

5G and health

To: the President of the House of Representatives of the Netherlands
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Health Council of the Netherlands



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executive summary

The latest standard for mobile telecommunications (5G) is faster and more reliable and can process more data at the same time. 5G was developed to cope with the increasing demand for mobile telecommunications and to make new applications possible such as self-driving cars and remote surgery. The advent of 5G networks is, however, resulting in societal concerns about the potential influence of 5G on health. That is why the House of Representatives of the Dutch parliament has asked the Health Council of the Netherlands to analyse what is known about this from a scientific perspective. The Council's Standing Committee on Electromagnetic Fields has looked into this issue.

Effects of 5G frequencies on health not yet fully examined

To a certain extent, 5G uses the same frequencies as previous generations of mobile telecommunication such as 3G and 4G.

In addition, it will use new frequency bands. The rollout of 5G networks has only just begun. Therefore, there are no studies as yet into the health effects of (long-term) exposure to electromagnetic fields with the frequencies that are reserved for 5G. However, applications have been examined that use frequencies very close to the new 5G frequencies. These include 2G, 3G and 4G, as well as Wi-Fi and radar.

No actual health risks known

This report is a first step in the analysis of possible health effects of 5G frequencies. As yet, the committee is unable to answer the question of whether exposure to 5G frequencies actually poses risks to human health. There are two reasons for that. The first is that such a statement requires knowledge of the level of exposure that can cause health damage to humans. That requires a more detailed analysis of the scientific data than the committee was

able to carry out. The World Health Organization (WHO) is currently performing such an analysis and it is anticipated that it will be completed in 2022. Secondly, it requires knowledge of what the actual exposure to radiofrequency electromagnetic fields will be after the introduction of 5G. That is not yet known, because the use of 5G, as stated earlier, has only partially started.

Relations between 5G frequencies and health damage not demonstrated but cannot be excluded for a number of conditions

Therefore, the committee has investigated whether there are indications that electromagnetic fields with the frequencies of 5G have the *potential* to harm health. It has reviewed whether relations are known between exposure to radiofrequency electromagnetic fields on the one hand and the occurrence of diseases and conditions on the other. According to the committee, it cannot be excluded that the



incidence of cancer, reduced male fertility, poor pregnancy outcomes and birth defects could be associated with exposure to radiofrequency electromagnetic fields. However, the committee deems the relation between exposure and these and other diseases or conditions neither proven nor probable.

The committee has also examined the possible relation between exposure to radiofrequency electromagnetic fields and changes in biological processes. It is probable that changes in electrical activity in the brain are associated with exposure, but it is not known whether that is favourable or unfavourable in health terms. For the majority of other biological processes it has neither been demonstrated nor is it probable that changes in them are associated with exposure to radiofrequency electromagnetic fields, although this cannot be excluded. Only for changes in the immune system and hormone

levels, no relation was found. There has been almost no research into the effects of exposure to frequencies around 26 GHz.

The committee's recommendations

The committee has made four recommendations to Parliament.

1. Because the lower frequency bands for 5G (up to 3.5 GHz) have already been used for telecommunications applications and Wi-Fi for years without resulting in any proven adverse health effects, the committee sees no reason to stop or restrict the use of these frequency bands. It does however recommend that the exposure should be monitored before, during and after the rollout of the 5G systems. This will show to what extent exposure to radiofrequency electromagnetic fields changes as a result of the introduction of 5G and any long-term health risks can then be estimated better. The

WHO analysis can also be used in estimating the risks.

2. The committee recommends doing more research:
 - epidemiological research into the relation between exposure to the 5G frequencies used and the incidence of cancer, reduced male fertility, poor pregnancy outcomes and birth defects. An ongoing international study into the use of mobile telephones, in which the Netherlands is participating, can play a role in this.
 - experimental research into the health effects of exposure to electromagnetic fields in the 26 GHz frequency band.
 - scenario studies to get a picture of the exposure of individuals as a result of wireless communications systems (3G, 4G and 5G).



3. The committee recommends not to use the 26 GHz frequency band for 5G for as long as the potential health risks have not been investigated.
4. Finally, the committee recommends using the latest guidelines from the International Commission on Non-Ionizing Radiation Protection (ICNIRP) as the basis for exposure policy in the Netherlands. Because it cannot be excluded that exposure under the latest ICNIRP standards also has the potential to affect health, the committee recommends to take a cautious approach and keep exposures as low as reasonably achievable.



01 introduction



1.1 Motive and request for advice

The influence that electromagnetic fields have on health has been an issue for decades, for instance because of the growth in mobile telephony and other forms of wireless telecommunication. Now that 5G networks are being rolled out, society is worried about the possible health effects of exposure to '5G radiation'. As a result of that, the House of Representatives of the Dutch parliament asked the Health Council in November 2019 for advice about the possible health risks of exposure to electromagnetic fields with frequencies that will be used by 5G communication systems. The president of the Council asked the Standing Committee on Electromagnetic Fields to draw up that advice. The composition of the committee is given at the end of this advisory report; the request for advice (in Dutch) can be found on www.healthcouncil.nl.

The House of Representatives specifically asked the Health Council:

- to give an overview and assessment of the national and international studies that have been published on the possible health risks of 5G, as a supplement to earlier publications and advisory reports in this area;
- to assess to which extent the current public health standards in this area are based on the latest scientific understandings.

1.2 Methodology

1.2.1 Literature research

Relations with diseases, conditions and biological processes

The committee has analysed data from studies into the relation between health outcomes and exposure to electromagnetic fields in three frequency bands covering the frequencies that are going to be used by 5G:

- 700 MHz to 2200 MHz;
- 2.2 GHz (= 2200 MHz) to 5.0 GHz;
- 20 GHz to 40 GHz.

Studies into heating effects in the body or body parts that can occur upon exposure above the current limits (see Section 1.4) and that have previously been scientifically demonstrated to exist, have been excluded, as have studies into therapeutic effects of radiofrequency electromagnetic fields.

When analysing the data, the committee has made a distinction between diseases and conditions on the one hand and biological processes on the other.

Review by the WHO and reports by SSM as the basis

The committee has used a draft literature review by the World Health Organization (WHO) on the effects of radiofrequency electromagnetic



fields (with frequencies between 100 kHz and 300 GHz). This draft was published in October 2014 to solicit comments and additions.¹ A finalised version has not yet been published. The WHO review includes data from approximately 1992 onwards. In addition, recent annual reports by the Swedish radiation protection organisation (SSM) have been used as a source.²⁻⁵ To obtain the most recent data that has not been included in earlier advisory reports of the Health Council or in the reports by the WHO and SSM, the committee searched the scientific literature.

For frequencies between 700 MHz and 5 GHz, the committee has searched for data that supplement the information that the Health Council has reported on in earlier advisory reports. For the frequency band around 26 GHz, which the Health Council has not previously reported on, the committee looked for studies into health changes relating to frequencies between 20 and 40 GHz. In that frequency range, the only studies available are epidemiological studies looking into occupational exposure to radar. Fields with these frequencies do not penetrate the body any further than the skin.

The analyses by the WHO and SSM only include studies that meet quality criteria that were set in advance. Studies with scientific shortcomings (such as the absence of proper characterisation of the exposure in experimental research) have been excluded. For the more recent studies, which appeared after the reports by the WHO and SSM, the committee

adopted the criteria set by the WHO and SSM to determine whether or not to include the studies in its analysis.

The background document to this advisory report, which is also published on www.healthcouncil.nl, includes the committee's search strategies and the WHO's quality criteria. Additionally, overviews of all the studies have been included. Where studies have been excluded from the analysis, the reason for their exclusion is also stated.

Epidemiological studies and experimental research in humans and animals

For this report, the committee has analysed data from epidemiological research and experimental research in humans or laboratory animals. The committee has not included in vitro research (studies of cultured cells). The committee discusses the types of research used in Chapter 3.

1.2.2 Scope of the conclusions: health risk versus the potential to cause harm

In this advisory report, the committee does not make any statement about the actual occurrence of health damage after exposure to 5G. The committee only makes statements about the *potential* for radiofrequency electromagnetic fields to cause adverse health effects.

When determining a possible relationship between exposure to a specific factor – in this case, radiofrequency electromagnetic fields – and changes



in health, it is important to distinguish between the *risk* (the probability that a given exposure to the factor actually causes adverse health effects) and the *hazard* (the intrinsic characteristic of a factor that gives it the *potential* to cause harm). The conclusions that the committee draws in this report are only about the *hazard*, i.e. the potential to cause harm. To be able to make statements about health risks, first of all knowledge is needed of the relationship between exposure and effects, and also data is needed about the anticipated levels of exposure for individuals. The committee has not been able to investigate what levels of exposure cause adverse health effects or whether there may be a threshold value beneath which no harm occurs. To answer these questions, a thorough analysis of the available data is needed. Such analysis is currently being performed by the World Health Organization (WHO) and the results are expected in 2022. Furthermore, it is not yet known what the levels of exposure for individuals will be when the 5G systems are operational.

In this report, the committee has focused solely on health damage that is a direct consequence of exposure to radiofrequency electromagnetic fields: what does exposure do to the human body? The committee has not looked at other consequences of the use of mobile telecommunications devices, such as the increased risk of traffic accidents resulting from the use of mobile phones while driving vehicles, or people becoming addicted to using mobile phones, nor has it looked at therapeutic effects (such as electrotherapy). It is also possible that electromagnetic fields can affect

the living environment, for example affecting plants and animals. If the environment that people live in were to be adversely affected in some way, this could indirectly have adverse effects on their health. Such effects are also outside the scope of this report.

1.3 Earlier recommendations by the Health Council

The Health Council has previously published reports about health risks resulting from exposure to radiofrequency electromagnetic fields in mobile telephony, in particular about the incidence of cancer.⁶⁻¹¹ Those reports combine data on the various frequencies currently used for 2G, 3G and 4G, which range from around 800 MHz to around 2100 MHz. The key conclusion of the most recent report is that no association has been proven between long-term and frequent use of mobile phones and an elevated risk of tumours in the brain or the head and neck area, but that such a link can also not be excluded.⁸

The conclusions from those earlier reports are also relevant for 5G as far as the frequency bands around 700, 1400, 1800 and 2100 MHz are concerned. For the current report, the committee searched for recent scientific literature in order to update the data on exposure to radiofrequency electromagnetic fields and cancer. Unlike for the earlier reports, it did not limit the search to mobile phones as the source of exposure or to tumours of the brain and head and neck area as the effect,



instead taking account of all sources of exposure to radiofrequency electromagnetic fields and all types of cancer.

The Health Council has not previously reported on the middle frequency band that is going to be used for 5G (3.5 GHz). This frequency is between the two frequency bands used by Wi-Fi (2.40-2.48 and 5.1-5.7 GHz). Investigations of the effects of Wi-Fi are therefore also relevant for 3.5 GHz. The Council has reported about Wi-Fi in the report *Influence of radiofrequency telecommunication signals on children's brains*.¹² That report concluded that the relatively limited available data does not indicate that there are effects on the development of the brain or on health when children are exposed to radiofrequency electromagnetic fields such as those produced by mobile phones, mobile telephone masts or Wi-Fi facilities.

The Health Council has not previously reported on the highest frequency band (26 GHz) that is going to be used by 5G. Because some radar systems also use frequencies of roughly 26 GHz (for instance 24 GHz is one of the frequencies used by police radar speed traps), the committee has made an inventory of studies looking into people who work with or in the vicinity of such systems.

1.4 Current exposure limits and government policy

Restriction of exposure to radiofrequency electromagnetic fields in the Netherlands is handled by the adoption of exposure limits that are then enforced by Radiocommunications Agency Netherlands. The exposure limits used for the general population are based on a recommendation made by the European Commission in 1999.¹³ That recommendation uses the guidelines published in 1998 by the International Commission on Non-Ionizing Radiation Protection (ICNIRP).¹⁴ ICNIRP has recently published new guidelines for exposure to radiofrequency electromagnetic fields that are based on an analysis of all currently available scientific information.¹⁵ In this process, ICNIRP used the same WHO and SSM reports as the committee.¹⁻⁵ The ICNIRP guidelines aim at preventing excessive heating of the body or parts thereof. This is because ICNIRP states in the most recent guidelines (as in the guidelines from 1998) that the only harmful effects that have been scientifically substantiated are those that are a direct consequence of heating of the entire body or body parts by radiofrequency electromagnetic fields.

The Netherlands authorities have designated the frequencies at which 5G is going to operate 'technology neutral', in other words they are being made available without imposing requirements on products or services as long as the producers and providers of services ensure that the exposure limits are not exceeded.



1.5 Reading guide

Chapter 2 contains background information about 5G. Chapter 3 gives the results of the committee's analysis of the research looking into a relationship between exposure to radiofrequency fields and the occurrence of diseases and conditions and of changes in biological processes. The committee formulates its conclusions in Chapter 4, making various recommendations.

With this report comes a background document (which is also published on www.healthcouncil.nl), giving the methodological justification, the WHO quality criteria, an overview of the literature that was found and the associations (for epidemiological studies) and effects mentioned therein (for experimental research), plus an overview of the studies that were excluded along with the reasons for their exclusion.



02 about 5G



5G is the new standard for wireless communication, with the key improvements being the higher capacity and more rapid data transfer. 5G makes more applications possible than just mobile telecommunication. On top of the higher capacity, 5G will in the longer term be utilising higher frequencies than those currently being used. 5G also uses not only the usual omnidirectional antennas, but also antennas that can transmit more focused bundles. Exactly what that means for the extent to which people will be exposed is not yet known.

2.1 Generations of mobile telecommunication

The fifth generation of mobile telecommunication, or 5G for short, is a further development based on earlier generations. The ‘language’ (the protocol) used for communication between the components is different for each new generation. 1G was an analogue system that could only be used for voice communication. 2G was a digital system (GSM). This made it possible to send text messages as well and the sound quality was improved. 3G (UMTS) was the first to provide the possibility of data exchange, allowing the smartphone to be developed. The speed of data exchange was increased with 4G.

In each successive generation, the information transfer rate (voice and data) increased, as did the capacity, thanks to the use of other frequencies. This meant that increasing numbers of people were able to transfer more and more data at the same time. Because demand keeps

increasing and because technological developments require rapid data exchange, the existing telecommunication systems are being developed further. Examples of technological developments are self-driving cars, remote surgery and the use of drones to monitor the condition of agricultural crops.

2.2 Frequency bands

5G does not only use a different protocol to 3G and 4G: other frequencies will also be used, in addition to those that are already employed by the current generations of mobile telecommunications. Some of these new frequencies are lower and others higher than the frequencies used until now. The lower frequencies will be used for building the basic networks, whereas the higher frequencies make higher capacity and faster data transfer possible.

When the first 5G network came into use in the Netherlands on 28 April 2020, a frequency band was initially used that is also employed for 4G, namely the 1800 MHz band. The frequency bands for mobile telecommunication are in fact auctioned off as ‘technology neutral’, i.e. without demanding that they are to be utilised for a specific technology such as 4G or 5G. The frequency bands around 700, 1400 and 2100 MHz will also be used for wireless communication, after they have been auctioned off. In an even later stage, frequency bands around 3.5 GHz and 26 GHz are also going to be used.



The 700 MHz band was until now used for applications other than telecommunication, such as wireless microphones and television (Digitenne). This band will be used for the basic structure of the 5G networks. It will be possible to modify some existing 3G and 4G base stations for this.

The frequency band around 1400 MHz was reserved for public broadcasting but has never been used. The frequency band around 2100 MHz is already being used for 3G and 4G telecommunication.

Use of the 3.5 GHz band will start later, in particular when the capacity of the network needs to increase. Until now, this frequency has been used by corporate networks and local broadband connections, as well as the ground station for the intelligence services in Burum. Its range is smaller than for 700 MHz: a base station using 3.5 GHz can cover a range of 100 to 150 metres because the signal will be blocked and reflected by buildings and vegetation at the level of the user. This band will therefore not only use the existing base stations, but also smaller antennas that can, for instance, be attached to street furniture items such as lampposts.

The frequency band around 26 GHz is currently used for microwave links, camera monitoring at railway stations and self-driving cars. This frequency band will not be used in the Netherlands for 5G in the short term. 26 GHz will in due course primarily serve to further expand the capacity of the network. The range of this frequency is even smaller than that of 3.5 GHz. Finally, the option of using even higher frequencies than 26 GHz for 5G is also being kept open.^{16,17}

Exactly what frequencies are going to be used for 5G applications and with what type of antenna may vary depending on the provider and producer.

Figure 1 (see page 15) summarises the current use of the 5G frequencies (as described in Section 2.2) and shows which frequencies have been the subject of previous reports of the Health Council (described in Section 1.3).














	700, 1400 and 2100 MHz		3.5 GHz		26 GHz
Recent or current use of the intended 5G frequency bands	700 MHz: includes wireless microphones		Company networks and local broadband		Radar (exempt from permits in car bumpers, limited use) 
	1400 MHz: public broadcasting, but never used		Satellite communications (from satellites to Earth)		Microwave links
	2100 MHz: 3G and 4G				
	Between 700 and 2200 MHz:		Between 2.2 and 5.0 GHz		Between 20 and 40 GHz
Recent or current use of similar frequency bands	800 MHz: 4G and before that for public broadcasting, analogue TV and by the department of Defence		2.45 GHz without permits including microwave ovens		Radar systems 
	900 MHz: 2G, 3G, 4G and before that for analogue car phones		2.6 GHz: 4G		Police speed-trap radar (including 24 GHz)
	1800 MHz: 4G		2.40 to 2.48 and 5.1 to 5.7 GHz: Wi-Fi		Microwave links
Health Council reports on similar frequency bands	The Health Council has published various reports up to 2016 about mobile phones and cancer. They combine data for frequencies around 800 MHz and around 2100 MHz (2G, 3G and 4G). ⁶⁻¹¹		The Health Council has reported about Wi-Fi in 2011 in the report titled <i>Influence of radiofrequency telecommunication signals on children's brains</i> . ¹²		Satellite communications

Figure 1. Overview of the current use of 5G frequencies and relevant advisory reports by the Health Council of the Netherlands.



2.3 Exposure

A key technical development associated with the introduction of 5G is antenna technology that makes it possible to form beams. Current base stations transmit in three sectors that together create a full circle, with the main direction of the signal tilting a little bit downwards. As a result, part of the energy is unused. Everyone who is at the same distance from such a base station and with an unobstructed line of sight is exposed to electromagnetic fields to roughly the same extent, irrespective of whether their mobile device has a connection or not. In practice, there is often no unobstructed line of sight and screening and reflection also play a role in the final level of exposure. For 5G, some base stations will use beams that can be aimed at the mobile device of the user who wants the connection. The beam then follows the device as it moves; screening and reflection occur in this case as well. When it reaches the user, a beam like this can have a diameter of several metres. Users will additionally be exposed to the emissions from their own mobile phones as well, of course. All this means that exposure in the future will be more variable than in the current situation. Figure 2 on page 17 gives a greatly simplified representation of how the concept of 5G antennas differs from the current antennas.

What these characteristics of 5G mean for the exposure of individuals cannot be predicted at the moment, primarily because it is not possible to estimate the extent to which the number of antennas and data traffic will increase in the future due to the introduction of 5G. Because 5G will initially

operate alongside the existing 3G and 4G systems, it is expected that the overall exposure per individual and for the population at large will increase at first, although this also depends on how the systems and antennas are switched on and off. The exposure could decrease when 3G is decommissioned. In addition, the changing way mobile phones are used is also important for the exposure of the individual. With 2G (GSM), the phone was mostly used for making phone calls and was then held close to the head. With 3G (UMTS) and 4G, for which the average output power of the phones is 100-200 times less than for GSM, there has been a shift towards using social media and online applications such as streaming movies, music and games. The phone is then held up to the head much less often and the exposure of the head is much lower as a result.

5G is not only intended for mobile telecommunication. Technological developments such as self-driving cars, remote surgery and the Internet of Things (communication between devices) will also use this high-speed network. This will result in an increase in data traffic and thereby potentially in higher exposure. Radiocommunications Agency Netherlands and the National Institute for Public Health and the Environment (RIVM) state in their report entitled *Verkenning van de blootstelling aan elektromagnetische velden afkomstig van 5G-systemen*¹⁸ (Exploration of the exposure to electromagnetic fields from 5G systems) that it is important to keep following the developments relating to exposure to 5G frequencies.



The difference with current antennas is that 5G antennas aim beams at the user

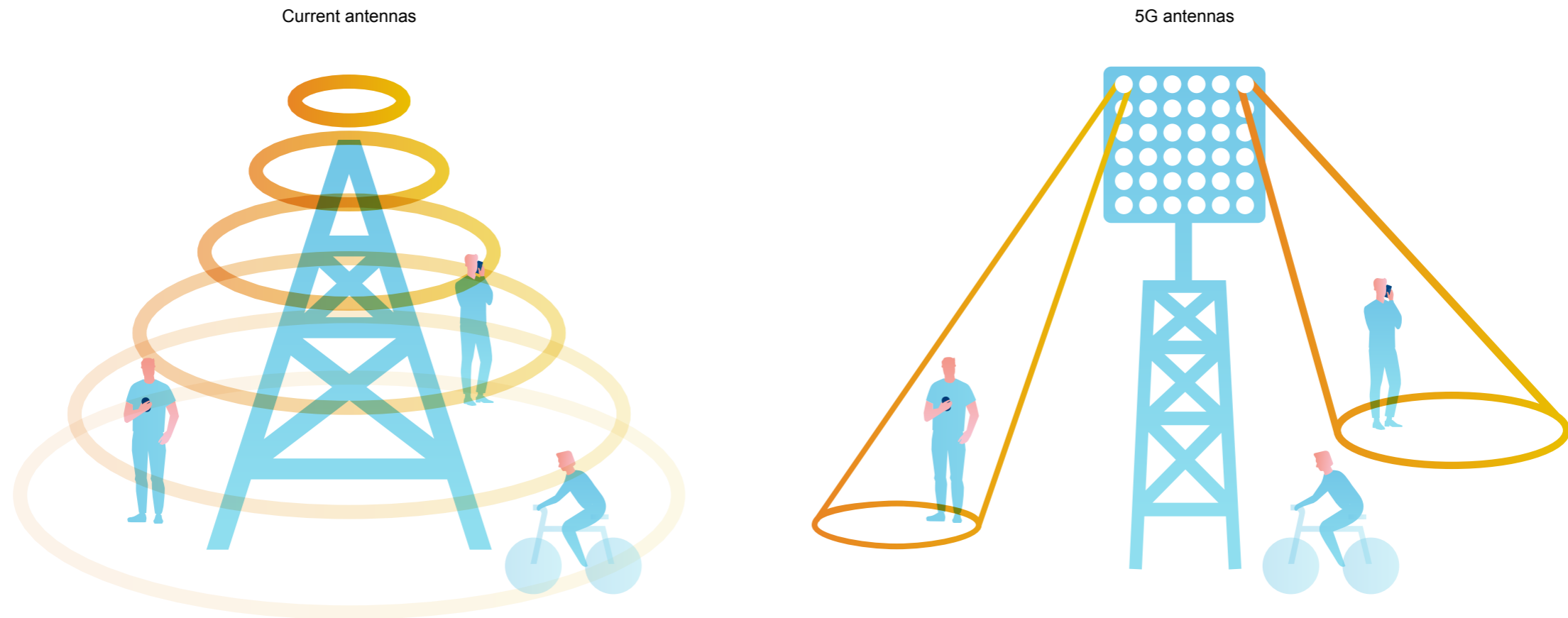


Figure 2. Difference between the transmission patterns of the current base stations and 5G base stations

03 studies into possible health damage from 5G



The committee has investigated whether electromagnetic fields with the frequencies that will be used for 5G have the *potential* to cause adverse health effects. A relationship with radiofrequency electromagnetic radiation is neither proven nor deemed probable for any of the diseases and conditions investigated. The committee has however classified relations with cancer, adverse effects on male fertility, adverse pregnancy outcomes and birth defects as ‘possible’. In addition, it is probable that there is a relationship with electrical activity in the brain. It is not known whether that is favourable or unfavourable to health. For the majority of other biological processes it has neither been proven nor deemed probable that changes in them are related to exposure to radiofrequency electromagnetic fields, but the committee has classified this as ‘possible’. Relations to changes in the immune system and hormone levels were not found. Virtually no data is available about the relationship between exposure to radiofrequency electromagnetic fields at frequencies of between 20 and 40 GHz and diseases, conditions and biological processes.

3.1 Weighing the scientific evidence

The committee has analysed various types of studies for each of the diseases, conditions and biological processes for each frequency band and classified them according to the strength of the scientific evidence.

- *Epidemiological research* looks for *associations* within groups of people between the occurrence of diseases and exposure to certain factors: does a disease or condition occur after exposure to radiofrequency

electromagnetic fields, taking account of possible confounding factors?

The benefits of epidemiological research are that it is carried out in humans and that long-term effects can be studied. Disadvantages are that there is no control of the circumstances of the exposure and that other factors can distort the results. Additionally, associations do not provide direct information about cause and effect.

- In *experimental research*, the circumstances of the exposure are controlled, allowing statements to be made about cause and effect. Such studies look at whether an effect occurs as a result of exposure to electromagnetic fields in the frequency range concerned. Experimental research can be done in both humans and animals. The disadvantages of research with human subjects are that it is in general only possible to work with a limited number of subjects, that the exposure can only occur for a short period and that only short-term effects can be studied. Furthermore, some things cannot be investigated with this type of research because there are limitations to what humans are allowed to be exposed to. Higher and longer exposures are possible in animal studies compared to experimental studies in humans, so that the effects of lengthy exposure and long-term effects can also be studied, making it possible to better investigate exposure-effect relations. The most important negative is that it is not known how well the results of animal experiments can be extrapolated to humans.



The classifications are based on the combined data from epidemiological and experimental studies, showing whether there is a relationship between exposure to radiofrequency electromagnetic fields and the occurrence of a disease or condition or changes in a biological process. In this report, relationship therefore means association or effect.

Table 1 gives an overview of the various classifications that the committee distinguishes for the strength of the scientific evidence.

Hazard versus risk

As stated earlier, all the associations and effects found in this report – and therefore the classifications too – are only referring to the hazard: the intrinsic characteristics of the radiofrequency electromagnetic fields that give them the potential to cause adverse health effects. They do not say anything about the actual health risks for the exposed population.

Table 1. Overview of the classifications for the strength of the scientific evidence for the potential to cause adverse health effects or changes in biological processes.

Classification	Conditions
No relations found	The vast majority of epidemiological studies show no associations and the vast majority of experimental studies in both humans and laboratory animals show no effects.
Relation possible	Some epidemiological studies show associations and/or some experimental studies show effects. Epidemiological studies and experimental studies in humans have a higher weight than animal studies. However, this classification can also be assigned if only sufficient high-quality animal studies are available.
Relation probable	The majority of epidemiological studies show associations and/or the majority of experimental studies in humans show effects. If effects are only assessed as probable in animal studies, the classification is <i>Relation possible</i> .
Relation demonstrated	Associations were found in all or virtually all epidemiological studies and/or effects were found in all or virtually all experimental studies in humans. If effects are only seen in animal studies, the classification is <i>Relation probable</i> .
No statement possible	There are insufficient studies or the results of the studies assessed were contradictory (both favourable and unfavourable effects were found).



3.2 Reservations about the findings

There are virtually no studies of possible relations between diseases, conditions or biological processes for the exact frequencies that 5G is going to use. The majority of studies have looked at frequencies in bands that are close to that of 5G and that are used e.g. for Wi-Fi, in addition to mobile telecommunication. For the frequency of 26 GHz, no experimental data is available. Because some radar systems also use frequencies of approximately 26 GHz (for instance 24 GHz is a frequency used by police radar speed traps), the committee has made an inventory of studies among people who work with or in the vicinity of such radar systems. Many of these studies cannot be used, however, because the radar systems used frequencies outside the range 20 to 40 GHz or because the studies did not state which radar systems or frequencies had been used.

The committee has not been able to investigate the levels of exposure at which associations or effects occurred. Neither has it been able to investigate whether there is a threshold value for the occurrence of the reported relations and whether and to what extent the relations become stronger as the exposure level increases. The WHO is currently carrying out an in-depth analysis of all relevant studies that will also address these questions. The results of that analysis are expected in 2022.

3.3 Findings about diseases and conditions

The committee has split the data about diseases and conditions into eight categories. None of the diseases and conditions investigated was classified by the committee as having relations that were either proven or probable. The committee has however classified relations as ‘possible’ for cancer, male fertility, pregnancy outcomes and birth defects. The findings about effects on male fertility and on pregnancy outcomes and congenital defects are based largely on animal studies. The extent to which these can be extrapolated to humans is not known. For the frequency range 20-40 GHz, little scientific research (or sometimes none at all) has been carried out into the relations with various diseases or conditions, so the classification ‘No statement possible’ had to be given for these frequencies.

For each of the diseases or conditions investigated, the committee has listed in Table 2 how strong the scientific evidence is for the hazard – the potential to cause adverse health effects: is there any relation with exposure to electromagnetic fields? For cancer, Table 2 and the background document only list the publications that have appeared since 2015 and that were not included in the earlier reports; however, the classification does also take account of the studies that were assessed in, and the conclusions from those earlier reports.⁶⁻⁸



Table 2. Overview of the conclusions per disease or condition, broken down by frequency band

Disease or condition	700-2200 MHz (number of publications and type of study)	2.2-5.0 GHz (number of publications and type of study)	20-40 GHz (number of publications and type of study)
Cancer	Relation possible (19 epidemiological, 4 animal studies since 2015)	Relation possible (no publications since 2015)	No statement possible (2 epidemiological studies)
Symptoms	No relation found (28 epidemiological, 36 human experimental studies)	No statement possible (1 epidemiological study)	No statement possible (no publications)
Hearing	No relation found (6 epidemiological, 10 human experimental, 9 animal studies)	No statement possible (no publications)	No statement possible (no publications)
Eyes	No relation found (4 human experimental, 1 animal study)	No relation found (4 animal studies)	No statement possible (no publications)
Cardiovascular system and autonomic nervous system	No relation found (1 epidemiological, 24 human experimental studies)	No statement possible (1 epidemiological study)	No statement possible (1 epidemiological study)
Neurodegenerative diseases	No statement possible (1 epidemiological study)	No statement possible (no publications)	No statement possible (no publications)
Male fertility	No statement possible (10 animal studies; conflicting findings)	Relation possible (9 animal studies)	No statement possible (no publications)
Pregnancy and birth defects	Relation possible (1 epidemiological, 9 animal studies)	Relation possible (1 epidemiological, 8 animal studies)	No statement possible (no publications)

3.4 Findings about biological processes

Changes are continuously taking place in the body in all kinds of biological processes under the influence of internal and external factors. Those are normal compensatory measures aimed at keeping the body healthy under varying circumstances. The ability of an organism to take such measures is however finite. If the influence of any specific factor becomes excessive and the body cannot compensate sufficiently, it can result in changes that are unfavourable for health. However, changes have also been reported that are favourable for health (e.g. responding more quickly in neurological tests after exposure).

The committee's opinion is that no relationship between changes in biological processes and exposure to radiofrequency electromagnetic fields has been proven for any of the biological processes studied. For changes in the electrical activity in the brain, it deems such a relationship to be probable, but it is unclear whether the changes are favourable or unfavourable for health. According to the committee, a relationship with changes in the neurodegeneration of brain tissue, behaviour, cognition, signal conduction in the brain, sleep, oxidative stress and gene expression in the brain could be possible. No changes were observed in the immune system or in hormone levels. For the frequency range 20-40 GHz, few scientific studies (or sometimes none at all) are available about changes in the biological processes investigated, so no statement is possible for this frequency range.



The committee has listed in Table 3 whether electromagnetic fields at one or more of the frequencies studied have the potential to be related to a change in the biological processes examined.

Table 3. Overview of the conclusions per biological process, broken down by frequency band

Biological process	700-2200 MHz (number of publications and type of study)	2.2-5.0 GHz (number of publications and type of study)	20-40 GHz (number of publications and type of study)
Behaviour	Relation possible, favourable and unfavourable effects (9 epidemiological, 29 animal studies)	Relation possible, favourable and unfavourable effects (1 epidemiological, 19 animal studies)	No statement possible (no publications)
Cognition	Relation possible, favourable and unfavourable effects (11 epidemiological, 46 human experimental, 24 animal studies)	Relation possible, unfavourable effect (2 human experimental, 24 animal studies)	No statement possible (no publications)
Sleep	Relation possible, favourable and unfavourable effects (21 epidemiological, 26 human experimental)	No statement possible (no publications)	No statement possible (no publications)
Signal conduction in the brain	Relation possible, favourable and unfavourable effects (14 animal studies)	Relation possible, favourable and unfavourable effects (14 animal studies)	No statement possible (no publications)
Electrical activity in the brain	Relation probable, not clear whether the effects are favourable or unfavourable (64 human experimental, 9 animal studies)	Relation possible, not clear whether the effects are favourable or unfavourable (1 human experimental, 6 animal studies)	No statement possible (no publications)
Blood-brain barrier	Relation possible, favourable and unfavourable effects (1 epidemiological, 26 animal studies)	Relation possible, unfavourable effect (5 animal studies)	No statement possible (no publications)
Neurodegeneration	Relation possible, favourable and unfavourable effects (14 animal studies)	No statement possible (no publications)	No statement possible (no publications)
Gene expression in the brain	Relation possible, not clear whether the effects are favourable or unfavourable (38 animal studies)	Relation possible, not clear whether the effects are favourable or unfavourable (13 animal studies)	No statement possible (no publications)
Immune system	No association found (3 human experimental, 9 animal studies)	No association found (10 animal studies)	No statement possible (no publications)
Blood	Relation possible, favourable and unfavourable effects (3 animal studies)	Relation possible, unfavourable effect (4 animal studies)	No statement possible (no publications)
Hormones	No association found (7 human experimental studies)	No statement possible (no publications)	No statement possible (no publications)
Oxidative stress	Relation possible, unfavourable effect (28 animal studies)	Relation possible, unfavourable effect (13 animal studies)	No statement possible (no publications)



3.5 Comparison against exposure limits

Where associations have been found in epidemiological studies or effects have been observed in experimental studies in humans, these generally involve exposure levels below the current ICNIRP exposure limits. This is because epidemiological studies are carried out among groups of people in their working or living environments, where the exposure limits must not be exceeded. In experimental research in humans, it is generally not possible for reasons of medical ethics to expose test subjects to levels that are above the exposure limits. In animal studies, however, exposure levels above the limits adopted for humans can be used.



04 conclusions and recommendations



The committee cannot answer the question of whether exposure to 5G frequencies actually poses risks to human health, because too little is known about the exposure. The committee has therefore investigated whether there are indications that electromagnetic fields with the 5G frequencies have the *potential* to cause adverse health effects. Such associations are deemed neither proven nor probable for any of the diseases and conditions studied, but cannot be excluded for a number of them. For the majority of biological processes as well, it has neither been proven nor is it probable that changes in them are associated with exposure to radiofrequency electromagnetic fields, although this cannot be excluded. The committee recommends monitoring the exposure levels, carrying out further research and postponing the start of using the highest frequency band for 5G (26 GHz) until more is known about any health effects.

4.1 Conclusions

In its analysis, the committee has assessed whether electromagnetic fields in the 5G frequency ranges have the *potential* to cause adverse health effects. It has assessed whether relations exist between exposure to radiofrequency electromagnetic fields on the one hand and the occurrence of diseases and conditions on the other. The relations between exposure to radiofrequency electromagnetic fields and the occurrence of cancer, reduced male fertility, poorer pregnancy outcomes and congenital defects have been classified by the committee as 'possible'. However, the committee deems the relation between exposure

and these and other diseases or conditions to be neither proven nor probable. The committee has also looked at the relation between exposure and biological processes, such as cognition, sleep and electrical activity in the brain. It is probable that changes in electrical activity in the brain are associated with exposure to radiofrequency electromagnetic fields, but it is not known whether that is favourable or unfavourable in health terms. For the majority of other biological processes it has neither been demonstrated nor is it probable that changes in them are associated with exposure to radiofrequency electromagnetic fields. Relations are classified as 'possible' for these processes. For changes in the immune system and hormone levels, no relation was found.

The findings about cancer have led the committee to reformulate its conclusion from earlier reports in more general terms. In the earlier reports, the conclusion was that no association has been proven between long-term and frequent use of mobile phones and an increased likelihood of tumours in the head and neck area, but that such a link could also not be entirely excluded.⁶⁻⁸ The committee now reaches the same conclusion but then for all sources of exposure to radiofrequency electromagnetic fields (not only mobile phones) and for all types of cancer (not only tumours in the head and neck area). Animal experiments and (to a limited extent) epidemiological research do in fact indicate that exposure to radiofrequency electromagnetic fields could possibly be associated with initiation of tumours or promotion of their development.



The findings about effects on male fertility and on pregnancy outcomes and congenital defects are based largely on animal studies. The extent to which these can be extrapolated to humans is not known.

It has not been possible for the committee to derive from the studies exposure levels at which the effects being investigated could occur in humans. Because there is also a lack of knowledge about future exposure levels of individuals as a result of the introduction of 5G telecommunication and other possible applications such as self-driving cars, the committee is unable to make any statement about the actual health risks of future exposures to 5G frequencies.

4.2 Recommendations

Start using the lower frequency bands and monitor exposure

The committee sees no reason to limit or stop the use of the lower frequency bands for 5G. Frequencies near 700 MHz and 3.5 GHz have been in use for current telecommunication systems or other applications such as Wi-Fi for years, without any demonstrable health damage as a result. The committee does recommend, however, that exposure of individuals and groups should be monitored before, during and after the rollout of the 5G systems. This will show to what extent exposure to radiofrequency electromagnetic fields has changed as a result of the introduction of 5G, so that any long-term health risks can then be

estimated better. The results of the analysis by the World Health Organization can also be used in due course in the analysis of health risks.

More research

The committee recommends setting up a research programme that should include research into the effect of exposure to the 5G frequencies that are relevant for mobile telecommunication and other applications on cancer, the male reproductive organs and fertility and on pregnancy outcomes and birth defects. An ongoing international prospective epidemiological study into the health of users of mobile phones, in which the Netherlands is participating, can play a role in this.¹⁹

Additionally, research is needed into the effects of exposure to electromagnetic fields with frequencies around 26 GHz at levels below the ICNIRP limits. This will have to be experimental research, given that exposure to these frequencies does not yet occur in practice. Fields with these frequencies do not penetrate the body any further than the skin and research should therefore focus on effects that originate in the skin, including effects on components of the immune system and nervous system that are located in the skin.

The committee also recommends carrying out scenario studies to effectively get a picture of the future exposure of individuals as a result of wireless communications systems (3G, 4G and 5G).



Wait before starting to use 26 GHz

Because almost nothing is known about the effects of exposure to 26 GHz, the committee recommends to postpone starting to use this frequency band for 5G until the results of research are available.

Exposure limits and ALARA

Parliament has asked about the extent to which the current standards for public health in this domain are based on the latest scientific understandings. The exposure limits currently used in the Netherlands for the general population are based on a recommendation made by the European Commission in 1999.¹³ That recommendation uses the guidelines published in 1998 by the International Commission on Non-Ionizing Radiation Protection (ICNIRP).¹⁴ ICNIRP has recently published new guidelines for exposure to radiofrequency electromagnetic fields that are based on an analysis of all available scientific information.¹⁵ The European Commission has indicated that it is considering revising the recommendation for exposure for the general population to

electromagnetic fields from 1999¹³ and the guideline for occupational exposure to electromagnetic fields from 2013²⁰ to align them with the latest recommendations from ICNIRP. The committee recommends using the latest ICNIRP guidelines in the Netherlands as the basis for exposure policy. The committee has noted, however, that adverse health effects cannot be excluded at exposure levels below these limits. That is why it also recommends, in anticipation of the results of further studies, to apply not only the new ICNIRP guidelines but also the ALARA principle (*As Low As Reasonably Achievable*). That means that the exposure of the general population and of workers must not be unnecessarily high, even if it remains below the limits, insofar as that is reasonably achievable. This is in line with the approach that the Health Council proposed in the advisory report *Prudent precaution*.²¹



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