

## Summaries and assessments of selected studies

In the period from early August to early November 2018, 120 new publications have been identified, and 14 of these were discussed in depth by BERENIS. Based on the selection criteria, five of these publications were selected as the most relevant ones. Their summaries and assessments are provided below.

### 1) *Experimental animal and cell studies*

#### *Impacts of radiofrequency electromagnetic fields on the male reproductive system (Houston et al. 2018)*

In the publication of Houston et al. (2018), earlier observations regarding damaging effects of RF-EMF on cells of the male reproductive system were investigated in more detail. Mouse cell lines and primary cells, originating from different developmental stages from germ cell to mature sperm, were exposed to a non-modulated RF-EMF (1.8 GHz, SAR: 150 mW/kg) for 1-6 hours. In addition, some of the experiments were also performed with a tenfold higher dose (SAR: 1.5 W/kg), with comparable results, yet without showing a clear dose-response relationship. In spermatogonia (germ cells before maturation) and in spermatocytes (cells in maturation), the authors found a significant increase in reactive oxygen species (ROS) in the mitochondria, which increased with exposure duration. In contrast, the mature sperm and various fully differentiated control cells from other tissues showed no increase in ROS. The authors tried to determine the origin of this increased ROS formation and found indications that the EMF interferes with a complex of the mitochondrial electron transfer chain that is responsible for cellular energy production (in the form of ATP). However, the germ cells seem to be able to neutralize the ROS formed in the mitochondria, since no signs of damage to fatty acids (lipid peroxidation) and genetic material (DNA strand breaks and oxidative damage) were found. This conclusion is seemingly contradictory to other publications using the same spermatocyte cell line and also a 1.8 GHz RF-EMF exposure (e.g.: Liu *et al.* 2013; Li *et al.* 2018). However, the longer and more intense exposure conditions could play a role, leading to cumulated ROS formation and ultimately to cell damage. The mature sperm showed a different behaviour, as the authors did not find an increase in ROS, but a temporary increase in signs of DNA damage, resulting in a slight but significant reduction in sperm quality (e.g. mobility) after 4 hours of exposure.

In general, this is a well-done study providing new evidence regarding the possible development of ROS under RF-EMF exposure in the male reproductive system, as well as the consequences for the different developmental stages of spermatogenesis. As discussed by the authors, these data from the mouse cannot directly be transferred to humans. This is due to the different sensitivity to exposure and the ability to deal with imbalances in oxidation-reduction status.

#### *Mechanistic investigation of the influence of extremely low frequency magnetic fields on fundamental cellular signal cascades (Wu et al. 2018)*

Although the *in vitro* study by Wu *et al.* (2018) does not provide direct insights with regard to impacts on health caused by electromagnetic fields, the comprehensive results of the study are noteworthy. The authors describe the activation of a complex network of signaling cascades and interactions under ELF-MF exposure (50 Hz, 0.4 mT, for 30 min), which eventually leads to altered dynamics of

the cytoskeleton (microtubule filaments). Thereby, it can affect the structure and mobility of cells as well as transport and proliferation mechanisms within the cells. A cell membrane bound calcium channel and a receptor of a growth factor could be identified to play a central role. Interestingly, numerous effects of EMF exposure described in other publications may have been triggered or influenced by these regulatory mechanisms (e.g. activation of signaling cascades, reduced cell proliferation). In fact, the activation or regulation of some of these components has been observed several times, but the step-by-step process has never been analysed so comprehensively, and demonstrated so coherently.

*Extremely low frequency magnetic fields, cryptochrome and reactive oxygen species (Sherrard et al. 2018)*

Cryptochrome (CRY) is a photoreceptor, i.e. a protein that reacts to blue light and requires light to perform its functions. The role of CRY as a potential magnetic field receptor has been discussed in detail in [BERENIS Newsletter No. 13](#). CRY plays a significant role in the perception of the Earth's magnetic field in a large number of animals such as migratory birds. The study by Sherrard *et al.* (2018) showed that pulsed ELF-MF (10 Hz) with a peak amplitude of 1.8 mT led to an avoidance behaviour in fruit fly (*Drosophila*) larvae and to the production of reactive oxygen species (ROS) in human and mouse cell lines (HEK and MEF). Interestingly, the authors observed that these reactions require the presence of CRY. Biochemical experiments and imaging techniques have shown that the exposure of mammalian cells to pulsed ELF-MF stimulates the formation of ROS, indicating a stress response and aging of cells. In addition, cell growth was slowed down and the expression of genes, known to be caused by ROS production, was induced.

This study confirms the role of CRY as a magnetoreceptor. The results also suggest that CRY is responsible for the increased avoidance behaviour of *Drosophila* larvae and ROS production in the investigated mammalian cells. In order to evaluate this, mutated flies and CRY-deficient cells ("knockout") were generated. Corresponding controls and positive controls (blue light) were performed as well.

*Spontaneous electric activity of neuronal cells is reduced after RF-EMF (1800 MHz) exposure (El Khoueiry et al. 2018)*

In the study from El Khoueiry *et al.* (2018) spontaneous electric activity (i.e. burst activity) was measured in embryonic neuronal cell cultures of rats using 60 electrodes. The cell cultures were exposed to RF-EMF (non-modulated and GSM, 1800 MHz, SAR: 0.01 bis 9.2 W/kg) for 15 minutes. During GSM and continuous wave exposure (without any modulation), the burst rate was reduced in a dose-dependent manner. At highest SAR level, the reduction of the burst rate lasted longer than the exposure period and the effects were somewhat stronger for GSM compared to non-modulated RF-EMF exposure of the same intensity. In a control experiment with sham exposure, a slight reduction of the burst rate was seen. Because high SAR values are likely to result in a temperature increase of the cells, the effect of heating was addressed. Temperature increase resulted in an increase of the burst rate, which continued into the cooling phase. The authors concluded that their observations indicate a dose-dependent effect from RF-EMF on neuronal activity, which cannot be explained by a thermal mechanism. However, it cannot be excluded that the heating has caused an artifact. To draw firm conclusions, additional exposure scenarios needed to be tested.

## 2) Epidemiological studies

### *RF-EMF and behavioural problems in 5-year old children (Guxens et al. 2018)*

The Dutch study by Guxens *et al.* (2018) addressed the association between RF-EMF at the place of residence and behavioral problems in a sample of 3,102 children aged 5 years. A validated propagation model was used to predict RF-EMF from mobile phone base station at the place of residence. Further information about indoor sources such as WLAN and cordless mobile phone base station as well as mobile and cordless phone use was obtained by a questionnaire. Parents and teachers answered a validated questionnaire on various aspects of behavioral problems. Numerous covariables were considered in the statistical analyses. Mobile and cordless phones were not associated with behavioural problems. According to the parental but not to the teachers' report, high RF-EMF exposure from mobile phone base stations was associated with more frequent emotional symptoms. Children who had a cordless phone base station at home showed a prosocial behavior less often according to the teachers and had more often maternal-reported peer relationship problems. Children who watched television for at least 90 minutes a day expressed more maternal-reported hyperactivity/inattention behavior

The large sample size is an asset of this study and a high number of potential confounders has been considered in the analysis. Nevertheless, it cannot be ruled out that these sporadically observed associations occurred by chance or are due to other factors that were not considered and corrected for. Also, the associations are inconsistent in terms of maternal and teachers' report. No information is given about the extent of mobile phone base station exposure. The use mobile and cordless phones in children at the age of five years is rather uncommon. Accordingly, the absence of associations for mobile and cordless phone use might not be significant for long-term mobile phone use.

## References

El Khoueiry C, Moretti D, Renom R, Camera F, Orlacchio R, Garenne A, Poullietier de Gannes F, Poque-Haro E, Lagroye I, Veyret B, Lewis N (2018): **Decreased spontaneous electrical activity in neuronal networks exposed to radiofrequency 1800 MHz signals.** J Neurophysiol. 2018 Aug 22.

<https://www.ncbi.nlm.nih.gov/pubmed/30133383>

Guxens M, Vermeulen R, Steenkamer I, Beekhuizen J, Vrijkotte TGM, Kromhout H, Huss A (2018): **Radiofrequency electromagnetic fields, screen time, and emotional and behavioural problems in 5-year-old children.** Int J Hyg Environ Health. 2018 Oct 9.

<https://www.ncbi.nlm.nih.gov/pubmed/30314943>

Houston BJ, Nixon B, King BV, Aitken RJ, De Iuliis GN (2018): **Probing the Origins of 1,800 MHz Radio Frequency Electromagnetic Radiation Induced Damage in Mouse Immortalized Germ Cells and Spermatozoa in vitro.** Front Public Health. 2018 Sep 21;6:270.

<https://www.ncbi.nlm.nih.gov/pubmed/30298125>

Li R, Ma M, Li L, Zhao L, Zhang T, Gao X, Zhang D, Zhu Y, Peng Q, Luo X, Wang M (2018): **The Protective Effect of Autophagy on DNA Damage in Mouse Spermatocyte-Derived Cells Exposed to 1800 MHz Radiofrequency Electromagnetic Fields.** Cell Physiol Biochem 48(1).

<https://www.ncbi.nlm.nih.gov/pubmed/29996120>

Liu C, Duan W, Xu S, Chen C, He M, Zhang L, Yu Z, Zhou Z (2013): **Exposure to 1800 MHz radiofrequency electromagnetic radiation induces oxidative DNA base damage in a mouse spermatocyte-derived cell line.** Toxicol Lett 218(1).

<https://www.ncbi.nlm.nih.gov/pubmed/23333639>

Sherrard RM, Morellini N, Jourdan N, El-Esawi M, Arthaut LD, Niessner C, Rouyer F, Klarsfeld A, Doulazmi M, Witczak J, d'Harlingue A, Mariani J, Mclure I, Martino CF, Ahmad M (2018): **Low-intensity electromagnetic fields induce human cryptochrome to modulate intracellular reactive oxygen species.** PLoS Biol. 2018 Oct 2;16(10):e2006229.

<https://www.ncbi.nlm.nih.gov/pubmed/30278045>

Wu X, Du J, Song W, Cao M, Chen S, Xia R (2018): **Weak power frequency magnetic fields induce microtubule cytoskeleton reorganization depending on the epidermal growth factor receptor and the calcium related signaling.** PLoS One. 2018 Oct 12;13(10):e0205569.

<https://www.ncbi.nlm.nih.gov/pubmed/30312357>

## 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 \(pdf\)](#)