjoining dwelling and the base station will always be such as to prevent the ICNIRP reference value being exceeded. When no call is being made via the base station, the field strength that is generated in the adjoining dwelling will always be less than 1 V/m.

4.4 Determination of the absorbed power

Kühn *et al.* have also performed SAR measurements on four types of DECT telephones.[30] The maximum SAR values (averaged over 10 g tissue) ranged from 0.019 to 0.052 W/kg. The ICNIRP limit value for such local exposure is 2 W/kg.

The field strengths at some distance from the base stations, in the far field, are well below the ICNIRP reference values, which also means that the basic restriction (an average, whole-body SAR of 0.08 W/kg) is not exceeded.

4.5 Results of studies into possible health effects

The concerns of the people who attribute their symptoms to the presence of DECT telephones in their environment are based on the assumption that a DECT signal is biologically effective.

4.5.1 Epidemiological research

The only studies to have explored a possible relationship between the use of a cordless telephone and health problems are a number of epidemiological studies into the occurrence of brain tumours, conducted by Hardell *et al.* in Sweden[15,16] and Schüz *et al.* in Germany.[47] The Schüz study is the only one to have specifically investigated the association with the use of DECT telephones and also looked at a possible association with the presence of DECT base stations. No experimental research has been performed into effects of DECT signals.

Schüz *et al.*[47] did not find that the presence of a DECT base station beside the bed (and therefore continuous exposure to the EM field caused by the beacon signal during the night) had any effect on the occurrence of brain tumours. However, due to the small numbers involved*, they were only able to look at the presence of the base station (and therefore exposure at night) and could not make an

* A distinction was drawn between the definite and the possible presence of a DECT system, and between the occurrence of two types of brain tumour: menigiomas and gliomas. Only 3-5 patients and 10-13 controls were found for each category.

adjustment for the use of a DECT and/or mobile telephone (sources of daytime exposure). As the researchers themselves concede, this study is therefore of only limited scientific value. The Committee feels that the researchers are going too far in viewing this data as the first indication that continuous exposure to low-level EM fields in the living environment does not lead to an increase in the risk of brain tumours.

Schüz *et al.* have also analysed the same material with regard to the use of mobile or cordless telephones, including DECT.[47] Although the question as to whether people were using a DECT or an older type of (analog) cordless telephone was, in fact, asked, no distinction was made between these types in the analysis. The use of a cordless telephone did not correlate with the occurrence of brain tumours – not even in the sub-group that had already been using a cordless telephone for more than five years.

The robustness of this study is also limited, however. This is because the actual exposure was not measured or estimated, because the follow-up time did not extend beyond “5 years or longer”, because the use of a cordless telephone only was not ascertained (most users of a cordless telephone will also use a mobile telephone), and because there was a difference in the percentages of participants from the patient and control groups, respectively. It is therefore not possible to draw any conclusions from this study about possible effects of exposure to a DECT signal.

According to Hardell *et al*., their results do, in fact, point to an association between the use of a cordless telephone and the occurrence of brain tumours.[15,16] These studies monitored usage over a prolonged period (more than 10 years), but no distinction was made between the use of analog and digital (DECT) telephones.

Although the researchers report having discovered an increased risk of brain tumours associated with the use of a cordless telephone, it is hard to surmise this from the published material. A relative risk of 1.3 (95% confidence interval = 0.99-1.7) is given for the sub-group “users of a cordless telephone only”.[16] The increase in risk is therefore not statistically significant. Moreover, the length of the period of use and the extent of use (and thus the degree of exposure) were not taken into consideration.

The Committee considers it likely that those individuals who use a cordless telephone for the longest period have, in any case, initially had an analog handset. It is not possible, therefore, based on this study, to draw any conclusions about the possible impact of DECT on the occurrence of brain tumours.

4.5.2 *Experimental research*

The available epidemiological studies do not provide any information on possible health effects of DECT exposure. The question then arises as to whether it may perhaps be possible (either based on theoretical considerations or through extrapolation of data obtained using other, similar sources) to draw any conclusions about the possible impact of a DECT signal on health. The most obvious alternative source is GSM, and more specifically the GSM 1800 MHz signal. The carrier frequency of these systems approximates that of DECT (1880–1900 MHz) and it is also a pulsed signal that works according to the same technical protocol – provided that a pulse frequency of 217 Hz is used, rather than 100 Hz as in the case of DECT. In both systems, the information is transmitted by modulating the carrier frequency in each pulse. This is achieved by means of phase shifts in the carrier frequency, with the amplitude and the frequency themselves remaining the same.

There are several studies – both with *in vitro* cell cultures and experimental studies in human beings – in which exposure to a pulsed GSM signal resulted in a stronger effect than with exposure to a similar, but continuous, signal. The majority of these studies have, however, been performed with exposure to 900 MHz GSM signals and are therefore less readily comparable with a study involving DECT signals. The Committee will nevertheless consider these studies. On the other hand, there are also several studies – including both *in vitro* research and studies with animals and human subjects – in which no difference has been found between effects of exposure to pulsed and continuous radiofrequency fields.

Studies on brain activity

Huber *et al.* exposed study participants to a normal (pulsed) 900 MHz GSM signal, an unmodulated 900 MHz signal or a sham signal for 30 minutes.[24] Brain activity increased during and after exposure (in the form of an increase in the strength of the so-called alpha waves: electrical activity with frequencies of 8-13 Hz) when subjects were exposed to the (pulsed) GSM signal, but this did not happen in the case of exposure to the continuous signal or sham exposure. In other studies too, pulsed EM fields have been found to have an impact, though no comparisons have been made with a continuous signal.[5-7,25,29,32]

Krause *et al.* studied EEG responses in children during a memory task both with and without exposure to a (pulsed) 900 MHz GSM signal.[29] They discovered changes of between 5 and 10% in certain brain activities. In earlier research, however, these researchers had found that exposing children in the same age range to a 900 MHz GSM signal had no effect on various cognitive functions.[13] The effects on brain activity would therefore appear to have no implications with regard to brain function. There are also several studies in which a GSM signal has been found to have no bearing on brain functions.[14,51]

Research into on effects on thermoregulation

Research into thermoregulation has not found pulsed signals to be either more or less effective than continuous signals.[1,10,11] These studies have, however, been performed with signals other than those from a mobile telephone.

Studies on carcinogenesis

Two studies into carcinogenesis failed to identify any effect either from continuous, or pulsed RF fields.[23,54]

In vitro research

Various *in vitro* studies have been conducted with a view to investigating differences in effects of pulsed and continuous radiofrequency fields. Several authors failed to detect any differences in human white blood cells between the two modalities at SAR values of up to 10 W/kg.[34-37,52]

Research into cellular stress effects and intracellular calcium levels has identified no difference between reactions to continuous and GSM-modulated signals in human leukaemia cells or normal white blood cells.[4,31,33,48]

Finally, a study has been conducted on the release of melatonin from isolated pineal glands of hamsters following exposure either to a continuous or to a GSM-modulated 1800-MHz signal at various SARs.[49] Both types of signal increased melatonin release at 0.8 W/kg, but at 2.7 W/kg the researchers discovered an increase in melatonin levels with the continuous signal and a reduction with the GSM signal. It is possible that temperature effects may have played a role at 2.7 W/kg.

4.6 Conclusions

Normal use of DECT does not lead to exceeding of exposure limits

The field strength caused by DECT base stations varies depending on whether or not a call is being made, on the distance between the exposed individual and the base station, and on possible attenuation of the signal. Even when no call is being made, the base station still continuously emits a weak signal (the "beacon signal"). The exposure limits are not exceeded, however. When a DECT telephone is used, exposure always remains well below the exposure limit.

No indications for a possible association between DECT and brain tumours

There are only two known epidemiological studies in which the occurrence of brain tumours has been investigated in relation to exposure to DECT signals. Only small numbers of patients have been identified in both studies and actual exposure has not been measured. Consequently no conclusions can be drawn on the basis of this data with regard to the possible impact of DECT on the occurrence of brain tumours.

Adverse health effects of DECT signals are unlikely

In a few studies it has been observed that (pulsed) signals from a GSM telephone can have some effect on certain brain activities, whereas the effect of a comparable non-pulsed signal was less marked. However, other data indicate that GSM signals have no effect on learning processes. No evidence of other health effects has been discovered in research with volunteers.

Research with experimental animals and cell cultures has not shown any difference in the effectiveness of pulsed and non-pulsed electromagnetic fields – in fact neither of these two field types produced an effect in the majority of studies.

Based on these data and on the lack of any evidence of a mechanism that might explain increased effectiveness of pulsed fields [8], the conclusion to be drawn is that there are no indications and that it is unlikely that DECT signals have an adverse impact on health upon exposure below the limit values.

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A The Committee

Annex

Annex **A**

The Committee

The membership of the Electromagnetic Fields Committee at the time of the writing of this Annual Update was as follows:

- Dr. G.C. van Rhoon, *chairman*
  physicist; Erasmus University Medical Centre, Rotterdam
- Dr. L.M. van Aernsbergen, *adviser*
  physicist; Ministry of Housing, Spatial Planning and the Environment, The Hague
- Prof. G. Brussaard
  professor of Radio Communications (emeritus); Eindhoven University of Technology
- Dr. J. Havenaar
  psychiatrist; Buitenamstel Mental Health Service (GGZ), Amsterdam
- Prof. H. Kromhout
  professor of Occupational Hygiene and Exposure Assessment, Institute for Risk Assessment Sciences, Utrecht University
- Prof. F.E. van Leeuwen
  professor of Cancer Epidemiology; Free University of Amsterdam, epidemiologist; Netherlands Cancer Institute, Amsterdam
- Dr. H.K. Leonhard, *adviser*
  physicist; Ministry of Economic Affairs, Groningen
- Dr. M.M. Sitskoorn
  neuropsychologist/cognitive scientist; University Medical Centre, Utrecht

- Prof. W.J. Wadman
  professor of Neurobiology, University of Amsterdam
- D.H.J. van de Weerdt, MD
  specialist in environmental medicine; Central Gelderland Municipal Health Service (GGD), Arnhem
- Prof. A.P.M. Zwamborn
  professor of Electromagnetic Effects; Eindhoven University of Technology, physicist; TNO (Organisation for Applied Scientific Research), The Hague
- Dr. E. van Rongen, *secretary*
  radiobiologist; Health Council, The Hague