

## Summary

### 1. Background

The last few decades have seen an incredible development of technologies known as information and communication technologies (ICTs). These include wireless communications used for cell phones and, for example, Wi-Fi, which uses radio frequency (RF) in the radio frequency (RF) range..

The first generation of portable cell phones was available in the late 1980s. Subsequently, the second (2G), third (3G), and fourth (4G, Long Term Evolution = LTE) generations dramatically increased their penetration in society, so that today there are more devices than inhabitants in Europe. In addition, Wi-Fi and other forms of wireless data transmission are now omnipresent and available worldwide. Nevertheless, there are new inequalities in access to high-speed Internet (even in high-income countries), and control by authoritarian regimes shows risks to democracy and European values.

The rollout of the next generation of radio spectrum, 5G, has begun in mobile networks. 5G is not a completely new technology, but a further development of the already existing G1 to G4 technologies. 5G networks will operate in several different frequency bands, of which the lower frequencies are proposed for the first phase of 5G networks. Several of these frequencies have been or are already being used for earlier generations of mobile communications. There are also plans to use much higher radio frequencies in later phases of the 5G technology development. The new bands are well above the so-called ultra-high frequency (UHF) range and have wavelengths in the centimeter range (3-30 GHz) or in the millimeter range (MMW) at 30-300 GHz. The latter bands are traditionally used for radar and microwave communications, and very few have been studied for their effects on human health.

### 2. Methodology

This review of the currently available scientific evidence focuses on both the carcinogenic and reproductive/developmental effects of RF from cellular telecommunications systems using 2G-5G networks, relying on both in vivo animal studies and as well as epidemiological studies in humans. The studies assessed were divided into two groups:

1) Studies evaluating the health effects of RF in the lower frequency (FR) range (FR1: 450 to 6000 MHz), which includes the frequencies used in the existing 2 to 4 generations of cellular broadband network. The current findings from the 2G-4G studies are the best currently available. The studies were evaluated using descriptive methods.

2) Studies evaluating the health effects of radiofrequency radiation at higher FRs (FR2: 24 to 100 GHz - MMW). The higher frequencies are new, have not been previously used for mobile communications, and are specific to the new 5G technology, which has particular physical properties and interactions with biological matter (lower penetration, higher energy, etc.): they were considered separately using a scoping-review-method.

The narrative review (FR1) is distinguished from the scoping review (FR2), but the selection and evaluation criteria given for scoping reviews were used for both searches and for the inclusion/exclusion of studies on the biological endpoints of cancer and reproductive/developmental.

In the final evaluation of the results of both the epidemiological and experimental study and the cancer and reproductive/developmental outcomes, the parameters specified in the preamble of the IARC Monograph (2019) were considered, which are tailored to the needs of this report and apply to both endpoints (i.e., cancer and reproductive/developmental effects):

**Sufficient evidence:** A causal relationship between exposure to RF EMFs and the specific adverse effect has been demonstrated. That means, a positive association was found in the totality of the evidence on the following topics: Exposure to the agent and the specific adverse effect in studies in which chance, bias, and confounding factors could be excluded with reasonable certainty.

**Limited evidence:** A causal interpretation of the positive association observed in the evidence base on exposure to RF-EMF and the specific adverse effect is credible, but coincidence, distortion, or disturbance factors cannot be ruled out with reasonable certainty.

**No Evidence:** No data or evidence are available to indicate the absence of adverse effects (to be specified).

The overall assessment for both cancer and reproductive/developmental effects was made by the aggregation of evidence for humans and animals was determined as follows:

Evidence in humans	Evidence in experimental animals	Evaluation based on strength of evidence
Sufficient	Not necessary	Clear association between exposure and the adverse effect
Limited	Sufficient	Probable association between exposure and the adverse effect
Limited	Less than sufficient	Possible association between exposure and the adverse effect
Inadequate	Inadequate or limited	Not classifiable

### 3. Exposure assessment

The issue of exposure assessment in the deployment of 5G is complicated, especially with respect to monitoring the continuous changes in activity of both base stations (BS) and user equipment (UE) associated with multiple input, multiple output (MIMO) technology. In addition, the technical approach for exposure assessment in the future scenario, which is based on the simultaneous emissions of 1G, 2G, 3G, 4G, and 5G is still being formulated and is therefore uncertain.

### 4. Non-thermal effects

The adverse effects of non-thermal biological interactions of RF/EMF with human and animal tissues were not considered in the establishment of the ICNIRP 2020 guidelines (ICNIRP 2020a), although there is a large body of scientific literature demonstrating the harmfulness or potential harmfulness of these effects. Athermal bio resonances do exist, and indeed some frequencies are used for therapeutic purposes in a number of areas of medicine. As we know, any medicine, even the most beneficial, can also bring some adverse effects. Therefore, thermal as well as non-thermal effects of RF-EMF must be considered in the risk assessment.

## 5. Current state of research on RF-EMF

The introduction of wireless communication devices operating in the RF region of the electromagnetic spectrum (450 to 6,000 MHz, lower frequencies) has triggered a substantial number of studies addressing health issues. These studies include investigations on humans (epidemiological studies), on animals (experimental rodent studies), and on in vitro cellular systems.

5G networks will increase the number of wireless devices, requiring much larger infrastructure to support a higher mobile data volume per geographic area. In addition, a higher network density will need to be built, as the higher frequencies needed for 5G (24 to 100 GHz, MMW) will have a shorter range. Only a few studies of varying quality are available on these frequencies.

This raises the question of whether these higher frequencies will have different health and environmental impacts than lower frequencies. RF safety assessments have been conducted at various levels around the world, and scientific and policy papers have been published.

With respect to cancer, IARC's 2011 analysis of the literature reviewed through 2011 (Baan, 2011), published in 2013 and cited throughout as IARC (2013), defined RF EMFs in the frequency range from 30 kHz to 300 GHz as "possibly carcinogenic" to humans, based on "limited evidence of carcinogenicity" in humans and experimental animals. The studies available in 2011 examined RF in the range we refer to here as FR1, i.e., from 450 to 6 000 MHz. FR2 frequencies (24 to 100 GHz) are in the MMW range.

The 2011 IARC analysis looked at RF EMF. While there were no studies on 5G, some studies on high-frequency occupational radar and microwave exposures were included.

The new MMW frequencies (FR2: 24 to 100 GHz) will be added to the lower frequencies already in use, including by 5G. It follows that for 5G in the 450 to 6,000 MHz range (FR1), there are many studies, many of which were collected in the IARC monograph related to cancer, while for 26 GHz and other MMW frequencies in general, there is little literature examining the potential adverse effects on health that have been investigated. The simple reason for this is that these frequencies have not previously been used for mass communications, and thus there have been few suitable populations exposed to these frequencies to study them; likewise, there have been very few adequate studies of non-thermal effects on laboratory animals.

## 6. Results of the present study

Using PubMed and the EMF Portal database and applying the scoping review method to our research, we found 950 papers on the carcinogenicity of RF-EMF in humans and 911 papers on experimental rat studies, for a total of 1,861 studies. In terms of reproductive/developmental studies, we found 2,834 papers on epidemiology and 5,052 studies on experimental rat studies, for a total of 7,886 studies. Based on this literature review and the considerations outlined above, we reach the following conclusions:

### 6.1 Cancer in humans

- **FR1** (450 to 6,000 MHz): there is limited evidence on the carcinogenicity of RF radiation in humans. In updating the results of the 2011-2020 global assessment, positive associations were again found between exposure to RF radiation from cordless phones and gliomas (brain tumors) and acoustic neuromas, but evidence in humans is still limited.
- **FR2** (24 to 100 GHz): no adequate studies on the effects of the higher frequencies have been conducted.

## 6.2 Cancer in experimental animals

- **FR1** (450 to 6,000 MHz): there is adequate evidence for carcinogenicity of RF radiation in experimental animals. Recent studies following the 2011 IARC assessment showed a positive association between RF EMF and tumors of the brain and Schwann cells of the peripheral nervous system, the same type of tumors which have also been observed in epidemiological studies.
- **FR2** (24 to 100 GHz): no adequate studies have been performed for the higher frequencies.

## 6.3 Reproductive/developmental effects in humans

- **FR1** (450 to 6,000 MHz): There is sufficient evidence of adverse effects on fertility of males. There is limited evidence of adverse effects on female fertility. There is limited evidence of effects on the development of children of mothers who used cell phones intensively during pregnancy.
- **FR2** (24 to 100 GHz): adequate studies have not been conducted for the higher frequencies.

## 6.4 Reproductive/developmental effects in laboratory animals

- **FR1** (450 to 6000 MHz): There is sufficient evidence of adverse effects on fertility in male rats and mice. There is limited evidence of adverse effects on the fertility of female mice. There is limited evidence of adverse effects on the development of the offspring of rats and mice exposed during the embryonic period.
- **FR2** (24 to 100 GHz): No adequate studies on non-thermal effects have been conducted for the higher frequencies.

## 7. General Evaluation

### 7.1 Cancer

- **FR1** (450 to 6,000 MHz): these FR1 frequencies are likely to be carcinogenic to humans.
- **FR2** (24 to 100 GHz): adequate studies have not been performed for the higher frequencies.

### 7.2 Reproductive/Developmental Effects

- **FR1** (450 to 6,000 MHz): these frequencies clearly affect male fertility. They potentially affect female fertility. They may have adverse effects on the Development of embryos, fetuses, and newborns.
- **FR2** (24 to 100 GHz): No adequate studies have been conducted on non-thermal effects at the higher frequencies.

## 8 Policy options

### 8.1 Decision to adopt new technologies for cell phones that reduce RF EMF exposure

The sources of RF emissions that currently appear to pose the greatest risk are cell phones. Although transmitting devices (cell towers) are considered by some people to pose the greatest risk, the greatest exposure to humans generally comes from their own cell phones, and epidemiological studies have observed a statistically significant increase in brain tumors and Schwann cell tumors of the peripheral nerves, especially among heavy cell phone users.

Therefore, measures must be taken to ensure that increasingly safer phone devices are produced that emit little energy and, if possible, operate only at a certain distance from the body. The wired earpiece solves much of the problem, but is inconvenient and therefore discourages users; on the other hand, it is not always possible to use the hands-free function. The option to reduce RF/EMF exposure associated with phones as much as possible applies regardless of the frequencies used, from 1G to 5G. Countries such as the U.S. and Canada, which have stricter SAR limits for cell phones than in Europe, have nevertheless been able to establish efficient 1G, 2G, 3G, and 4G communications (Madjar, 2016). Since 5G is expected to be more energy efficient than existing technologies, the adoption of stricter limits in the EU for mobile devices would be both a sustainable and precautionary approach.

## **8.2 Revision of public and environmental exposure limits to reduce RF EMF exposure from cell towers**

Recently, EU policy (European Commission, 2019) has promoted the sustainability of a new economic and social development model that uses new technologies to constantly monitor the health of the planet, including climate change, energy transition, agro-ecology, and biodiversity conservation. The use of low 5G frequencies and the adoption of precautionary exposure limits, such as those used in Italy, Switzerland, China, and Russia, among others, which are which are significantly lower than those recommended by ICNIRP, could help achieve these EU sustainability goals.

## **8.3 Adoption of Measures Providing Incentives to Reduce RF EMF Exposure**

Much of the remarkable performance of the new lower frequency 5G wireless technology can also be achieved by using fiber optic cables and implementing technical measures to reduce exposure from 1-4G systems (Keiser, 2003; CommTech Talks, 2015; Zlatanov, 2017). This would minimize exposure wherever fixed-site connections are required. For example, fiber optic cables could be used to connect schools, libraries, workplaces, homes, public buildings, and all new buildings, etc., and public gathering places could be "RF EMF-free" areas (similar to non-smoking areas) to avoid passive exposure to people who do not use a cell phone or long-range transmission technology, and thus protect many vulnerable elderly or immunocompromised people, children, and electro-sensitive individuals.

## **8.4 Encourage multidisciplinary scientific research to assess the long-term health effects of 5G and find an appropriate method to monitor exposure to 5G**

There are no adequate studies in the literature to assess the risk of tumors and adverse effects reproductive and developmental effects from exposure to 5G-MMW, or to rule out the possibility of synergistic interactions between 5G and other frequencies already in use.

Therefore, the deployment of 5G is subject to uncertainties, both in terms of health issues and in terms of predicting or monitoring actual population exposure: these gaps in knowledge justify the call for a moratorium on 5G-PMW until the relevant research has been completed.

Given these uncertainties, one policy option is to continue multidisciplinary team research on various factors of exposure assessment and also on the biological effects of 5G-MMW at frequencies between 6 and 300 GHz, both on humans and on environmental flora and fauna, e.g., nonhuman vertebrates, plants, fungi, and invertebrates.

MMW will not be deployed until the final 5G protocol, which is three to five years away. Given this timeframe, one opportunity is to study the effects before the entire world population and the environment are exposed.

The introduction of MMW-5G technology without further preventive studies would mean that an "experiment" on the human population would be conducted, the consequences of which are

completely uncertain. To limit ourselves to Europe, this could be done in an area such as chemistry, which is currently regulated by REACH (EC, 1907/2006).

REACH aims to improve the protection of human health and the environment through better and earlier identification of the intrinsic properties of chemical substances. EU REACH regulates the registration, evaluation, authorization and restriction of chemicals. In addition, it aims to improve the innovation.

Manufacturers and importers are obliged to collect information on the properties of their chemical substances that enable them to be handled safely, and to register this information in a central database at the European Chemicals Agency (ECHA). A policy option could be to apply the same approach to all types of technological innovations.

The results of these studies could provide the basis for the development of evidence-based policy regarding RF/EMF exposure of human and non-human organisms from 5G EMF frequencies. Further studies are needed to better understand the health effects of RF EMF in general and of MMW in particular to be better and independently investigated.

### **8.5 Promote information campaigns about 5G**

There is a lack of information about the potential harms of RF EMF. The lack of information creates space for deniers and alarmists and leads to social and political tensions in many EU countries. Public information campaigns should therefore be a priority.

Information campaigns should be conducted at all levels, starting with schools. People should be informed about the potential health risks, but also about the possibilities of digital development, the infrastructural alternatives for 5G transmission, the safety measures taken by the EU and member states (exposure limits), and the proper use of cell phones. Only with sound and accurate information can we regain the trust of citizens and reach a common agreement on a technological choice that, if properly managed, can bring great social and economic benefits.