

Wireless communication technologies: New study findings confirm risks of nonionizing radiation

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Digital mobile devices emit nonionizing radiation. The risks of electromagnetic fields (EMF) to human health have been known from medical and military research since the 1950s. This article documents the latest study findings regarding the endpoints of genotoxicity, fertility, blood-brain barrier, cardiac functions, cognition, and behavior. A verified mechanism of damage is oxidative cell stress. New hypotheses of additional mechanisms of action will also be presented. Users are only insufficiently informed about the risks of wireless communication technologies; prevention policies are not introduced. The uncertainties regarding the risks among the public are not due to unclear research findings, but to the industry's controlling influence over politics and the media.

Keywords: *Mobile communications, wireless communication technologies, digital media, oxidative cell stress, free radicals, mechanisms of action, combination effects, electromagnetic fields*

Published in umwelt-medizin-gesellschaft |29|3/2016; translated by Katharina Gustavs, May 2017

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Wireless communication applications are all around us. They transmit and receive pulsed, polarized RF radiation from 400 to 6000 MHz. Since the 1990s, humans, animals, and plants have been exposed to a frequency mixture of technical microwave radiation of ever increasing intensity to which living organisms have not adapted. Due to RF transmitters, smartphones, tablets, DECT cordless phones, wireless video games, Wi-Fi hotspots, wearables, smart home applications, and Wi-Fi-controlled devices, there are less and less radiation-free zones; nonusers, too, are exposed.

The exposure already starts at an early age with baby monitors and the latest addition of “smart” diapers. The Mimo Baby Monitor is embedded in rompers, monitoring sleep, breathing, physical activity, position, and skin temperature. Parents can then watch the diaper status and other vital statistics on their smartphone displays via the Wi-Fi connection of the app. There are only very few young people who do not have their own smartphone; children and adolescents use them constantly from waking up in the morning until going to sleep (KNOP 2015, p.124). They are exposed to continuous RF radiation, especially due to constantly emitting apps. Billions

of people use mobile devices close to their body; therefore, even a small risk can have major effects. For over 20 years, the German information service Strahlentelex/Elektrosmog-Report has reviewed the scientific evidence on a monthly basis; since 2009, the consumer protection organization diagnose:funk also has done so, among others, with quarterly study reviews.

The cell phone boom took off at the beginning of 2000, wireless communication turned into a government-sponsored hype, and new needs were being developed. The risks – which were known especially from medical research (BECKER 1993, SCHLIEPHAKE 1960, STENECK 1984, VARGAS 1995) and military research (e.g. COOK 1980, HECHT 1996, WENZEL 1967) – were ignored. In 2011, IARC, the cancer research agency of the WHO, classified nonionizing radiation as “possibly carcinogenic” as a Class 2B carcinogen. The documentation by the European Environment Agency “Late Lessons from Early Warnings: Science, Precaution, Innovation” ranks cell phones as a risk technology and dedicates one entire chapter to the brain tumor risk (HARDELL et al. 2013).

Main focus: study findings regarding carcinogenicity

New research results regarding RF EMF (radio-frequency electromagnetic fields) now suggest that cell phone radiation is considered to be carcinogenic. Until recently, there had been uncertainties regarding the long latency period between the exposure of a carcinogen and the diagnosis of a tumor and the relatively short time of using wireless communication technologies. The WHO classification of “possibly carcinogenic” was based on the findings of the Interphone study (INTERPHONE STUDY GROUP 2011) for heavy users (more than 1640 hours) and the studies by the oncologist and epidemiologist Prof. Lennart Hardell that found an up to five-fold increase in tumor risk for heavy users of more than 20 years of cell phone use, and all the above studies observed the same types of tumors that have been developing in the animals of the most recent NTP study (DAVIS et al. 2013, HARDELL et al. 2011, 2012, 2013). In the U.S., the first partial findings of the National Toxicology Program (NTP) study, which is the most comprehensive animal study (rats) on nonionizing radiation and cancer to date, were presented on 27 May 2016 (WYDE et al. 2016). This study was financed by the U.S. government with 25 million dollars. The findings of the NTP study: Cell phone radiation can lead to tumors. In the exposed group of the male rats, tumors (schwannoma, glioma) were found and, in an additional number of rats, precancerous cell changes (hyperplasia of glial cells). In the control group, no tumors were found.

The NTP animal study supports the results of the REFLEX studies, which found that cell phone radiation can trigger DNA breaks in isolated human fibroblasts and thus can cause damage to their genes (DIEM et al. 2005, SCHWARZ et al. 2008). Besides these large studies, which also caused quite a stir in the media, there are now more than 50 individual in vivo and in vitro studies that demonstrate DNA breaks (HARDELL/CARLBERG 2012, RÜDIGER 2009). They are all listed at the EMF-Portal, the reference database of the WHO and the German federal government. The BioInitiative Report 2012 also includes a list (BIOINITIATIVEREPORT 2012, Chapter 11 – 14). We also refer to the Israeli studies by SADETZKI et al. (2008) and CZERNINSKI et al. (2011) that found a significantly increased tumor risk of the parotid glands, which has been reflected in a fourfold increase in the Israeli Cancer Registry (MORGAN et al. 2014).

In the diagnose:funk study review 2015-2, four new studies were analyzed that had observed genotoxic effects.

DESHMUKH et al. (2015) studied three of the frequencies used in telecommunication networks. This study shows that low-level microwave radiation exposure (nonthermal effects) of 900, 1800 and 2450 MHz causes adverse effects in rat brains. The significantly increased levels of stress proteins (HSP70) indicate cell stress and the increasing number of DNA strand breaks can lead to cell death or cell degeneration. AKHAVAN-SIGARI et al. (2014) demonstrate that the p53 gene (tumor suppressor gene), which plays an important role in cancer development, can mutate due to RF radiation expo-

sure. The risk of mutant p53 genes occurring in the peripheral area of the tumor is significantly higher when a cell phone is used for three hours or more per day; this corresponds significantly to a shorter survival time. The findings of CARLBERG/HARDELL (2014, 2016) and MOON et al. (2014) confirm that for long-term cell phone users the likelihood of a tumor and its size increase.

ATHEM Report Part II of the AUVA — Austrian Workers' Compensation Board

In August 2016, the Austrian Workers' Compensation Board (AUVA) published the ATHEM Report II “Untersuchung athermischer Wirkungen elektromagnetischer Felder im Mobilfunkbereich [Investigation of nonthermal effects of electromagnetic fields in the cell phone frequency range]” (AUVA 2016), which was carried out at the Medical University of Vienna. One reason for the investigation was that the Court of Cassation in Rome, the highest court of appeal in Italy, had for the first time attributed a manager's brain tumor to his heavy use of cell phones. The plaintiff has received a disability pension of 80%.

One main area of the ATHEM project focused on laboratory tests of cellular mechanisms of possible genotoxic effects. The experiments in humans showed that “RF EMF exposure can cause minor genotoxic and cytotoxic effects in buccal mucosa cells. In heavy users, discrete evidence suggested an accumulation of effects due to exposure” (Summary of ATHEM Report). The in vitro results confirm the risk potential:

- “Some cells are **sensitive** to radiation and **others are not**. The investigation of a total of eight cell types confirmed the findings of ATHEM-1 that RF EMF exposure increases the DNA lesion rate in some cells, while other cells do not show any changes. Published findings of effects (found in sensitive cell types) do NOT contradict findings of cells not sensitive to radiation.
- There is a **latency period**. The finding of ATHEM-1 that a certain period of time is required between the beginning of an exposure to the occurrence of effects was confirmed.
- The **oxidation rate** increases. We observed that RF EMF exposure causes oxidation in the DNA and thus can make it more prone to breakage.
- RF EMF exposure can act **synergistically** with other factors such as cell stress. In previously stressed cells, RF EMF exposure significantly increased the rate of DNA breaks.
- RF EMF exposure can activate **specific cellular repair mechanisms**. On the one hand, this finding confirms that DNA lesions occurred and, on the other hand, it supports the assumption that DNA damage caused by RF EMF exposure can be repaired. The DNA breaks are repaired. We were able to confirm another finding of

the ATHEM-1 Project, that is, the exposure-induced DNA damage in the cells disappeared within two hours after the exposure had stopped" (AUVA 2016).

The findings of the ATHEM Report regarding cells that do not respond to EMF exposure (nonresponders), which include lymphocytes, has political significance. In its 5th Mobile Telecommunications Report to the German Government (Printed Document 17/12027) in 2013, the German Commission on Radiological Protection presented the results of a study on lymphocytes to disprove the results of the REFLEX study (DIAGNOSE:FUNK 2013). This was a betrayal of the members of parliament because it had been the REFLEX study, in particular, that showed lymphocytes to be nonresponders (SCHWARZ et al. 2008). As to DNA repair: that this option might also fail has been demonstrated by BELYAEV et al. (2009). The cause: UMTS exposure delays DNA repair, which can cause cells to degenerate.

According to the studies by Prof. Michael Kundi (Vienna), cell phone use has already been reflected in increased tumor rates; though, not the total rate, but especially in the younger population. At the hearing at the Landtag of South Tyrol (May 2015), he presented the conclusions of his evaluation as follows:

- *"The evidence from epidemiological studies currently points to an increased brain tumor risk in cell phone users, whereby a causal interpretation is valid. Owing to the still short period of use (in comparison to the development period of the disease), it is not possible to rate the actual level of risk at this time.*
- *Statistical evaluations show an increase in brain tumors, which, due to the latency period, has currently to be attributed to a cancer-promoting, not a cancer-causing effect of the nonionizing radiation. A damaged cell will turn into a tumor faster and more easily. There is clear evidence for the tumor-promoting effect. The new study by Lerchl et al., which had been published by the Federal Office for Radiation Protection in March 2015, confirmed this view"* (KUNDI 2015).

In March 2015, based on findings of a replication study, the Federal Office for Radiation Protection announced that there is clear evidence of a cancer-promoting effect below the exposure limits (LERCHL et al. 2015). This is also confirmed by the assessment of the U.S. cancer statistics by GITTLEMAN et al. (2015). For certain types of cancer, significant increases in children and adolescents have been observed: *"The incidence of the most common cancers in adults decreased between 2000 and 2010, as did the incidence of malignant central nervous system tumors (MCNST). However, the incidence of non malignant central nervous system tumors (NMCNST) increased significantly. In comparison, adolescents had increasing rates of MCNST and NMCNST, and children had increasing rates of acute myeloid leukemia (AML), non-Hodgkin lymphoma (NHL), and MCNST."* (GITTLEMAN et al. 2015, p. 111).

The Robert Koch Institute in Germany also documents an increase by ca. 25% between 1994 and 2012 for all malignant tumors in children (RKI 2015, p. 137). Prof. Franz Adlkofer,

coordinator of the REFLEX Project, concludes after the release of the NTP study: *"Based on the current state of research, the genotoxicity of cell phone radiation can now be considered a scientific fact"* (ADLKOEFER 2016).

Findings regarding mechanisms of action of nonionizing radiation - Oxidative cell stress

The ATHEM Report confirms the mechanism of action based on oxidative cell stress. Oxidative stress occurs when oxidative processes due to free radicals exceed the capacity of the antioxidative processes to neutralize, shifting the balance toward oxidation. In cells, various inflammatory injuries can be caused by, for example, oxidation of unsaturated fatty acids, proteins, and DNA: *"Intrinsic mutagens, for example, include free radicals (e.g. reactive oxygen species, ROS)." (JACOBI /PARTOVI 2011, p. 56)*

Reactive oxygen species (ROS) include superoxides, peroxides, and hydroxyl radicals. This mechanism has been proven and accepted for ionizing radiation (radar, X-ray, and gamma radiation) (HECHT 2015, OHLENSCHLÄGER 1995, SIES 1997, 2015, YOUNES 1994). When Dr. Ulrich Warnke explained in his UMG article "An Initial Mechanism for Damage Effects Through Magnetic Fields under Simultaneously Occurring High Frequency Exposure from Mobile Telecommunications" (WARNKE 2009) that this mechanism of action also applies to nonionizing radiation, his opponents argued that the role of free radicals is still unclear and that nonionizing radiation does not have the type of energy it takes to damage cells. The 50 billion euros in licensing fees to the German government during the introduction of the UMTS networks in 2001 obviously caused a shift in the opinions of agencies and commissions, which until then had been regarded as valid. Let us therefore quote from the "Handbook of Toxicology":

"Free radicals are chemical entities characterized by a high reactivity. The formation of free radicals during the metabolism of xenobiotics is therefore an important mechanism of action through which some toxic agents may cause cellular damage. (...) The interaction of free radicals with cellular components may lead to the formation of secondary radicals derived from proteins, lipids, or nucleic acids. These may, in turn, react with other cellular macromolecules, and initiate and thus maintain a chain reaction. Consequently, cellular damage may be exacerbated to a large extent. (...) Radicals may have immediate effects, such as cellular necrosis and, eventually, fibrosis. They may, however, also result in delayed long-term effects, for example, tumorigenesis" (YOUNES 1999: p. 111).

In the handbook "Strahlentherapie und Onkologie" [Radiation Therapy and Oncology] (1993), Sauer explains two variations of radiation effects: *"Energy absorption can either cause primary damage at molecules (direct radiation effect) or form radicals, mostly hydroxyl radicals. The latter radicals, in turn, cause damage to the molecules (indirect radiation effect)"* (SAUER 1993, p. 91).

Low-level exposure can cause the formation of free radicals. In the largest review on “Oxidative Mechanisms of Biological Activity of Low-intensity Radiofrequency Radiation” to date, YAKYMENKO et al. (2015) assessed 100 studies. Ninety-three out of these studies showed an EMF-related overproduction of reactive oxygen species (ROS):

“In turn, a broad biological potential of ROS and other free radicals, including both their mutagenic effects and their signaling regulatory potential, makes RFR a potentially hazardous factor for human health” (YAKYMENKO et al. 2015, p. 12). The EMF exposure-related increase in oxidative damage occurs, according to Yakymenko et al., already at levels thousands of times below the exposure limits in the nonthermal range at a power density of $0.1 \mu\text{W}/\text{cm}^2$ ($= 1000 \mu\text{W}/\text{m}^2$) and specific absorption range (SAR) of $3 \mu\text{W}/\text{kg}$.¹ These levels are well below exposure limits and exposure levels users experience during normal operation of mobile devices, routers, cell towers, and Wi-Fi hotspots.

In their UMG article “Increasing Incidence of Burnout due to Magnetic and Electromagnetic Fields of Cell Phone Networks and Other Wireless Communication Technologies” (WARNKE 2013), Warnke and Hensinger summarize:

- *“EMFs produce excessive cell-damaging free radicals and strongly reactive oxygen and nitrogen species, which, in turn, can damage the DNA. Simultaneously, the body’s own defense in the form of endogenous radical scavengers (antioxidants) is weakened by EMFs.*
- *EMFs interfere with the center of our metabolism, the mitochondria, and thus interfere with our energy production: ATP production is inhibited. The decrease in ATP production debilitates the entire system.”*

Spin conversion and free radicals

In 2012, Dr. H.-Peter Neitzke from the ECOLOG Institute published the article “Einfluss schwacher Magnetfelder auf Biologische Systeme: Biophysikalische und biochemische Wirkungsmechanismen [Impact of Weak Magnetic Fields on Biological Systems: Biophysical and Biochemical Mechanisms of Action]” (NEITZKE 2012) in which he discusses the effect of radiation at the level of electrons.

In this paper, the induction of electric currents, the coupling via magnetite crystals, and the radical pair mechanism are presented as biophysical approaches to explain the impact of magnetic fields on physiological processes. Electromagnetic fields affect the spin, a quantum-mechanical property of particles. When free radicals come close to one another, these molecules (as cations and anions) will combine as radical pairs, whereby a spin coupling of the two free electrons takes place. This results in short-lived bonds that can oscillate between a singlet state (both spins point in opposite directions) and a triplet state (both spins point in the same directions). Neitzke describes the consequences:

“Due their high reactivity, radicals have a key function in the process and control of many chemical reactions. Radical pairs are generated as intermediates in many elementary chemical processes. Transient radical pairs play a crucial role, for example, in bacteria and plant photosynthesis in which light energy is converted into chemical energy. In carcinogenesis, radicals can also be active. When an external factor such as UV radiation causes the formation of radical pairs in a cell, which attack the highly reactive parts of DNA, and the cell should not be able to successfully repair the defects caused by a free radical, this can lead to cancer or other damage. When the chemical kinetics of radicals are changed by an external magnetic field and, as a result, the number or lifetime of radicals also changes, this could have implications for the development of diseases” (NEITZKE 2012, p. 5).

Neitzke concludes that this constitutes a plausible mechanism of action. Magnetic fields generate free radicals and extend the lifetime of the latter. With this, he confirms the elaborations of Warnke. These mechanisms of action are also described in the recent article “Some Effects of Weak Magnetic Fields on Biological Systems: RF Fields Can Change Radical Concentrations and Cancer Cell Growth Rates” by the renowned RF researchers BARNES/GREENEBAUM (2016) from the U.S..

Polarization: cell membranes as a crucial point of attack

In their study “Polarization: A Key Difference Between Man-made and Natural Electromagnetic Fields in regard to Biological Activity,” which was published in the Scientific Reports of the Nature Publishing Group, PANAGOPOULOS et al. (2015) put the hypothesis forward that polarization, which is the fixed spin direction of the electric field vector of a wave, is a crucial factor in understanding biological effects of low-level electromagnetic radiation. In the UMG supplement 3/2016, the physicist Dr. Klaus Scheler explains this study in a more easy-to-understand way:

“Within the framework of a generally accepted electrochemical model of the cell membrane and its function, they can demonstrate that polarized (!) electromagnetic waves — such as cell phone radiation — already due to their polarization and their low intensity are capable of irregularly activating special ion channels (channel proteins) in the cell membrane without any biological need (...) Ion channels act as gates and control the ion flow between the inside and outside of the cell, depending on the membrane voltage. An irregular opening or closing of these channels from the outside causes the electrochemical equilibrium between the inside of the cell and its environment to go out of balance and, as a result, initiates a broad range of cell-impairing and maybe even damaging chemical reactions on the inside of the cell. The predominant outcome is oxidative cell stress. With their analysis, PANAGOPOULOS et al. can even estimate quantitative threshold levels of the electric and magnetic field strengths at which polarized electromagnetic waves trigger an opening of the ion channels and thus become biologically relevant” (SCHELER 2016, p. 2).

Scheler points out that the foundations for this knowledge have already been laid in cell biology:

“Even after the introduction of wireless communication technologies, nonthermal effects have been researched extensively in connection with cell membranes. In their review papers ‘Effects of Electromagnetic Fields on Cells’ and ‘Electromagnetic Effects – From Cell Biology to Medicine,’ FUNK et al. provide an overview of the state of research until 2006. They show, among other things, that electric fields with an electric field strength of 1 millivolt per meter (mV/m) — which corresponds to a power density level of ca. $0.0027 \mu\text{W}/\text{m}^2$ — can cause biologically relevant changes in the charge density at the cell membrane and thus may interfere with reactions inside the cell. The order of magnitude of these critical electric field strengths is by several tens of thousands times lower than current exposure limits (GSM - 900 MHz: $41 \text{ V}/\text{m} = 4,500,000 \mu\text{W}/\text{m}^2$; UMTS: $61 \text{ V}/\text{m} = 10,000,000 \mu\text{W}/\text{m}^2$)” (SCHELER 2016, p. 2).

Additional hypotheses regarding mechanisms of action

Impact of endogenous electric currents and fields

The process of expanding our scientific knowledge regarding mechanisms of action continues to advance. In cells and tissues, electric and ionic currents flow. At the same time, each cell and tissue features an electric potential and thus generates an electric field. These endogenous currents and fields are significantly involved in crucial physiological cell processes (LEVIN 2014). Artificial EMFs can interfere with these endogenous factors and thus can also disrupt biological processes. For example, effects on the membrane potential of cells have been demonstrated. The membrane potential significantly controls the state of cells, e.g. whether a cell divides itself or not. Another aspect: more and more studies show that there are electric “conductors” inside cells: the cytoskeleton and also mitochondria. Mitochondria can form networks that are capable of conducting electric currents. Between cells, there are also electric connections in the form of actual “wires” (“membrane nanotubes”), which may even contain mitochondria. These connections from cell to cell most likely serve long-range electric signaling (SCHOLKMANN 2016). At the same time, mitochondria inside the cell act as an electric wiring system. The new understanding of the bioelectric wiring functions of mitochondria may turn out to be groundbreaking. It cannot be ruled out that technical EMFs may disturb these delicate cellular communication pathways.

Impact on diffusion by affecting the properties of water

In 2014, the researchers around Maie Bachmann (Tallinn University, Estonia) could demonstrate that another mechanism of action for nonthermal EMF effects can be those influences that affect diffusion (HINRIKUS et al. 2015). When exposing

water to EMF (also at low levels), the physiochemical properties of water change. Microwave radiation exposure leads to a polarization of water molecules and thus has an impact on hydrogen bridging bonds. This, in turn, leads to a lower water viscosity. The flow properties of water change so that substances, which are dissolved in water, can diffuse at different rates. This fact could be demonstrated experimentally (RF frequency: 450 MHz, electric field strength: $24.6 \text{ V}/\text{m}$). Diffusion processes in cells and tissues are essential to the functioning of biological processes. Factors that affect this fundamental aspect could have far-reaching consequences.

These mechanisms of damage show clearly why no adverse effect threshold levels can be defined and currently valid thermal effects-based exposure levels do not provide any protection. Already in 2007, the Professors Josef Lutz and Franz Adlkofer issued a joint statement regarding this problem:

“In living organisms, biological processes take place such as cell division, cell differentiation, etc. that render the molecules, especially the DNA and the RNA, very vulnerable. Chemical bonds are opened and new bonds are formed. DNA chains are opened, copied, and new cells are formed. Much lower threshold energies may be sufficient for a disturbance of the cellular processes. It is certainly very difficult to define a minimum energy level to exclude perturbations in vital processes for which molecular instability is a genuine prerequisite” (LUTZ/ADLKOEFER 2007, p. 121).

In the “Handbook of Toxicology”, it says in the chapter on ionizing radiation and radiation protection *“that a radiation exposure that has a specific benefit should be ‘as low as reasonably achievable.’ In the context of setting so-called ‘exposure limits,’ however, it should be emphasized here that such a dose limit is a ‘guidance value’ since — in view of the stochastic nature of triggering cancer diseases or genetic damage — there is no dose limit below which no risk exists and above which risk begins. This differs significantly from the toxic effects of many chemicals for which a proper exposure limit can be set”* (MARQUARDT/SCHÄFER 1994, p. 645). Based on the findings regarding the mechanisms of action, this also applies to nonionizing radiation (HECHT 2015).

Impact on sperm and embryo

The above-listed mechanisms of action lead to a range of organ impairments and make their etiology plausible. There is hardly any other research area where findings are as extensive and clear as the damaging effects to reproductive organs (testes, sperm, ovaries, embryo). As of February 2016, there are 130 studies available: 57 cover male organs, 73 female organs. Thirteen systematic reviews conclude that the risk potential is high. diagnose:funk documented this in its 24-page publication “Smartphones & Tablets schädigen Hoden, Spermien und Embryos [Smartphones & Tablets Cause Damage in Testes, Sperm and Embryos]” (DIAGNOSE:FUNK 2016).

A decrease in sperm count and sperm quality has been shown by KUMAR et al. (2014), LI et al. (2010), MEO et al.

(2011), and TAS et al. (2014). The predominant mechanism of action and damage in sperm regarding their reduced count and quality is an excess production of reactive oxygen species. The excess production of free radicals, among other things, leads to lipid peroxidation and a weakening of the body's own defenses, the antioxidants, which has been shown in the following studies: AGARWAL et al. (2009), AL-DAMEGH et al. (2012), ATASOY et al. (2012), DEIULIIS et al. (2009), GHANBARI et al. (2013), JELODAR et al. (2013), KESARI et al. (2011, 2012), KUMAR et al. (2011&2012), MAILANKOT et al. (2009), MEENA et al. (2013), OKSAY et al. (2012), and SOKOLOVIC et al. (2015). DNA changes and breaks have been observed in the following studies: AVENDANO et al. (2012), DEIULIIS et al. (2009), GORPINCHENKO et al. (2014), KUMAR et al. (2014), and RAGO et al. (2013). A decrease in sperm motility (movement) has been shown by: AGARWAL et al. (2009), AVENDANO et al. (2012), GHANBARI et al. (2013), GORPINCHENKO et al. (2014), and LUCAC et al. (2011). Defective sperm heads, changes in morphometry, and a decrease in bonding capacity have been shown by DASDAG et al. (2015), FALZONE et al. (2011), KESARI et al. (2012), a lowered testosterone level by KESARI et al. (2012) and MEO et al. (2010).

In March 2013, the British Columbia Centre for Disease Control (BCCDC) in Canada published a 376-page research overview "Radiofrequency Toolkit for Environmental Health Practitioners" in which oxidative stress is named as the main cause for risks regarding sperm: *"Overall, oxidative stress seems one of the more plausible mechanisms of RF-induced sperm damage. It has been found fairly consistently in human and animal studies on sperm specifically and on other cells in general"* (BCCDC 2013, p. 272).

In contrast to the statements by the German federal government that we would not know anything about the effects on embryos, EMF research studies make clear statements. A total of 73 studies describe severe damage during fetal development and oogenesis.

Again, many studies showed interactions between ROS, lipid peroxidation, and a decrease in antioxidants: BURLAKA et al. (2013), CETIN et al. (2014), HANCI et al. (2013), HOU et al. (2015), JING et al. (2012), MANTA et al. (2014), OZGUR et al. (2013), OZORAK et al. (2013), SHAHIN et al. (2013), and TÜREDI et al. (2014). DNA strand breaks in embryos have been shown by: CHAVDOULA et al. (2010), HANCI et al. (2013), PANAGOPOULOS et al. (2009, 2012), and SHAHIN et al. (2013). Decrease in reproductive capacity to infertility and malformations have been shown by: BUCHNER et al. (2014), CHAV-DOULA et al. (2010), GERONIKOULOU et al. (2014), MARGARITIS et al. (2014), and PANAGOPOULOS et al. (2009, 2010). An increase in apoptotic cellular processes (programmed cell death) has been shown by: HANCI et al. (2013), HOU et al. (2015), PANAGOPOULOS et al. (2012), and UMUR et al. (2013). Prenatal exposure has postnatal consequences. When embryos are exposed in dams, the newborns may develop pathological changes, e.g. in testes, behavioral disorders, and developmental delays. These pathological changes have been observed by: ALDAD et al. (2012), FURTADO-FILHO et al. (2014), HANCI et al. (2013), LI et al. (2012), and SANGUN et

al. (2015). A more detailed description of the contents of these studies and reviews can be found in the diagnose:funk study review "Brennpunkt," which can be downloaded from the homepage at www.diagnose-funk.org.

Opening of the blood-brain barrier

The working group of the Swedish researcher Leif Salford found an increase in the permeability of the blood-brain barrier for albumin proteins and, as a result, also neuronal damage in an experimental series with more than 2,000 rats after a two-hour GSM exposure (SALFORD et al. 2003, NITTBY et al. 2009, NITTBY et al. 2011). The RF exposure levels were SAR 1 W/kg and well below that (NITTBY et al. 2011: 0.37 mW/kg). Salford says: *"We have good reason to believe that what happens in a rat's brain also happens in humans"* (BBC 2003). So there was also a possibility that exposure to mobile phone radiation could trigger Alzheimer's disease and early dementia in some people: *"We cannot exclude that after some decades of often daily use, a whole generation of users may suffer negative effects maybe already in their middle age"* (BBC 2003). The research groups SIRAV/SEYHAN demonstrated in 2011 and 2016, TANG et al. again in 2015, that cell phone radiation opens the blood-brain barrier at even lower levels: *"The authors conclude that exposure of rats to electromagnetic fields of 900 MHz or 1800 MHz might increase the permeability of the blood brain barrier with sex-specific differences"* (EMF-Portal on SIRAV/SEYHAN 2016).

Impact on cognition, behavior, and changes in neurotransmitters

In view of the rapid spread of Wi-Fi in schools, especially through the introduction of tablets as a universal educational tool, study findings regarding cognition and behavior gain practical relevance. The studies mentioned in the sections below have been reviewed by diagnose:funk Study Reviews and can be downloaded at www.mobilfunkstudien.org.

DESHMUKH et al. (2015) studied three of the frequencies used in telecommunication networks. The study shows that low-level microwave radiation at 900, 1800, and 2450 MHz (nonthermal effect) causes adverse effects in rat brains, which manifest themselves as a reduced learning performance in the brain, memory, and spatial orientation. The neurotransmitters (dopamine, noradrenaline, adrenaline, and serotonin), which are chemical substances that transmit electric impulses to the synapses in the brain, are adversely affected by the frequencies 900 MHz and 1800 MHz; this has been shown in the studies by ERIS et al. (2015) and MEGHA et al. (2015). This can lead to a reduced learning performance as well as learning and memory disorders, also affecting sleep, appetite, and learning. A lack of serotonin generates e.g. depression, discomfort, nausea, and diarrhea. DE CAIRES et al. (2014) studied the impact of 1800 MHz on the central nervous system, demonstrating stress effects. LI et al. (2015) showed changes in rat neurotransmitter levels, especially in their serotonin metabolism, that lead to deficits in brain per-

formance. SAIKHEDKAR et al. (2014) observed neurodegenerative changes in the cells of the hippocampus and cerebral cortex, resulting in more severe anxiety, more stress and depression. ROGGEVEEN et al. (2015) studied whether smartphone radiation changes the EEG. The result: The activities of the alpha, beta, and gamma bands increased in almost all brain regions measured. In the hippocampus, spatial learning and memory are processed, stored, and recalled. SHAHIN et al. (2015) showed that the constant exposure to 2.45 GHz Wi-Fi radiation causes oxidative/nitrosative stress in the hippocampus and leads to cell changes that impair learning and the capacity to recall information. NARAYANAN et al. (2015) also observed structural changes in the hippocampus at 900 MHz that lead to reduced learning and recalling with respect to spatial orientation. As to causes, the authors point to ROS and DNA damage. IKINCI et al. (2015) showed that biochemical and pathological changes can occur in the spinal cord when male rats are exposed to 900 MHz fields one hour a day from day 21 to day 46. As a cause, the authors identify lipid peroxidation. Since the spinal cord is the pathway from the brain to the peripheral nervous system, any disturbance along its way can lead to behavioral changes because the flow of information is disrupted. MORTAZAVI et al. (2011) studied 469 students with respect to the impact of their cell phone use. There was a statistically significant association between call duration and frequency of certain symptoms, including headaches, muscle aches, heart palpitations, tiredness, tinnitus, vertigo, and sleep problems. In addition, problems with attention, concentration, and nervousness were higher than expected in heavy users. SCHOENI et al. (2015) studied whether the frequent use of smartphones affects memory performance. The evaluation of the memory tests performed by the adolescents revealed a significant association between the higher dose of RF EMF and a poorer figural memory performance after one year.

Impact on heart and blood functions

In the case-control study of EKICI et al. (2016), the impact of cell phone radiation on the heart function of healthy persons, especially heart rate variability (HRV), has been investigated. It has been shown that the duration of cell phone use may influence the autonomic balance of the heart rate variability in healthy persons. During a phone call, the mobile device is close to the head, which has a connection to the controls of heart activity (pacemaker). The electromagnetic fields of cell phones can cause changes in the heart rate variability, especially in long-term users. SAILI et al. (2015) showed changes in heart rate variability, increased blood pressure, and catecholamine efficacy (neurotransmitters) induced by the exposure to Wi-Fi signals. LIPPI et al. (2016) studied the impact of 900 MHz radiation of smartphones on leukocytes. After 30 minutes of exposure, a significant decrease in myeloperoxidase has been observed in all 16 samples as well as a significant decrease in segmented neutrophil leukocytes. Myeloperoxidase plays an important role in the oxidative cellular processes. Structure, volume, and function of blood platelets (thrombocytes) changed significantly. The authors concluded that blood products that contain leukocytes should be pro-

tected from smartphone radiation during manufacture and storage.

Cell tower studies

Due to the almost complete coverage, the impact of cell tower radiation exposure cannot be studied very well in long-term studies: there are no exposure-free residential control areas available anymore. Furthermore, people are exposed to many different RF sources by now (smartphones, WLAN/Wi-Fi, DECT cordless phone, baby monitor, etc.). When in the 2004 Naila study (EGER et al. 2004) an increased cancer risk had been observed for the first in the vicinity of cell towers, the lead author Dr. Horst Eger demanded from the German Federal Office for Radiation Protection to carry out follow-up studies for as long as there were still radiation-free zones available. This did not happen. The population, as deplored by the Federal Office for Radiation Protection in its radiation protection guidelines in 2005, still faces "uncontrolled exposures" (BUNDESAMT FÜR STRAHLENSCHUTZ 2005, p. 44).

For the past two years, cell tower studies have been carried out, in particular, outside of Europe. Two new Iranian studies have been published on the impact of cell tower radiation (ALAZAWI 2011, SHAHBAZI-GAHROUEI et al. 2014). The frequency of health symptoms was compared between residents living within 300 m of the cell antenna site to those living farther away than 300 m. The identical results of both studies: *"Most of the health complaints such as nausea, headache, dizziness, irritability, discomfort, nervousness, depression, sleep disturbance, memory loss and lowering of libido were statistically significantly more often reported by residents living near a base station (≤ 300 m distance) compared to those living in a distance of more than 300 m to a base station. The authors suggested that mobile phone base stations should not be sited closer than 300 m to residences to minimize exposure of the residents"* (EMF-Portal on the study by SHAHBAZI-GAHROUEI et al. 2014).

MEO et al. (2015) presented a clinical study on cell sites. For this study, two elementary schools with a total of 159 students were selected, each of which was exposed to a different level of RF radiation. It was the goal of this cross-sectional study to investigate the association between RF radiation and glycated hemoglobin (HbA1c) and the risk of type 2 diabetes mellitus. The result: The students with the high RF exposure levels had a significantly increased risk of developing type 2 diabetes mellitus in comparison to those with the lower RF exposure levels. For the dispute over cell sites and protective options, the experiment by MARZOOK et al. (2014) revealed important findings. Thirty-two adult male rats were divided into four groups: unexposed controls, exposed to 900 MHz radiation, exposed plus an administration of 1.5 or 3 ml sesame oil, respectively. The exposure was provided by a 900 MHz cell site, which was located 8 m away on a house in Cairo. The animals were exposed to a power density level of 0.5 mW/cm². The RF exposure lasted for 8 weeks for 24 hours per day; the animals in group 3 and 4 received an oral dose of sesame oil three times per week. One of the results: Com-

pared to the control group, testosterone had increased significantly and the significant increase in the sesame oil groups was dose-dependent. Antioxidant levels in the exposed animals decreased significantly and increased significantly in the sesame oil group with increasing dose. In fact, sesame oil has a protective function.

AKBARI et al. (2014) and JELODAR et al. (2013) simulated a base transceiver station (BTS) model in their laboratory, which emits 900 MHz and exposes rats. AKBARI et al. observed that the RF radiation exposure causes oxidative stress in the tissues of the brain and cerebellum and that vitamin C increases the enzyme activity of antioxidant enzymes and decreases lipid peroxidation. The results of the Jelodar research team also show that the exposure to 900 MHz radiation from cell sites causes oxidative stress in rat testes. Vitamin C significantly improved the activity of the antioxidant enzymes and significantly decreased the MDA concentration level (marker for oxidative stress), and lipid peroxidation was also decreased.

Mixture of frequencies and interactions not researched

The reader will notice the following: 1. In most studies only the impact of a single frequency is examined, but in real life all living organisms are exposed to a mixture of frequencies. 2. The combination effects with other environmental toxins such as amalgam, nitric oxides, fine particulate matter, lead, glyphosate, aluminum, fluorides, cadmium, plasticizers, and others have really not been researched in any depths. Radiation from wireless communication technologies results in combination effects with other environmental exposures (REA 2016). The Canadian environmental medical physicians Genuis and Lipp discuss this reinforcing combination effect in their article "Electromagnetic Hypersensitivity: Fact or Fiction?" (2011). Depending on previous exposures and the state of the immune system, EMFs have an impact. There is an absurd discussion going on about electromagnetic hypersensitivity. EMFs lead to oxidative stress and thus form an important basis for a range of inflammatory cellular processes with pathological consequences. To claim — especially when based on pseudoexperiments with short-term exposures (a smoker does not drop dead at his or her first deep drag) — that it can be ruled out that humans respond with sensitivities or allergies to these types of long-term exposures is absurd. To psychologize persons with electromagnetic hypersensitivity is discriminatory (GIBSON 2016).

The implementation of the Internet of Things, including smart homes and autonomous cars, the RF radiation exposures will increase tremendously. This will result in new combination effects. The new report from the Otto Hug Strahleninstitut "Unterschätzte Gesundheitsgefahren durch Radioaktivität am Beispiel der Radarsoldaten [Underestimated Risks from Radioactivity Using the Example of Radar Soldiers]" (MÄMPEL et al. 2015) also addresses, among other things, the interactions of radar and cell phone radiation:

"The exposure to radar radiation has so far only been recognized as harmful to health by official agencies and the Radar Commission when the power density level of the radiation results in a measurable increase in temperature in the tissue. However, we now have numerous scientific studies about the effects of cell phone radiation whose higher frequencies also fall into the microwave range. These findings show that at long-term exposures also below the so-called thermal threshold irreversible and pathological disorders such as infertility may occur. Combination effects between ionizing and nonionizing radiation are also to be considered as a possible cause of multiple disease phenomena, which can be observed in soldiers and staff members of radar facilities" (MÄMPEL et al. 2015, p. 9).

This interaction is of great importance now — not only for residents in the vicinity of airports and military facilities. Autonomous cars will be driven by a combination of radar, LTE, Wi-Fi, Bluetooth, and GPS, that is, humans and the environment will be exposed to another layer of a combination of different frequencies with complete coverage.

Conclusions: insights and interests

Based on a review of the research findings from in vitro, in vivo, and epidemiological studies, there can only be one conclusion: Long-term risks, in particular, pose huge health risks that cannot yet be determined. Why the public is not informed about this, Prof. Martin Blank (USA), former president of the Bioelectromagnetics Society, documents in his book "OVERPOWERED. What Science Tells Us About the Dangers of Cell Phones and Other WiFi-age Devices" (2014) the history and the current state of the research as well as his own experience of the U.S. industry's influence over politics and its communication of research findings. Some long-term effects are known through the research reviews by Prof. Karl Hecht (HECHT 1996, 2012, 2015, 2016), which he carried out on behalf of the German federal government as early as the 1990s. They were banished to the archives. We are in the middle of an open trial that was sanctioned by the government against its better knowledge as reported by the eye witness Prof. Hecht in the UMG interview 2/2016 (HECHT 2016). Fifty billion in licensing fees in 2001 and the German Chancellor Gerhard Schröder, also referred to as the "chancellor of the bosses," delivered: *"He often claimed that it would be completely wrong, in the context of innovations, to talk about risks first and opportunities second. The other way around, it would make sense: 'First realize opportunities and do not talk about risks; only talk about risks when they also manifest themselves, that is, when they cannot be avoided anymore,'"* Mirko Weber writes in the newspaper *Stuttgarter Zeitung*. The organizational theorist Günther Ortman calls this *"too late as a political program"* (WEBER 2016). The Federal Office for Radiation Protection responded to this in its 2005 radiation protection guidelines with criticism: *"On the other hand, we face a large-scale introduction of new exposures without having been able to reach a final estimate and assessment of their risks (e.g. wireless communication technologies)"* (p. 50). In the guidelines, the suspicion of a cancer-

promoting effect had already been confirmed. After calls from industry associations to withdraw the guidelines, the discussion about this issue stopped. So now we have an industry with a worldwide sale of billions of euros, excessive profits, hundreds of thousands of jobs, which is why people are expected to accept risks “without any alternative.” In his book *World Risk Society* (2007), the sociologist Ulrich Beck writes: *“The predominant definitions grant engineering and natural sciences monopoly status: They — in fact, the mainstream, not counter experts and alternative scientists — decide without any participation of the public what is tolerable and what is not in the face of threatening uncertainties and risks. (...) The sequence of laboratory first, implementation second no longer applies. Instead, assessment comes after implementation and manufacturing prior to research. The dilemma, the big risks have rushed scientific logic into, applies universally: The sciences hover blindly above the boundary of risks”* (BECK 2007, p. 73ff). This is why Ulrich Beck, with reference to the English state theorist Thomas Hobbes, advocates *“an individual right of resistance for citizens. When the government produces or tolerates life-threatening conditions, then, according to Hobbes, ‘citizens are free to refuse them’ (...) For risks are produced by the industry, externalized by the economy, individualized by the legal system, legitimized by natural sciences, and played down by politicians”* (BECK 2007, p. 177).

As early as 1994, the ECOLOG Institute warned in its book *Risiko Elektromog? [Electromog a Risk?]*:

“The entire earth turns more and more into a huge laboratory in which we, depending on our attitude and profession, observe with eagerness or horror which global impact the mass use of chemicals, electromagnetic fields, genetically manipulated organisms will have - only we cannot clean up this laboratory quite as easily when we realize the experiment went wrong” (NEITZKE et al. 1994, p. 319).

We cannot allow this to continue because, for reasons of profit, the sum total of all human-caused environmental damage poses a risk to the very existence of the human species.

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(1) In Germany, the 26. BImSchV (Federal Immission Control Ordinance) regulates exposure limits. They are based on the recommendations by the ICNIRP, a private association of scientists with close ties to the industry based in Munich, Germany. The guideline value for cell phone radiation at close range is 2.0 W/kg (SAR) for the head and 0.08 W/kg (SAR) for the whole body. A guideline value is only a recommendation. For fixed cell phone base stations, the valid exposure limit for GSM 900 is 41 V/m (electric field strength) or 4,500,000 $\mu\text{W}/\text{m}^2$ (power density), for UMTS 61 V/m, which corresponds to 10,000,000 $\mu\text{W}/\text{m}^2$.

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www.diagnose-funk.org | www.mobilfunkstudien.org 05/ 2017