Summaries and assessments of selected studies

In the period from beginning of February to end of April 2021, 88 new publications have been identified, and six of these were discussed in depth by BERENIS. Based on the selection criteria, four of these publications were selected as the most relevant ones. Their summaries and assessments are provided below.

1) Experimental animal and cell studies

20-kHz magnetic fields and effects on tumor incidence as well as memory performance, coordination, and anxiety behavior in female mice (Lerchl et al. 2021)

The study of Lerchl *et al.* (2021) investigated effects of chronic magnetic field exposure (20 kHz, 360 µT) on the behavior of mice and on carcinogenesis/tumor incidence. Magnetic fields in this frequency range are used, e.g., for induction cookers or wireless charging of electric cars. To date, relatively few studies have been published in this frequency range.

Two groups of 80 female mice were exposed or sham-exposed in cages with 5-6 animals each from the age of three months on for a total of 13 months (24 hours per day, 7 days per week, homogeneous magnetic field at a frequency of 20 kHz and an intensity of 360 µT). At this intensity, the induced body currents in mice are comparable to those in humans at the limit value recommended for the general public (27 µT). After 10 months of exposure, behavioral tests were performed to assess memory performance, motor ability and coordination, and anxiety behavior of the animals. After 13 months of exposure, finally, tissue samples from the brain, liver, kidney, spleen, and lungs of the mice were routinely examined histologically to evaluate the development of tumors and their type.

The results showed no differences between exposed mice and those in the control group regarding weight gain and survival rate. Behavioral tests of memory performance revealed no differences between the groups. However, balance and coordination were different in the MF-exposed mice, with longer retention times of the animals on the rotating rod. The authors attribute these differences to increased stress, and thus increased vigilance.

Although the tumor incidence was not significantly different between groups, more tumors and hyperplasias (tumor precursors) were observed in exposed mice by trend (11 in controls, 17 in exposed). Some tumor types or tumor precursors were more frequent in the exposed mice: malignant lymphomas, meningiomas, bronchiolo-alveolar carcinomas, hemangiosarcomas, and renal tube carcinomas. In the controls, bronchiolo-alveolar adenomas and spleen red pulp hyperplasias were more frequent. The only remarkable finding was the increased incidence of malignant lymphomas (2.5% versus 8%) in MF-exposed animals, which warrants follow-up studies. Due to the extremely low tumor incidence (0-2%) for many tumor types, the non-significant increase in individual tumors is difficult to evaluate. In this case, historical controls would be beneficial for data comparison within a period of a few years in the same laboratory. In addition, only one tissue section was prepared per organ, although the standard procedure would be to perform the analysis in two sections.

Decreased neurogenesis and cognitive processes after long-term exposure of mice to a hypomagnetic field (Zhang et al. *2021).*

The study of Zhang *et al.* (2021) is not about technology-caused EMFs, but investigates the influence of the Earth's magnetic field (geomagnetic field, GMF) on biological functions. It is well recognized that the GMF can be used for navigation by some animal species. Various studies regarding exposure to a hypomagnetic field (HMF, absence of a magnetic field), as occurring in space travel, show negative effects on the central nervous system. However, it is largely unexplored whether the GMF has a general effect on all organisms or basic cellular functions. Such a correlation with the absence of a magnetic field has been investigated in this study using neurogenesis as an example. Neurogenesis is closely linked to learning and memory performance, which can be impaired by stress as well as various environmental exposures. Thus, it is conceivable that such an evolutionary dependence may be observed when a magnetic field is largely reduced, which might indicate functional effects due to EMF.

Male mice (inbred strain C57BL/6, also referred to as "black6") exposed to a static hypomagnetic field (HMF), i.e., eliminating the geomagnetic field, showed significant impairment of neurogenesis after a 2-week exposure, as indicated by inhibition of neural stem cell proliferation. The static HMF of 0.29 µT was about 190 times weaker than the local geomagnetic field (approximately 55 µT). Following HMF exposure of a few weeks, neurons in the hippocampal brain region (dentate gyrus) of newborns showed decreased differentiation. An analysis of the transcriptome showed that the inhibition of differentiation corresponded to an upregulation of genes related to metabolic processes and cell proliferation. At the same time, the learning behavior of the animals was significantly decreased after HMF exposure. These observations correlated with decreased levels of superoxide, a reactive oxygen radical (a form of ROS). The inhibition of neurogenesis as well as the decrease in neural stem cell differentiation and learning behavior were reversible by pharmacological inhibition of superoxide removal. The authors concluded that the geomagnetic field plays an important role in neurogenesis in the hippocampal brain region and hippocampus-dependent learning in adults. This is regulated by maintaining superoxide levels, which are reduced under HMF conditions. In this case, ROS/superoxide acts as a signaling molecule and regulator of neuronal development and does not result in toxic cell effects. The underlying mechanism of these observations needs further investigation but it is well possible to be influenced by other ELF-MFs and RF-EMFs.

Effects of radiofrequency electromagnetic fields on skin cells (Kim et al. *2021)*

The skin, being a physical barrier to the environment, is the body part that is most exposed to electromagnetic fields and other environmental influences. In this respect, Kim *et al.* (2021) investigated effects of an LTE-modulated RF-EMF (1.76 GHz, SAR: 4 W/kg, 2 hours/day, for 4 days) on human skin cells (keratinocytes HaCaT) *in vitro*. Some experiments included UV-A irradiation as a positive control. The authors observed an increase in the formation of ROS by LTE RF-EMF exposure, although to a lesser extent than after UV-A irradiation. However, the increased ROS levels did not affect cell morphology, viability, and proliferation, nor did they lead to changes in apoptosis markers, which would indicate a toxic effect. Furthermore, the expression and activity of "matrix metalloproteinases" (MMPs) was analyzed. Proteins of this enzyme family degrade collagen (collagenase) and gelatin (gelantinase) in the extracellular matrix. They are considered an aging factor for the skin. Exposure to RF-EMF increased the levels of collagenases MMP1, -3, and -7 and the activity of gelatinases MMP2 and -9, but again to a lesser extent than UV-A irradiation. In addition, analysis of the transcription factor FoxO3 indicated an effect on cell aging (senescence). The authors found an activation of the MAPK signaling cascade and an increase of the active phosphorylated form of Erk1/2, while the inflammatory marker Cox2 remained unchanged.

Based on their data, the authors concluded that RF-EMF exposure, such as an LTE signal, may potentially lead to an acceleration of the skin aging process through the formation of ROS, similar to the known mode of action of higher-energy radiation, such as UV-A. The same research group had

previously reported comparable effects of RF-EMF exposure on aging processes of other cell types (see Choi *et al.* 2020, Newsletter 24). However, existing evidence in this regard is rather sparse and further studies are needed to evaluate these conclusions. In this regard, it would be interesting to see the effect of these two environmental exposures in the case of simultaneous and sequential exposure.

2) Dosimetrical study

Exposure assessment in a commercial 5G network in Bern, Switzerland (Aerts et al. *2021)*

In an initial in situ measurement campaign, an assessment of the exposure from fifth-generation base station antennas (New Radio (NR) massive multiple-input-multiple-output (MaMIMO)) was carried out in a commercial mobile network (Swisscom) in Bern, which is also equipped with 5G. In a 5G-NR-network within reach of four base station sites, measurements were performed at a total of 22 line-of-sight positions and at distances between 30 and 410 m from the NR antennas. 20 of the measurement positions were at 1.5 m height from the ground and two were on roofs at a height of 20.5 m. Field strengths were determined for two scenarios. The first scenario comprised the field strength in the currently running network operation. The second scenario additionally comprised the exposure due to an experimentally induced connection between the NR antenna and a mobile phone, with a maximal utilization of the traffic channels. The mobile phone was placed in the extension of the line-of-sight to the antenna. The NR antennas of the four base stations under investigation operated in the n78 band (3.3 - 3.8 GHz) with input powers ranging from 1.5 to 8 W, and used codebook-based beamforming, i.e. predefined and preset beam distributions of the adaptive antennas, whose radiated transmission power at the time of the measurement campaign is limited in Switzerland in such a way that the maximum exposure of places of sensitive use[1] may not exceed 10% of the exposure limit values. Without actively induced traffic data, the emissions of the NR antennas operated with 1.6 to 8W input power generated field strengths of less than 0.05 V/m at the selected measurement sites. When operating with the additional experimentally induced traffic channel load, the field strengths reached a maximum value of 0.6 V/m at the selected measurement points. This maximum value corresponds to the highest value measured within a so-called "resource element" within a transmission packet of 20ms duration. Extrapolated to the maximum antenna input power of 200 W allowed by the manufacturer, this leads to maximum field strengths of 4.9 V/m at the selected measurement points. This approximately corresponds with the Swiss installation limit values, and 0.5 - 0.6% of the ICNIRP limits with regard to power density (10 W/m^2 at 3.5 GHz). At the time of the measurement in Bern, the average contribution of NR antenna exposure to the total electromagnetic field immission was 2%.

Based on this first in situ measurement campaign in a commercial network on currently generated and extrapolated field strengths by 5G-NR-antennas, the authors conclude that the EMF contribution of the new antennas to the already existing EMF immissions is small. Even in the case of 100% occupancy of the traffic channel, the levels remained well below the international limits.

It has to be noted that the spatial and temporal validity of such measurements is limited. Further comprehensive measurement campaigns are needed to confirm these conclusions, especially when 5G is more widely used in Switzerland. The study was supported by Mobile & Wireless Forum (international association of companies with an interest in mobile and wireless communications).

[1] places of sensitive use = places where humans can stay for a prolonged time. For more information please see https://www.bafu.admin.ch/bafu/de/home/themen/elektrosmog/fachinformationen/massnahmen-elektrosmog/orte-mit-empfindlicher-nutzung--omen-.html.

3) Information on additional publications

Expert reports on EMF and health

The French Agency for Food, Environmental and Occupational Health & Safety (ANSES) has published an expert report on "EMF exposure associated with the deployment of 5G technology and potential associated health effects" in March 2021 (in French).[2]

Furthermore, the fifteenth report of the Scientific Council of the Swedish Radiation Safety Authority on recent EMF research and health risk was published in April 2021.[3]

References

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[2] ANSES (2021): **Expositions aux champs électromagnétiques liées au déploiement de la technologie de communication « 5G » et effets sanitaires éventuels associés.** (saisine 2019-SA-0006). Maisons-Alfort: ANSES, 241 p. https://www.anses.fr/fr/system/files/AP2019SA0006_Rapport_5G_consultation.pdf

[3] SSM (2021): **Recent Research on EMF and Health Risk. Fifteenth report from Swedish Radiation Safety Authority's (SSM) Scientific Council on Electromagnetic Fields.** April 2021. https://www.stralsakerhetsmyndigheten.se/2021-08

Additional information:

BERENIS - Swiss expert group on electromagnetic fields and non-ionising radiation

List of abbreviations (pdf)