Summaries and assessments of selected studies

In the period from mid of January to end of April 2020, 91 new publications have been identified, and twelve of these were discussed in depth by BERENIS. Based on the selection criteria, six of these publications were selected as the most relevant ones. Their summaries and assessments are provided below.

1) Experimental animal and cell studies

Modulated radiofrequency electromagnetic fields and impact on the genome (Schuermann et al. *2020)*

The *in vitro* study by Schuermann *et al.* (2020) systematically investigated the influence of modulated RF-EMF signals, used in wireless communication systems, on DNA damage and repair. The authors mainly used primary human lung fibroblasts and a trophoblast cell line, which were exposed intermittently (5/10 min on/off) to different modulations of a 1.95 GHz carrier frequency (GSM/2G, UMTS/3G, Wi-Fi, RFID[1]) at 0.5, 2 and 4.9 W/kg SAR. After 1, 4 and 24 hours of exposure, DNA damage was analysed by Comet assay; yet, no significant increase was observed for any of these exposure conditions. In order to exclude possible side effects, two research teams independently performed key experiments in separate laboratories. This study could not confirm or conclusively replicate previously observed effects in the REFLEX study[2] and another study[3] (DNA damage due to a GSM signal), which were the trigger and starting point for this study. Furthermore, in order to lower the detection threshold of the Comet assay, experimental approaches that visualise oxidative and other types of unrepaired DNA damage were applied.

Damage to the genetic material might also be caused when RF-EMF affects DNA repair and/or replication. For this reason, these mechanisms were explored as well on a selective basis, yet without discovering significant and reproducible differences. Only when fibroblast cells were simultaneously exposed to a UMTS signal (SAR 4.9 W/kg) and a known DNA-damaging and carcinogenic substance (ethyl methanesulfonate - EMS) for one hour, significantly increased DNA damage was found. However, this effect by co-exposure was not found if the RF-EMF exposure was preceding and lasted longer than the EMS treatment. This indicates that cells can adapt relatively quickly to the conditions and protective measures become active (adaptive response). As no effects above the detection limits were observed for a large number of tested exposure conditions, the authors concluded that it is unlikely that the RF-EMF signals cause direct or indirect damage to the genetic material. However, indications for effects on genome integrity might be caused or amplified by additional or unidentified stress factors under certain experimental conditions.

---

[1] Radio-frequency identification: a system that transmits the identity of an object, a person or an animal wirelessly by using radio waves (www.emf-portal.org)

[2] Diem E, Schwarz C, Adlkofer F, Jahn O, Rüdiger H (2005): **Non-thermal DNA breakage by mobile-phone radiation (1800 MHz) in human fibroblasts and in transformed GFSH-R17 rat granulosa cells in vitro.** Mutat Res. 2005 Jun 6;583(2):178-83. https://pubmed.ncbi.nlm.nih.gov/15869902/

[3] Franzellitti S, Valbonesi P, Ciancaglini N, Biondi C, Contin A, Bersani F, Fabbri E (2010): **Transient DNA damage induced by high-frequency electromagnetic fields (GSM 1.8 GHz) in the human trophoblast HTR-8/SVneo cell line evaluated with the alkaline comet assay.** Mutat Res. 2010 Jan 5;683(1-2):35-42. https://pubmed.ncbi.nlm.nih.gov/19822160/

Long-term exposure to radiofrequency electromagnetic fields in rats and effects on oxidative stress, working memory and DNA damage in the brain (Sharma et al. *2020)*

In this *in vivo* study with rats, the effects of RF-EMF on oxidative stress, on DNA damage in the brain, and on memory function were investigated. The study was conducted under controlled conditions (temperature, climate, light). Male Wistar rats (inbred strain) were exposed for 1, 2 or 4 hours per day for 90 days (900 MHz, average SAR in the brain: 0.231 W/kg). SAR values were estimated based on the electric field strength at a distance of one meter. In addition to conducting various experiments related to oxidative stress and acetylcholinesterase (an enzyme involved in neuronal transmission), the authors also studied cognitive functions after RF-EMF or sham exposure (speed and efficiency in finding the reward or food). Following RF-EMF exposure, considerable cognitive deficits were observed, and they increased with longer daily exposure duration. The enzymes catalase (CAT) and superoxide dismutase (SOD), which counteract oxidative stress, were significantly reduced depending on exposure time, while lipid peroxidation (oxidative degradation of lipids, which can lead to damage of cell membranes and thus to cell damage) increased correlating with exposure time; the highest value was found at 4 hours of daily exposure. At the same time, the redox enzymes glutathione S-transferase (GST), glutathione peroxidase (GPx) and reductase (GR), and glucose-6-phosphate dehydrogenase (G-6PDH) were diminished.

The authors attribute the decrease in acetylcholinesterase, as well as the reduced memory performance of RF-EMF exposed rats to increased oxidative stress. If the increase in oxidative stress upon exposure cannot be compensated, neurodegenerative diseases in the brain may develop and/or increased neuronal activity may occur, leading to convulsions (epilepsy). Being a weakness of the study, the calculation of the SAR for the brain bears uncertainties.

2) Human experimental studies

Sleeping next to a router: no sleep disturbing effects of Wi-Fi exposure (Danker-Hopfe et al. 2020)

There is public concern that exposure to Wi-Fi routers can cause sleep disturbances. The study by Danker-Hopfe *et al.* (2020) is a first human experimental study that investigated the effects of a Wi-Fi router emitting all night on sleep. The study participants were 34 healthy young men aged 20-30 years who were exposed to Wi-Fi (2.45 GHz) or sham exposure during sleep. A baseline night was followed by an experimental night with real or sham exposure, and this procedure was repeated a week later with the other condition (double-blind and randomised). The exposure consisted of a Wi-Fi signal, with traffic of varying intensity alternating with "beacon only" transmission. The maximum local SAR was <25 mW/kg, and the time average over 6 minutes was <6.4 mW/kg. This corresponds to a rather strong Wi-Fi exposure, but is still realistic in a home setting.

Subjective and objective sleep parameters were not affected by whole-night Wi-Fi exposure. Also, arousals (wake-up reactions) did not differ between the two exposure conditions. However, the proportion of non-REM sleep stage 1 (light sleep) was slightly increased in the second half of the night. Analysis of the spectral composition of the non-REM sleep EEG showed a slight reduction in EEG power in the alpha frequency range after Wi-Fi exposure. This reduction, though, is not an indication of disturbed sleep and the effect size was small. In addition, multiple testing was not adjusted for, so this could also be a chance finding. In summary, sleeping next to a Wi-Fi router did not result in any sleep disturbing effects. The interpretation of the results is limited by the fact that only young healthy men participated in the study who were not concerned about Wi-Fi exposure, and that the observation was restricted to a single night of exposure.

3) Epidemiological studies

Brain tumours and distance to high-voltage power lines at the place of residence (Carles et al. *2020).*

In the framework of the French CERENAT case-control study, Carles *et al.* (2020) investigated whether people living near a high-voltage power line are more likely to develop brain tumours. The study included 273 glioma patients and 217 meningioma patients diagnosed in France between 2004 and 2006 (participation rate: 73%). A total of 980 control subjects (participation rate: 45%) were randomly selected from electoral rolls. The geocoded distance to the nearest high-voltage power line (<45 kV to 400 kV) was used for exposure assessment, with no distinction made between overhead and underground lines. The duration of exposure, i.e. the cumulative duration of living within a 50m corridor around high-voltage power line was calculated, and an exposure corridor was defined in which exposure might be higher than 0.3 µT (for 63 kV: 60 m; for 90 kV: 80 m; for 150 kV: 100 m; for 225 kV: 150 m; for 400 kV: 200 m). The data analysis took into account several possible risk factors (gender, age, education, tobacco and alcohol consumption, pesticide exposure, residential magnetic field exposure and mobile phone use). Eight percent of the study participants lived in a 0.3 µT exposure corridor at least once, and five percent within 50 m of a high-voltage power line. The majority of the different analyses indicate a correlation between extremely low frequency magnetic field exposure and the incidence of brain tumours, although the number of exposed cases is small and the risk estimates show a large uncertainty (confidence interval, CI)[4]. As an example, based on 7 patients, the brain tumour risk was 4.33 times higher for people who lived near a high-voltage power line for more than 15 years (confidence interval: 1.11-16.9).

In principle, distance to high-voltage power line is a suitable exposure measure, as shown in the recently published analysis by Amoon *et al.* (2020)[5]. The advantage of this approach is that other factors associated with high-voltage power lines can also be accounted for, such as the electric field or electrically charged ions due to corona discharges in highest-voltage power lines.[6] However, a limitation of this study is that for 30% of the participants, the coordinates of their place of residence were unknown, and substituted by the coordinates of the municipality's town hall building. Yet, according to the authors, this did not have any influence on the results (results are not shown). The fact that no distinction was made between overhead and underground lines is another source of uncertainty. The participation rate in control persons is relatively low (45%), which is a potential risk of bias. The small number of exposed persons makes the study susceptible for chance findings. It can be assumed that an increased risk by a factor of four in connection with all high-voltage power lines

[4] A confidence interval (CI) is an interval used to estimate the likely size of a population parameter. It gives an estimated range of values that has a specified probability of containing the parameter being estimated. Most commonly used is the 95% confidence interval that has .95 probability of containing the parameter (www.emf-portal.org/en)

[5] Amoon AT, Crespi CM, Nguyen A, Zhao X, Vergara X, Arah OA, Kheifets L (2020): **The role of dwelling type when estimating the effect of magnetic fields on childhood leukemia in the California Power Line Study (CAPS).** Cancer Causes Control. 2020 Jun;31(6):559-567. https://pubmed.ncbi.nlm.nih.gov/32277327/

[6] In the last newsletter period, for the first time, a study was published that explicitly investigated the health effects of electrically charged ions in the vicinity of high-voltage power lines on respiratory tumours and skin cancer (Toledano *et al.* (2020), https://www.ncbi.nlm.nih.gov/pubmed/32276731). It has been hypothesised that these ions attach to aerosols, which could lead to more efficient adsorption in the respiratory tract or on the skin. However, this hypothesis could not be confirmed based on more than 55,000 tumours in the mouth, respiratory tract and lungs and 179 keratinocyte tumours.

would have already been discovered in earlier studies. For example, a much larger study from England[7] based on 6,781 brain tumour patients and 20,343 control persons did not find evidence of an increased brain tumour risk for persons living within 50 m of a highest-voltage power line (≥275 kV) (OR[8] =1. 22, 95% CI[9] : 0.88-1.69) or exposed to more than 1 µT (OR=1.02, 95% CI 0.47-2.22) or between 0.40 and 0.99 µT (OR=0.92, 95% CI: 0.54-1.55).

Mobile phone use and self-reported sleep quality in the COSMOS study (Tettamanti et al. *2020)*

First results of the COSMOS cohort study on mobile phone use and symptoms such as of headaches, tinnitus and hearing loss were presented in Newsletter No. 20 (Auvinen *et al.* 2019)[10]. In a second publication, possible associations between mobile phone use and self-reported sleep quality were investigated (Tettamanti *et al.* 2020). Again, data from over 24,000 participants from Sweden and Finland were included in the analysis. Data on mobile phone use were collected by means of a questionnaire at the beginning of the study. In addition, objective data on call duration in the GSM (2G) and UMTS (3G) networks were obtained from the mobile phone operators for a period of three months at the start of the study. At the beginning of the study and after four years, the study participants completed a questionnaire regarding sleep disturbance, sleep adequacy, daytime sleepiness, sleep latency, and insomnia. The group of participants with the longest talk duration (>258 minutes/week) had a higher risk of insomnia than those with the shortest call duration (OR=1.24, 95% confidence interval: 1.03-1.51). However, the correlation was less pronounced in an analysis accounting for the fact that less radiation is emitted while using the UMTS network compared to the GSM network. For the other aspects related to sleep quality, no significant associations with mobile phone use were observed.

In addition to the prospective approach mentioned above, major strengths of this study are the large number of participants and the use of objective data from mobile phone operators. According to the authors, the fact that the correlation with insomnia was associated rather to the length of use than to the level of radiation emissions suggests that other factors than RF-EMF may be relevant for the observed association. For example, such factors could be stress, high demands, problematic mobile phone use, displacement of sleep due to mobile phone use, exposure to blue light from screens or other behavioural factors.

4) Dosimetric studies

Radiofrequency electromagnetic fields and honey bees (Thielens et al. *2020)*

By using numerical simulations, Thielens *et al.* (2020) investigated the absorption of RF-EMF in honey bees. The frequency range considered was between 600 MHz and 120 GHz. Five different models of honey bees - two workers, a drone, a larva, and a queen - were generated using micro-CT scanning.

[7] Elliott P, Shaddick G, Douglass M, de Hoogh K, Briggs DJ, Toledano MB (2013): **Adult cancers near high-voltage overhead power lines.** Epidemiology. 2013 Mar;24(2):184-90. https://pubmed.ncbi.nlm.nih.gov/23337237/

[8] OR = odds ratio

[9] CI = confidence interval, see above

[10] Auvinen A, Feychting M, Ahlbom A, Hillert L, Elliott P, Schüz J, Kromhout H, Toledano MB, Johansen C, Poulsen AH, Vermeulen R, Heinävaara S, Kojo K, Tettamanti G; COSMOS Study Group (2019): **Headache, tinnitus and hearing loss in the international Cohort Study of Mobile Phone Use and Health (COSMOS) in Sweden and Finland.** Int J Epidemiol. 2019 Jul 13. https://www.ncbi.nlm.nih.gov/pubmed/31302690

The contours of the different bees were segmented. The simulations were combined with measurements near beehives in Belgium in order to estimate realistic exposure and absorbed power in honey bees. The highest increase in absorbed power in the different bee models is between 600 MHz and 6 GHz. With higher frequencies, the absorbed power slightly decreases again. Depending on the absorption cross section, and for frequencies from 600 MHz to 6 GHz, the difference in absorbed power in the bee models can increase by a factor of 16 to 121. The absorbed power value for an electric field strength of 1 V/m varies between the nW range at 600 MHz to fractions of µW at 6 GHz. Field strengths between 0.016 and 0.2 V/m were measured near the beehives. Based on a uniform distribution of the field strength over the entire frequency range, the researchers investigated to what extent the absorbed power in the bees changes if the telecommunication frequencies shift from frequencies below 3 GHz to frequencies above 3 GHz. A shift of 10% of the spectral components from below 3 GHz to frequencies above 3 GHz would result in an increase of the absorbed power by a factor of 3-5. Such a shift to higher frequencies is expected in the near future.

The authors point out several limitations of this first study on mobile phone radiation absorption in bees. No dielectric measurements and no thermal measurements of tissue parameters of bees were performed, but were determined based on literature values and extrapolations. The models are homogeneous animals, i.e. the structures (such as organs) were not differentiated. For the numerical simulations, an FDTD-based[11] simulation platform was used, with known limitations regarding accuracy. No computations have yet been made with regard to the temperature increase resulting from the absorbed power. As with all simulation studies, the question is whether the results can be confirmed by measurements. In the case of bees this is an almost impossible task. Due to these limitations, the published values are subject to a high degree of uncertainty. However, the main conclusion of the study is valid, which states that an increase in frequency between 600 MHz and 6 GHZ leads to a higher absorbed power. Nevertheless, future research should investigate the required power levels above which biological effects can occur in bees. As stated by the authors as motivation for their study, bees are insects with global relevance both ecologically and economically. The study is an important contribution regarding the clarification of potential effects of electromagnetic fields on insects.

References

Carles C, Esquirol Y, Turuban M, Piel C, Migault L, Pouchieu C, Bouvier G, Fabbro-Peray P, Lebailly P, Baldi I (2020): **Residential proximity to power lines and risk of brain tumor in the general population.** Environ Res. 2020 Jun;185:109473. Epub 2020 Apr 4.
https://www.ncbi.nlm.nih.gov/pubmed/32278161

Danker-Hopfe H, Bueno-Lopez A, Dorn H, Schmid G, Hirtl R, Eggert T (2020): **Spending the night next to a router - Results from the first human experimental study investigating the impact of Wi-Fi exposure on sleep.** Int J Hyg Environ Health. 2020 May 11;228:113550.
https://www.ncbi.nlm.nih.gov/pubmed/32408065

Schuermann D, Ziemann C, Barekati Z, Capstick M, Oertel A, Focke F, Murbach M, Kuster N, Dasenbrock C, Schär P (2020): **Assessment of Genotoxicity in Human Cells Exposed to Modulated Electromagnetic Fields of Wireless Communication Devices**. Genes (Basel). 2020 Mar 25;11(4).
https://www.ncbi.nlm.nih.gov/pubmed/32218170

[11] FDTD = *Finite Difference Time Domain*, a technique for simulating electromagnetic wave propagation

Sharma S, Shukla S (2020): **Effect of electromagnetic radiation on redox status, acetylcholine esterase activity and cellular damage contributing to the diminution of the brain working memory in rats.** J Chem Neuroanat. 2020 Mar 20;106:101784.
https://www.ncbi.nlm.nih.gov/pubmed/32205214

Tettamanti G, Auvinen A, Åkerstedt T, Kojo K, Ahlbom A, Heinävaara S, Elliott P, Schüz J, Deltour I, Kromhout H, Toledano MB, Poulsen AH, Johansen C, Vermeulen R, Feychting M, Hillert L; COSMOS Study Group (2020): **Long-term effect of mobile phone use on sleep quality: Results from the cohort study of mobile phone use and health (COSMOS).** Environ Int. 2020 Apr 7:105687.
https://www.ncbi.nlm.nih.gov/pubmed/32276731

Thielens A, Greco MK, Verloock L, Martens L, Joseph W (2020): **Radio-Frequency Electromagnetic Field Exposure of Western Honey Bees.** Sci Rep. 2020 Jan 16;10(1):461.
https://www.ncbi.nlm.nih.gov/pubmed/31949179

Contact

Dr Stefan Dongus
BERENIS Secretariat
Swiss Tropical and Public Health Institute
Department of Epidemiology and Public Health
Environmental Exposures and Health Unit
Socinstr. 57, P.O. Box, CH-4002 Basel, Switzerland
Tel: +41 61 284 8111
Email: stefan.dongus@swisstph.ch

Additional information:

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

List of abbreviations (pdf)