Bundesamt
für Strahlenschutz

Spotlight on EMF Research

Spotlight on “Biological effects of electromagnetic fields on insects: a systematic review and meta-analysis” by Thill et al. in Reviews on Environmental Health (2023)

Category [across frequencies, review]

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Competence Centre Electromagnetic Fields (KEMF)

1 Putting the paper into context by the BfS

Compliance with recommended exposure limits [2, 3] ensures protection against scientifically established adverse health effects of electromagnetic fields (EMFs). These limits are established to protect humans. It is generally assumed that if humans are protected, animals, plants, and ecosystems will also be protected. Flying animals, such as insects, may get closer to sources of EMFs, such as power lines or base stations. They therefore may be exposed at levels that exceed accepted limits. In addition, insects possess receptors and structures that are not present in humans, which could lead to additional biological effects with potentially lower thresholds than those observed in humans. To summarize the current state of knowledge and to identify knowledge gaps, the BfS organized an international workshop on environmental effects of EMFs in 2019. Research needs concerning insects were identified and field studies recommended [4, 5]. Insects, especially pollinators, are declining worldwide. Many influencing factors, such as climate change, loss of suitable habitats, herbicides, pesticides, parasites, and diseases are currently being investigated. Less attention is paid to possible effects of EMFs. In contrast to the factors mentioned above, there is only limited scientific evidence on the effects of EMFs on insects.

2 Results and conclusions from the authors‘ perspective

The present systematic review and meta-analysis summarizes the available published information on biological effects of EMFs on insects [1]. The authors followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [6]. They searched the databases EMF-Portal, Google Scholar and PubMed for the years 2012 – 2020 and included experimental field and laboratory studies that were published in English or German after 1980. Studies investigating exposure levels below the ICNIRP exposure limit recommendations were included, and studies on the magnetic sense of insects were excluded. After removing duplicates, a total of 587 publications were identified. The authors assessed the

study quality according to a published set of review criteria for research manuscripts [7] and excluded studies that didn't meet certain criteria (e.g., lack of EMF measurements). After applying the exclusion and quality criteria, 119 studies were included in the systematic review, 64 considering low frequency (LF) and 55 considering high frequency (HF) EMFs. Most of the experiments were performed in fruit flies (47.4%) and honey bees (31.4%). LF-EMF exposure sources were mainly coil systems and power lines, while HF-EMF exposure sources were mainly mobile phones, signal generators and base stations. Studies on LF-EMFs focused on change in behaviour as an endpoint, whereas studies on HF-EMFs focused on reproduction. Data from 53% of the reported experiments (from 39% of the included studies) were included in meta-analyses. Meta-analyses were performed separately for different exposure sources (base stations, mobile phones, DECT phones, signal generators, coil systems). For each exposure source, all biological endpoints were combined into an overall assessment of toxicity. Statistically significant negative effects were found for mobile phones, DECT phones, signal generators and coil systems, but not for base stations. According to the authors, this is probably due to the lower exposure level in studies investigating HF-EMFs of base stations. The authors calculated a statistically significant effect size of 1.5 for the overall toxicity of exposure to mobile devices. For reproductive effects of HF fields in fruit flies, an organism- and endpoint-specific meta-analysis was performed and stratified into three exposure levels, and the authors reported that the reproductive toxicity in fruit flies increased with increasing field strength.

Overall, the authors conclude that the majority of experimental laboratory and field studies report predominantly adverse effects and that non-thermal effects of EMFs on insects are thus clearly demonstrated in the laboratory, but only partially in the field, with exposure to HF-EMFs being more harmful than exposure to LF-EMFs.

3 Comments by the BfS

The authors stated to have performed a systematic review according to PRISMA guidelines [6]. These guidelines state that registration of the review protocol prior to conducting the review aims to reduce bias, increase transparency, facilitate scrutiny and improve the trustworthiness of systematic reviews. However, in the present publication [1] there is no information about a registration or a published protocol. In addition, the published study itself provides only a rather vague description of the review objectives, methods and rationale, which prevents an independent replication and a critical assessment of the validity of the approach.

For example, the rationale for choosing the ratio of means metric (ROM) as a common effect size estimate is not explained and it is also not clear which reference condition was used for the calculation, as no comparator was specified in the review objectives.

Study quality was assessed using published review criteria for research manuscripts [7]. However, these criteria were not developed for systematic reviews but as a guideline for the review of manuscripts submitted for publication. Furthermore, this quality assessment was only used to exclude studies and was not systematically used for weighting the evidence or deriving conclusions. For systematic reviews, the PRISMA guidelines recommend to assess the various risks of bias (RoB) of studies [6]. Such an evaluation was not performed and important quality aspects like randomization, blinding, and the quality of exposure generation and assessment [8] were not considered in the study quality assessment. Due to the lack of critical appraisal of study quality, the conclusion of the authors might be based on scientifically not very reliable evidence.

A total of nine meta-analyses were performed. One meta-analysis was conducted for LF-EMFs generated by Helmholtz coils, and all other meta-analyses focused on HF-EMFs from various sources. For each exposure source, all results for very different endpoints (e.g., reproductive outcomes, behaviour, DNA damage) were combined in one meta-analysis. The rationale for combining data from different species and for different outcomes instead of evaluating them separately (as was done for fruit fly reproduction only) is not

explained. The statistical measure of heterogeneity in the meta-analyses presented ranged from 64% to 99%, indicating substantial to considerable heterogeneity in the data [8]. A pooled evaluation of studies despite existing heterogeneity between the studies makes the reliability of the results of the meta-analyses questionable.

Furthermore, in several cases more than one result for a certain outcome from the same study was included in a meta-analysis (e.g., different exposure levels or durations) and it remains unclear whether these data refer to shared control groups or not. Therefore, it cannot be excluded that the data are not statistically independent and that the meta-analysis result is driven by highly correlated data.

In addition, the high proportion of statistically significant asymmetric funnel plots indicates a high risk of publication bias which describes the well-known phenomenon that study results showing effects are much more likely to be published than study results that point to no effect [8]. The risk of publication bias may have affected the results of the meta-analyses, but this was not addressed in the discussion and conclusion.

All these aspects need to be considered when assessing the certainty of the scientific evidence on the effects of EMFs on insects. However, the authors did not perform such an evaluation, although it is recommended to do so before drawing conclusions. According to the “Grading of Recommendations Assessment, Development, and Evaluation” guideline [9], low study quality, inconsistent study results, and evidence of publication bias, as well as other factors, reduce the certainty of the evidence. Therefore, the certainty of evidence of the published conclusions of this systematic review and meta-analyses is low.

The result that most studies show negative effects of EMFs on insects is consistent with results of several recent reports, showing either no effects or negative effects of EMFs on insects [10, 11, 12]. However, these reports also document the very low quality and large heterogeneity of the individual included studies, which does not currently allow reliable statements to be made on the effects of EMFs on insects [10, 11, 12].

The lack of critical assessment of the certainty of the evidence may be the reason why the authors of the present review overinterpret the results regarding harmful effects of EMF exposure on insects and why their conclusion is in contrast to the conclusions of the other recent reviews: A report commissioned by the European Parliament [10] concludes that several studies on the effects of radiofrequency EMF exposure on invertebrates have experimental shortcomings. Another report commissioned by the Swiss radiation protection authority [11] summarized the state of knowledge on the effects of EMFs on arthropods. The authors were able to identify potential mainly negative effects on behaviour, metabolism, cell stress, reproduction, and DNA damage, but the quality of the studies was mostly insufficient, in particular due to technically inadequate or statistically biased experimental designs and protocols. A recent systematic map study [12] summarized the available evidence on the effects of anthropogenic RF-EMFs on animals and plants in the environment. The majority of the studies identified were experimental studies. The endpoints of most of the animal studies were reproduction, behaviour, and development and most studies had methodological shortcomings.

In the view of the BfS, the present review [1] has too many serious methodological shortcomings to contribute substantially to the body of evidence regarding potentially harmful effects of EMFs on insects.

References

[1] Thill A, Cammaerts MC, Balmori A. Biological effects of electromagnetic fields on insects: a systematic review and meta-analysis. *Rev Environ Health*. Published online November 23, 2023. doi:10.1515/reveh-2023-0072

[2] International Commission on Non-Ionizing Radiation Protection (ICNIRP). Guidelines for limiting exposure to time-varying electric and magnetic fields (1 Hz to 100 kHz) [published correction appears in Health Phys. 2011 Jan;100(1):112]. *Health Phys*. 2010;99(6):818-836. doi:10.1097/HP.0b013e3181f06c86

[3] International Commission on Non-Ionizing Radiation Protection (ICNIRP). Guidelines for Limiting Exposure to Electromagnetic Fields (100 kHz to 300 GHz). *Health Phys*. 2020;118(5):483-524. doi:10.1097/HP.0000000000001210

[4] Pophof B, Henschenmacher B, Kattnig DR, Kuhne J, Vian A, Ziegelberger G. Biological Effects of Electric, Magnetic, and Electromagnetic Fields from 0 to 100 MHz on Fauna and Flora: Workshop Report. *Health Phys*. 2023;124(1):39-52. doi:10.1097/HP.0000000000001624

[5] Pophof B, Henschenmacher B, Kattnig DR, Kuhne J, Vian A, Ziegelberger G. Biological Effects of Radiofrequency Electromagnetic Fields above 100 MHz on Fauna and Flora: Workshop Report. *Health Phys*. 2023;124(1):31-38. doi:10.1097/HP.0000000000001625

[6] Page MJ, Moher D, Bossuyt PM, et al. PRISMA 2020 explanation and elaboration: updated guidance and exemplars for reporting systematic reviews. *BMJ*. 2021; 372:n160. Published 2021 Mar 29. doi:10.1136/bmj.n160

[7] Bordage G, Caelleigh AS, Steinecke A, et al. Review criteria for research manuscripts. *Acad Med*. 2001;76(9):897-978.

[8] Higgins JPT, Thomas J, Chandler J, Cumpston M, Li T, Page MJ, Welch VA. eds. Cochrane Handbook for Systematic Reviews of Interventions, version 6.4 (updated August 2023): Cochrane; 2023

[9] Guyatt GH, Oxman AD, Schunemann HJ, Tugwell P, Knottnerus A. GRADE guidelines: a new series of articles in the Journal of Clinical Epidemiology. *J Clin Epidemiol* 2011; 64(4), 380-382. https://doi.org/10.1016/j.jclinepi.2010.09.011

[10] Thielens A. Environmental impacts of 5G. A literature review of effects of radio-frequency electromagnetic field exposure of non-human vertebrates, invertebrates and plants. STOA, European Parliament 2021

[11] Mulot M., Kroeber T., Gossner M., Fröhlich J. Wirkung von nichtionisierender Strahlung (NIS) auf Arthropoden, Bericht im Auftrag des Bundesamts für Umwelt (BAFU), Neuenburg, Juli 2022.

[12] Karipidis K, Brzozek C, Mate R, Bhatt CR, Loughran S, Wood AW. What evidence exists on the impact of anthropogenic radiofrequency electromagnetic fields on animals and plants in the environment: A systematic map. *Environmental Evidence*. 2023, 12(1). https://doi.org/10.1186/s13750-023-00304-3

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Bundesamt für Strahlenschutz
Postfach 10 01 49
38201 Salzgitter

Tel.: +49 30 18333-0
Fax: +49 30 18333-1885
E-Mail: spotlight@bfs.de
De-Mail: epost@bfs.de-mail.de

www.bfs.de

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