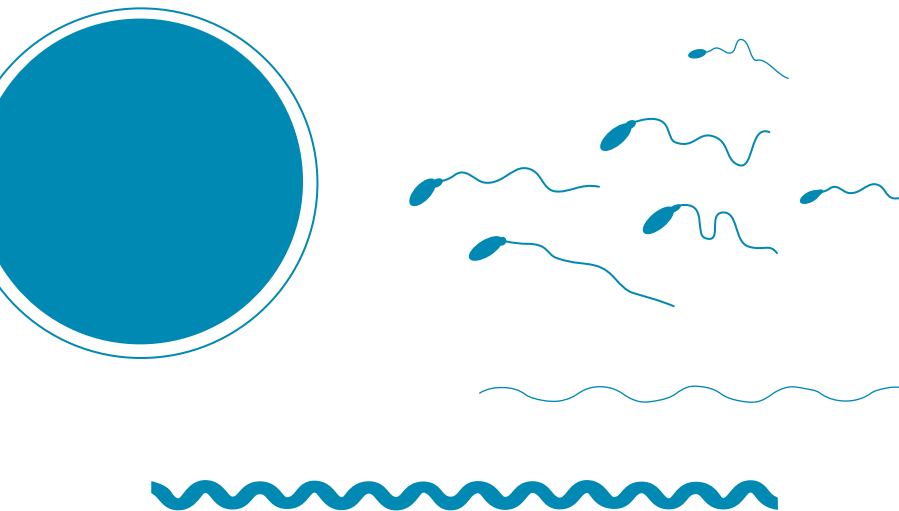


# ElektrosmogReport

Technical information on the significance of electromagnetic fields for the environment and health.



## Wi-Fi causes degenerative changes in the testes

### Histomorphometry and sperm quality in male rats exposed to 2.45 GHz Wi-Fi

Vijay S, Ibrahim SF, Osman K, Zulkefli AF, Ros MFM, Jamaludin N, Taha SMAS, Hairulazam A, Jaffar FHF (2025). Histomorphometry and sperm quality in male rats exposed to 2.45 GHz Wi-Fi. Reproduction, 169(5). <https://doi.org/10.1530/REP-25-0048>

The widespread use of Wi-Fi raises questions about its potential health effects. Male fertility is a particular focus because an increasing number of studies suggest that exposure to radiofrequency radiation from cellular or Wi-Fi networks causes impairment. This study uses a rat model to investigate the impact of 2.45 GHz Wi-Fi radiation on male fertility.

#### Study design and implementation:

Eighteen male Sprague Dawley rats were randomly assigned to three groups of 6 rats each: sham-exposed, exposed 4 h per day, and exposed 24 h per day. Exposure lasted 8 weeks. A commercial Wi-Fi router positioned 20 cm from the cages served as the radiation source. Based on the router's maximum power density ( $0.141 \text{ W/m}^2$ ), the authors calculated a whole-body SAR of  $0.41 \text{ W/kg}$  for the rats. After exposure, the testes, epididymides, seminal vesicles, seminiferous tubules, and coagulating glands were examined histologically. In addition, spermatogenesis was semi-quantitatively assessed (Johnson score), and sperm parameters (concentration, motility, and vitality) were quantitatively analyzed.

#### Imprint

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**Results:**

Macroscopically, there were only minor differences between the control group and the exposed groups. However, the seminal vesicles were significantly enlarged after a 4-hour daily exposure. The exposed groups showed histological changes, including interstitial edema in the testicular tubules, vacuolization of the epididymal epithelium, and hyperplasia of the seminal vesicles. No alterations were found in the coagulating glands. Continuous 24-hour exposure led to a statistically significant reduction in seminiferous tubule diameter. The Johnson score decreased significantly in both exposed groups compared to the control group. Sperm concentration also declined significantly in a dose-dependent manner. Motility decreased significantly in the 4-hour group, but recovered to control levels in the 24-hour group. Surprisingly, sperm vitality increased significantly in the 24-hour group.

**Conclusions:**

Microscopic findings indicate degenerative alterations to the male reproductive organs caused by Wi-Fi exposure. These structural changes impair spermatogenesis and sperm maturation. According to the authors, these findings suggest that 2.45 GHz Wi-Fi radiation may pose a risk to male fertility. However, the paradoxical increase in sperm vitality and recovery of motility under continuous daily exposure indicates the activation of compensatory processes.

**Editor's note:**

The study's validity is supported by its realistic exposure scenario, which employed a commercial Wi-Fi router within the sub-thermal range, and its examination of a wide array of tissues. The 8-week exposure period covered several full spermatogenesis cycles, which is another positive aspect of the study's methodology. Unfortunately, no biochemical analyses were conducted (e.g. oxidative stress or DNA damage), which could have illuminated the underlying mechanisms and supported the morphological findings. Overall, this study contributes to the growing body of evidence indicating that radiofrequency radiation poses a serious risk to male fertility (Jamaludin et al., 2025; Maluin et al., 2024; Kaur et al., 2023). (RH)

Jamaludin N, Ibrahim SF, Jaffar FHF, Zulkefli AF, Osman K (2025). The Influence of 2.45 GHz Wi-Fi Exposure Duration on Sperm Quality and Testicular Histopathology: An Exploration of Peroxidative Injury. *Antioxidants*, 14(2), 179. <https://doi.org/10.3390/antiox14020179>

Kaur P, Rai U, Singh R (2023). Genotoxic Risks to Male Reproductive Health from Radiofrequency Radiation. *Cells*, 12(4), 1–20. <https://doi.org/10.3390/cells12040594>

Maluin SM, Jaffar FHF, Osman K, Zulkefli AF, Mat Ros MF, Ibrahim SF (2024). Exploring edible bird nest's potential in mitigating Wi-Fi's impact on male reproductive health. *Reproductive Medicine and Biology*, 23(1), 1–13. <https://doi.org/10.1002/rmb2.12606>

**Mobile phone & Wi-Fi exposure impair sperm****Does electromagnetic pollution in the ART laboratory affect sperm quality? A cross-sectional observational study**

Baldini GM, Lot D, Ferri D, Montano L, Tartagni MV, Malvasi A, Laganà AS, Palumbo M, Baldini D, Trojano G (2025). Does Electromagnetic Pollution in the ART Laboratory Affect Sperm Quality? A Cross-Sectional Observational Study. *Toxics*, 13(6), 510. <https://doi.org/10.3390/toxics13060510>

In recent years, the widespread use of mobile communication devices has raised questions about their potential impact on male fertility. These devices are also present in in vitro fertilization (IVF) laboratories, raising concerns about their potential impact on reproductive health, particularly sperm quality. There is ongoing scientific debate about this issue. It is important to note that many other electronic devices used in these laboratories also emit electromagnetic fields. This cross-sectional observational study examined the effects of different electromagnetic sources on the progressive motility of human sperm *in vitro*.

**Study design and implementation:**

From a pool of 487 candidates, researchers selected 102 healthy men between 20 and 35 years of age according to strict inclusion criteria, which included a review of genital history, a Doppler ultrasound of the scrotum, a negative sperm culture, and normal hormonal test results. After an initial seminogram, the researchers divided each participant's semen sample into seven aliquots. Six of these samples were exposed to common electromagnetic field (EMF) sources present in fertilization laboratories: (1) a PC monitor, (2) a time-lapse incubator, (3) an iPhone 12, (4) a Wi-Fi repeater, (5) an inverted microscope, and (6) a laptop. The remaining aliquot served as the unexposed control. The samples were placed 10 cm from each EMF source for one hour. Field strength was measured in mV/m. The mobile phone (peak 1,610.6 mV/m, mean 295 mV/m) and Wi-Fi repeater (peak 4,259.2 mV/m, mean 241.5 mV/m) generated the strongest fields. For the motility assessment (progressive, non-progressive, and immotile), the other exposed groups (PC monitor, inverted microscope, time-lapse incubator, and laptop) served as controls.

**Results:**

The average baseline motility in the unexposed samples was 45.1% progressive, 16.4% non-progressive, and 38.7% immotile sperm. Compared with the other exposed groups, progressive motility decreased significantly after exposure to the mobile phone and Wi-Fi repeater. The reduction amounted to 19.5%. Conversely, the proportion of non-progressive sperm increased by 9%, while the proportion of immotile sperm increased by 10%. Both changes were statistically significant.

**Conclusions:**

The data suggest that electromagnetic fields from standard laboratory equipment do not significantly impair sperm motility. By contrast, wireless communication devices, specifically the iPhone 12 and a Ubiquiti UniFi 6 Wi-Fi repeater, significantly reduced motility. The decline in progressively motile (and thus fertile) sperm was nearly 20%. The authors note that potential confounders (e.g. lifestyle and genetic factors) were not controlled for in the regression analysis. In addition, the measurement system could only detect fields between 50 MHz and 3.5 GHz. Therefore, the intensity of the Wi-Fi repeater, which also operates at 5 GHz, may have been underestimated. Based on these findings, the authors strongly recommend excluding mobile phones and Wi-Fi devices from fertilization laboratories.

**Editor's note:**

A high-quality dataset was obtained through a systematic study design, stringent participant screening, standardized exposure conditions (uniform distance and temperature control), and an adequate sample size ( $n = 102$ ). Since the tested Wi-Fi repeater was a commercial product, underestimation of field intensity is not a significant concern. Therefore, the authors' recommendation to handle biological material only in the absence of mobile phones and Wi-Fi devices is appropriate and prudent. Although this was an *in vitro* study, the possible implications for the general population should not be underestimated. (RH)

**Laptops/tablets and male fertility**

## **The use of laptops and tablets and their influence on the total number of motile sperm: Is there an association between laptops and infertility in Jamaican men?**

Sterling L, Carroll K, Harris LR (2024). Laptop and tablet use and their influence on total motile sperm count parameters: are laptops linked to infertility in Jamaican men? *Rev Int Androl.* 2024 Dec 1;22(4):25-32. <http://doi.org/10.22514/j.androl.2024.027>

Infertility is defined as the inability to conceive after one year of unprotected intercourse. It is estimated that 20% of couples of reproductive age worldwide are affected by infertility, half of whom are affected by male infertility. Wi-Fi has become ubiquitous and is used in a wide range of devices. These devices emit signals that are absorbed by the human body and are thought to have harmful effects on the male reproductive system. Compared to other commonly used wireless devices, laptops and tablets are used closer to the male reproductive sys-

tem. The authors investigated the association between total motile sperm count (TMSC), a good predictor of male fertility, and laptop and tablet use in Jamaican men who underwent infertility evaluation.

**Study design and implementation:**

A total of 156 participants provided written informed consent and were included in the study. Men with a self-reported medical history of conditions known to affect sperm quality were excluded from the study. These conditions included previous diagnoses of mumps, undescended testicles, varicocele/varicocele repair, and certain diagnosed sexually transmitted diseases. Data were collected between February 2020 and July 2021. The 25-item wireless device use questionnaire, was designed by the principal investigators (an embryologist and a wireless communication engineer) to capture the frequency of laptop and tablet use. Semen analyses were performed according to the guidelines established by the World Health Organization. Semen analyses were performed without prior knowledge of wireless device use. The primary independent variable of interest was a measurable indicator of the frequency of laptop and tablet use. Laptop and tablet use were both categorized into three groups: low use ( $< 2$  h/day), medium use (2–5 h/day), and high use ( $> 5$  h/day). Other independent variables included in the statistical analyses were age, duration of attempts to become pregnant, previous pregnancies, and recreational drug use. Unadjusted and adjusted analyses of total motile sperm count (TMSC) and associated parameters (semen volume, sperm count, and sperm motility) were performed for indices of laptop and tablet use and previously selected confounders. All analyses were performed using SPSS.

**Results:**

Of the 156 participants who gave consent, 68% were younger than 40 years old. Their ages ranged from 22 to 60 years old (mean = 37.21, standard deviation = 7.27). Most subjects were of normal weight and consumed alcohol; only a few reported using drugs in their free time. Laptop and tablet users accounted for 64% ( $n = 100$ ) and 36% ( $n = 57$ ) of participants, respectively. Most participants reported using their laptops and tablets at a desk (73% and 78%, respectively). Participants who reported high laptop use were more likely to have been trying to conceive for one or more years and were more likely to be younger ( $< 40$  years).

The only statistically significant difference was between participants with normal versus abnormal semen volume and those who reported 2 hours or more of laptop use per day, which corresponds to medium and high use. The only semen parameter associated with device use was volume. Unadjusted logistic regression analyses showed that medium laptop use was approximately 16 times more likely to result in low semen volume than non-use ( $p = 0.004$ ). A significant correlation was also

found between high laptop use and TMSC score ( $p = 0.052$ ). The observation that laptop use is related to low semen volume, a TMSC parameter, is of great clinical significance.

### Conclusions:

The study found that frequent laptop use was associated with decreased semen volume in men seeking fertility evaluation. Users who spent 2 to 5 hours per day on their laptops were approximately 16 times more likely to be diagnosed with low semen volume. Although both laptops and tablets emit radio-frequency electromagnetic radiation (RF-EMR), the relative size and proximity of their Wi-Fi antennas to organs and tissues may lead to different distributions and absorptions of RF-EMR. Tablets are typically held farther away from the lap and reproductive organs than laptops, which may result in less RF-EMR exposure to the testes. This difference in positioning may explain why the effects of tablet use on TMSC are less significant.

Future studies are needed to determine what constitutes "safe" distances for operating wireless devices and to distinguish between RF-EMR-specific thermal and non-thermal effects on sperm parameters. However, since most participants reported using their laptops on a desk rather than on their lap, the likelihood of non-thermal RF-EMR exposure is (significantly) greater than that of thermal effects. The finding that increased laptop use correlates with a reduction in semen volume is concerning.

Secretions from the seminal vesicles and prostate account for approximately 90% of semen volume. Animal studies have shown significant pathological changes in the seminal vesicles after exposure to Wi-Fi radiation. Although the association between increased laptop use and TMSC was only nearly significant, it may have reached significance with a larger sample size. Several reports show that African-Caribbean men, particularly Jamaican men, respond differently to certain external factors. This results in an unusually high incidence of prostate cancer compared to the global rate. Overall, these findings underscore the need for further culturally relevant studies. Of particular concern is the finding of an association between increased laptop use and longer times to conceive.

The authors suggest adding screening for wireless device use to the standard procedure when screening men for infertility. In particular, men in the medium and high use groups should be advised to take protective measures to minimize the risk of excessive EMR exposure from these devices. Some limitations of the study design should be noted. The results may not be generalizable to the entire male population because the study focused exclusively on Jamaican men undergoing infertility screening. In addition, RF-EMR emissions were estimated based on the participants' reported level of use rather than measured during the analysis. (AT)



### Mobile devices and prostate cancer

## Use of mobile and cordless phones and the association with prostate cancer

Hardell L, Carlberg M. Use of Mobile and Cordless Phones and the Association with Prostate Cancer (2025). *Fortune Journal of Health Sciences*. 2025;8:267-73. <https://doi.org/10.26502/fjhs.272>

In this article, Hardell and Carlberg present evidence of an association between radiofrequency (RF) radiation exposure and an increased risk of prostate cancer. This evidence is based on two previous case-control studies. The first study examined the link between the use of mobile and cordless phones and the development of malignant brain tumors in deceased patients; deceased individuals served as the control group. The second study investigated the association between perfluoroalkyl substances (PFAS), environmental contaminants, and prostate cancer. During the study period from 2007 to 2011, an increased risk of certain PFAS was found in the case group. Heredity was also identified as a risk factor for prostate cancer. Cell phone use was also examined. Prostate cancer is the most common malignancy in Sweden, accounting for 30.9% of all cancers in men with 12,066 new cases in 2022. The risk factors are numerous and heterogeneous. These include genetic, inflammatory, infectious, hormone-related, dietary, age-related, and ethnic factors that contribute to prostate cancer susceptibility.

### Study design and implementation:

The first study included patients with histopathologically confirmed brain tumors diagnosed between 1997 and 2003. All patients were deceased. The control group was drawn from the Swedish death registry. The present study was based on individuals in the control group who died of prostate cancer and individuals who died of diseases other than cancer (defined as controls in this study). This study included the use of analog 1G and digital 2G mobile phones, as well as DECT cordless phones. The control group consisted of 619 deceased individuals. Of those, 51 had died of prostate cancer.

The second study looked at patients with prostate cancer, who were admitted to the Department of Oncology at Örebro University Hospital in Sweden between 2007 and 2011 and recruited for a study on persistent organic pollutants. The patients were asked to provide a blood sample for chemical analysis. Blood was drawn before treatment with cytostatics or radiotherapy.

This new analysis builds on two epidemiological studies and includes 51 subjects from Study I and 202 subjects from Study II with prostate cancer, for a total of 253 subjects. The control group includes 150 subjects from Study I and 186 subjects from Study II, for a total of 336 control subjects.

Exposure was determined using a questionnaire sent by mail to each patient or their next of kin. A similar questionnaire was used in both studies. Regarding mobile or cordless phone use, respondents were asked about their average daily use (minutes per day) and the duration of their cordless phone use. Since mobile phones were first introduced, technology has changed; therefore, the questionnaire was designed to collect information on all devices, including analog mobile phones (1G), digital mobile phones (2G and 3G), DECT cordless phones, and other cordless phones.

StataSE 12.1 was used to calculate odds ratios (OR) and 95% confidence intervals (CI). Subjects who reported not using mobile or cordless phones formed the control group. Latency was defined as the number of years from when the subject first used a mobile phone to when the subject was diagnosed. The cumulative number of hours of use was calculated. Latency was analyzed using time periods of > 1–5 years, > 5–10 years, and > 10 years. Cumulative use of different phone types was analyzed in three categories: 1–1,000 hours, 1,001–2,000 hours, and > 2,000 hours.

### Results:

In the pooled analysis of both studies, mobile phone use was associated with an OR = 1.8 [1.01–3.1]. The highest risk was found in the group with the longest latency: > 10 years, resulting in an OR = 2.8 [1.5–5.3]. Similar results were found for analog and digital mobile phones, as well as for cordless phones overall. Using DECT cordless phones was also associated with an increased risk, though not by a statistically significant amount.

A statistically significant increased risk was found in the group with more than 2,000 hours of total mobile phone use, with an OR = 2.4 [1.2–5.1]. The highest risk for total cordless phone use was found in the group > 2,000 h, with an OR = 2.2 [1.1–4.3].

The classification of prostate cancer showed no increased risk for Gleason grades 2–6. (The Gleason score predicts the prognosis of prostate cancer based on histological findings.) For Gleason grades 7–10, increased ORs were found for all types of cordless phones, with an OR = 2.0 [0.7–6.0]. A separate analysis of mobile phones and DECT cordless phones yielded similar results. The highest OR for prostate-specific antigen (PSA), a marker of prostate inflammation, was also found in the group with the most aggressive tumor. Thus, PSA > 10 for mobile phone use resulted in an OR = 2.5 [0.7–8.9]. The cases were further subdivided into groups of low risk, intermediate risk, and high risk based on PSA and Gleason scores. Mobile phone or DECT cordless phone use was not associated with low-risk prostate cancer. Increased ORs were calculated for intermediate- and high-risk prostate cancer.

Heredity and mobile phone use were associated with an increased risk of borderline statistical significance, with an OR = 2.8 [0.98–7.8]. The highest risks were found in patients with a hereditary predisposition to prostate cancer.

### Conclusions:

The main finding of this study is that mobile phone use is associated with an increased risk of prostate cancer. This risk increased with latency, reaching its highest point at a latency of more than 10 years. The literature on RF radiation and prostate cancer is sparse. The results of this study are supported by data from the UK Biobank Study (Zhang et al., 2024). A statistically significant increased risk of prostate cancer was found, with a hazard ratio (HR) = 1.19 [1.13–1.25]. The highest risk was observed for mobile phone use of more than 8 years, with a statistically significant trend ( $p < 0.001$ ). The NTP study also supports an increased risk of prostate neoplasia. In summary, the present study found an increased risk of prostate cancer associated with mobile or cordless phone use. This risk increased with latency and cumulative hours of use. In addition, the risk was highest in cases of more aggressive cancer, as determined by Gleason score, PSA, and high-risk profile. (AT)

Zhang Y, Zhang Y, Ye Z, Yang S, Liu M, Wu Q et al. (2025). Mobile phone use and risks of overall and 25 site-specific cancers: a prospective study from the UK Biobank study. *Cancer Epidemiology, Biomarkers & Prevention*. 2024 Jan 9;33(1):88-95.



### A WHO study confirms the carcinogenic effects of RF Effects of radiofrequency electromagnetic field exposure on cancer in laboratory animal studies, a systematic review

Mevissen M, Ducray A, Ward JM, Kopp-Schneider A, McNamee JP, Wood AW, Rivero TM, Straif K (2025). Effects of radiofrequency electromagnetic field exposure on cancer in laboratory animal studies, a systematic review. In *Environment International* (Vol. 199, Issue February 2024). <https://doi.org/10.1016/j.envint.2025.109482>

As exposure to mobile phones, Wi-Fi, and other wireless communication applications increases, the question of whether radiofrequency (RF) fields are carcinogenic to humans becomes highly relevant. The International Agency for Research on Cancer (IARC) currently classifies radiofrequency electromagnetic fields as “possibly carcinogenic” (2011) based on limited evidence from human and animal studies. For this review, the animal data are particularly pertinent. The IARC rationale is summarized in its preamble as follows: “The data indicate a carcinogenic effect, but are insufficient for a definitive evaluation because, for example, (b) unresolved questions remain concerning the adequacy of the design, conduct or analyses of the studies.” Since the IARC evaluation, many studies have been published, necessitating an updated assessment. This WHO-co-funded review

aims to systematically assess the quality of experimental animal studies that address increased cancer incidence and rate the evidence using GRADE/OHAT.

### Study design and implementation:

The authors conducted a comprehensive literature review up to July 2023 using MEDLINE, Web of Science, and the EMF Portal. They included chronic carcinogenicity bioassays (standardized long-term rodent studies,  $n = 10$ ), initiation/promotion models (additional administration of a tumor initiator or promoter,  $n = 24$ ), and experiments with tumor-prone strains ( $n = 18$ ), provided that exposure was quantified by SAR values or field strengths. Selection followed pre-published PECOS criteria, and data extraction was performed in HAWC. The OHAT RoB tool was used for risk of bias analysis, and GRADE was used to evaluate the quality of the evidence. Due to their high evidentiary value, chronic carcinogenicity bioassays were given special weight. Only endpoints (tumor types) confirmed in carcinogenicity bioassays could achieve a “high” evidence rating. A total of 52 primary studies published between 1978 and 2020 were included in this review.

### Results:

Compared with their respective controls, no indications of an increased cancer risk associated with mobile phone RF exposure were observed for most organ systems. Organ systems in which at least one study reported exposure-related effects were analyzed in detail. These included the lymphatic system, brain, heart, adrenal glands, liver, and lungs. A statistically and methodologically robust increase in tumor incidence attributable to RF exposure was found with high confidence in the heart (malignant schwannomas) and brain (malignant gliomas). The analysis also identified an increased tumor incidence with moderate confidence in the lymphatic system (malignant lymphomas), liver (hepatoblastomas), lungs (bronchioalveolar neoplasms), and adrenal glands (pheochromocytomas). However, a quantitative meta-analysis could not be performed due to the insufficient number of studies with sufficiently similar experimental designs.

### Conclusions:

In general, robust evidence of carcinogenic potential in animal models is relevant for identifying carcinogenic hazards to humans. Although extrapolating cancer bioassays to humans in the context of mobile phone exposure is complex, bioassays remain the best available tool for identifying hazards. This is partly because solid tumors in humans have such long latencies that epidemiological studies only become informative after technologies have been in widespread use for 10, 20, or more years.

### Editor's note:

The review's data clearly indicate a carcinogenic effect of

radiofrequency (RF) exposure from mobile phones in animal models. As noted above, these models are the best available means of assessing cancer risk in humans. In this context, the authors call for adapting the GRADE/OHAT criteria for animal studies. For instance, they argue that blinding prior to study initiation is irrelevant and that greater heterogeneity among animal models (e.g. inbred strains, outbred strains, and genetically heterogeneous models) is to be expected. This would explain many apparent irregularities, rendering it unnecessary to downgrade the quality of the evidence for multiple studies. The two studies chiefly supporting the high-confidence evidence of an increased cancer risk were published in 2018 (Falcioni et al., 2018; National Toxicology Program, 2018) and discussed in the ElektrosmogReport (June 2019), among others. In the Falcioni study, whole-body exposure was applied with SAR values between 0.001 and 0.1 W/kg, similar to human exposure levels. Despite having access to these data for about seven years, regulatory decision-makers have not taken any consequential action to date. Given the global implications for human health, the authors consider this omission negligent. (RH)

Falcioni L, Bua L, Tibaldi E, Lauriola M (2018). Report of Final Results Regarding Brain and Heart Tumours in Sprague-Dawley Rats Exposed from Prenatal Life until Natural Death to Mobile Phone Radiofrequency Field Representative of a 1.8 GHz GSM Base Station Environmental Emission. *Environmental Research*, 165, 496–503. <https://doi.org/10.1016/j.envres.2018.01.037>

National Toxicology Program (2018). Toxicology and carcinogenesis studies in Sprague Dawley (Hsd:Sprague Dawley SD) rats exposed to whole-body radio frequency radiation at a frequency (900 MHz) and modulations (GSM and CDMA) used by cell phones. *National Toxicology Program Technical Report Series*, 595. <https://doi.org/10.22427/NTP-TR-595>

### Mobile phone base stations and non-specific health symptoms

## Greater prevalence of symptoms associated with higher exposures to mobile phone base stations in a hilly, densely populated city in Mizoram, India

Sailo L, Laldinpuii, Zosangzuali M, Weller S, Varte CL, Tochwawng L, McCredde JE, Zothansiam (2025). Greater prevalence of symptoms associated with higher exposures to mobile phone base stations in a hilly, densely populated city in Mizoram, India. *Electromagnetic Biology and Medicine*, 00(00), 1–20. <https://doi.org/10.1080/15368378.2025.2513900>

Recently, potential adverse health effects of mobile phone base stations (MPBS) have been reported (Gulati et al., 2024;

see ElektrosmogReport 03/24, editor's note). The present study investigates the prevalence of non-specific health symptoms in relation to exposure from MPBS and the proximity of residences to these installations. The study is based on reports of an increased frequency of headaches, sleep disturbances, difficulty concentrating, low mood and related complaints following the installation of MPBS. The study was conducted from 2023 to 2024 in the hilly city of Aizawl, in the Indian state of Mizoram.

### Study design and implementation:

The authors selected 30 mobile phone base stations, 20 of which operated at 900 MHz and 10 of which operated at 1800 MHz. They recruited a total of 183 highly exposed residents (living within 300 m of a MPBS) and 126 reference residents (living more than 400 m away). The two groups were matched demographically, including lifestyle variables such as alcohol and tobacco use, as well as mobile phone use. Dosimetric measurements of RF power density were performed in 103 households, mainly in living rooms. The measured values ranged from 0.01 to 7.24 mW/m<sup>2</sup>, far below the ICNIRP reference levels for MPBS (4,500 mW/m<sup>2</sup> for 900 MHz; 9,200 mW/m<sup>2</sup> for 1800 MHz). Participants were categorized by their distance from the nearest base station (1–50 m, 51–300 m, > 400 m) and by their measured power density (0–3 mW/m<sup>2</sup>, 3–5 mW/m<sup>2</sup>, 5–8 mW/m<sup>2</sup>). Symptoms were grouped into four categories: (1) mood/energy-related, (2) cognitive/sensory, (3) inflammatory, and (4) anatomical. Data were collected via questionnaire. A four-level severity scale had been planned, but responses were dichotomized (yes/no) since most participants were unable to provide more graded information. The data underwent extensive statistical analysis.

### Results:

Statistically significant correlations were found between exposure intensity and the prevalence of symptoms (e.g. anxiety disorders, headaches, chest pain, sleep disturbances, difficulty concentrating, and digestive problems) for all four symptom categories. As expected, a strong negative correlation was documented between distance to MPBS and measured power density, that is, mean field strength decreased with increasing distance. However, due to overlapping factors, such as limited line of sight, topography, and buildings, measured power density was found to correlate more strongly with symptom prevalence than distance alone (hierarchical regression analysis). Demographic and lifestyle variables had no significant effect on symptom frequency except for age; participants over 40 reported significantly more anatomical complaints. Remarkably, younger participants (under 40 years of age) in the higher exposure groups reported significantly more inflammatory symptoms, such as allergies and increased infections.

### Conclusions:

Although the maximum measured power density was only 7.2 mW/m<sup>2</sup> (well below the ICNIRP limits of 4,500 and 9,200 mW/m<sup>2</sup>), residents of Aizawl with higher exposures reported significantly more non-specific health symptoms. These symptoms correlated with measured field strengths in a clear dose-response relationship. Of particular concern is the finding that mobile phone base stations may promote inflammatory processes in younger individuals, a phenomenon warranting further investigation. The authors argue that the ICNIRP limits, averaged over 5 or 30 minutes, do not adequately account for cumulative doses in real-world exposure scenarios.

### Editor's note:

The study benefits from real-world exposure measurements, consideration of lifestyle factors, and an extensive statistical evaluation. However, several limitations must be noted. Symptom data were self-reported and dichotomized, making them vulnerable to perception and recall bias. Information bias cannot be excluded since the assistants were not blinded with respect to exposure status (distance to MPBS). However interaction during questionnaire completion was minimized. In addition, group sizes between the exposed and reference participants were unequal, and the overall sample size is relatively small for epidemiological research. Unfortunately, there is an absence of biological markers or clinical examinations, especially given the finding of increased inflammatory complaints among younger participants. Such data could have helped establish causal links, as was achieved in the ATHEM-3 study (Gulati et al., 2024). Despite these limitations, the detailed statistical approach makes the study relevant. However, modifications to the study design would have been desirable. However, the same working group has already presented studies in which these requirements are realised. (RH)

- (1) Gulati S, Mosgoeller W, Moldan D, Kosik P, Durdik M, Jakl L, Skorvaga M, Markova E, Kochanova D, Vidasova K, Belyaev I (2024): Evaluation of oxidative stress and genetic instability among residents near mobile phone base stations in Germany. *Ecotoxicology and Environmental Safety*, 279(May), 116486. <https://doi.org/10.1016/j.ecoenv.2024.116486>
- (2) Zosangzuali M, Lalremruati M, Lalmuansangi C, Nghakliana F, Pachau L, Bandara P, Zothansiam (2021). Effects of radiofrequency electromagnetic radiation emitted from a mobile phone base station on the redox homeostasis in different organs of Swiss albino mice. *Electromagnetic Biology and Medicine*, 40(3), 393–407; DOI:10.1080/15368378.2021.1895207. <https://www.emfdata.org/de/studien/detail?id=686>
- (3) Zothansiam, Zosangzuali, M, Lalramdinpuui, M, & Jagetia, G C (2017). Impact of radiofrequency radiation on DNA damage and antioxidants in peripheral blood lymphocytes of humans residing in the vicinity of mobile phone base stations. *Electromagnetic Biology and Medicine*, 36(3), 295–305. DOI: 10.1080/15368378.2017.1350584, <https://www.emfdata.org/de/studien/detail?id=738>



### Wi-Fi's effect on bees and bumblebees

## Radiofrequency electromagnetic fields reduce bumblebee visits to flowers

Treder M, Glück M, England SJ, Traynor KS (2025). Radiofrequency electromagnetic fields reduce bumble bee visitation to flowers. *Environmental Pollution*. 2025 Jul 14:126836. <https://doi.org/10.1016/j.envpol.2025.126836>

Insects are exposed to anthropogenic electromagnetic fields, especially in urban areas where these fields are widespread. They typically encounter these fields in two ways: when their nests are located in exposed areas or when they cross such fields in search of food sources or nesting materials. Recently, there has been an increase of publications in this emerging field of research on the effects of radiofrequency electromagnetic fields (RF-EMF) on pollinators. The authors of the current paper asked whether exposure to commonly used Wi-Fi frequencies could affect pollinators' flower visitation rates and thus their foraging behavior. If this radiation causes interference or has negative effects, it could make exposed areas in cities less attractive to bee species, which would represent a disruptive factor that could affect pollinators in highly developed areas.

### Study design and implementation:

The experiment was conducted during the summers of 2023 and 2024 at the State Institute of Apiculture, University of Hohenheim, Germany. The goal was to study the short-term effects of electromagnetic fields on the visitation rates and foraging behavior of honeybees and bumblebees. Although the electromagnetic treatment may affect the plants as well, the researchers carried out an experiment to investigate only its direct effects on pollinator visits. A total of 12 flower pots with 3 plants each were used: 6 with *Lavandula angustifolia* (n = 18) and 6 with *Salvia* species (n = 18). To ensure consistent exposure, the flower pots were placed 2 m from the radiation source.

A software-defined radio (SDR) simulated realistic Wi-Fi radiation at 2.45 and 5.8 GHz. In technical terms, the radiation source corresponds to commercially used Wi-Fi devices. The new experimental setup included repeated exposure and control tests carried out at close intervals. Alternating frequently between short exposure and non-exposure periods every four days controls for interfering factors, such as natural temporal variations. This alternation occurred throughout the 2-year experimental period, resulting in 21 EMF exposure periods and 23 non-exposure periods.

To determine the effects of different pollinators on flower visitation rates, insects were recorded on 92 days spread over 2023 and 2024. All plants in each pot were observed together. A total of 1,307 observations of flower pots were made. Each flower pot was observed for visiting pollinators for exactly

5 minutes. Flower visitation rates were analyzed using generalized linear mixed models (GLMM).

### Results:

The authors recorded a total of 2,876 flower visitors, 50.4% of which were honeybees (n = 1,450) and 32.5% of which were bumblebees (n = 936) over the two years of the study. Overall, the main model revealed a significant negative effect of EMF on flower visits (EMF: 0.15, p = 0.0118). Closer analysis of the data showed that this effect was particularly evident among bumblebees (EMF: 0.25, p = 0.0029), which were observed significantly more frequently (28% higher) on flowers when plants were not exposed to RF-EMF. In contrast, this effect was not observed among honeybees (EMF: p > 0.05).

### Conclusions:

The use of electromagnetic fields to transmit information is enormously important for humans and technological progress. However, as these fields become more prevalent, we need to understand their potential impact on insects, especially pollinators. The experimental approach outlined here is suitable for determining weak EMF effects on pollinator flower visitation rates. This approach requires a large sample size and measurements taken over the course of days and months to control for environmental variability. Although no effect on honeybee visit frequency was found, the authors found that bumblebees reduced their visits when plants were exposed to RF-EMF. This suggests that bumblebees may avoid plants in urban areas when exposed to widespread Wi-Fi frequencies. Such avoidance reduces the availability of food sources and could force bumblebees to switch to other nectar and pollen sources. This could result in greater foraging effort and additional nutritional stress for these pollinators. At the same time, this could negatively impact plants by reducing their pollination rate.

### Editor's notes:

This is an excellent semi-field study in terms of methodology, with conditions as close to reality as possible. Further efforts in this direction using other insects (although honeybees and bumblebees are certainly the most important pollinators) or radiation sources other than the Wi-Fi signal used here would be interesting, e.g. high-voltage transmission lines or mobile phone base stations. It is possible that the findings presented here may be applicable to other technical radio frequencies. The only question that would need to be answered is what distance from a base station would correspond to the 2-meter distance to the Wi-Fi router used here. (AT)



### Honeybees in a Faraday cage

## The behavior of honeybees in a Faraday-shielded hive: mandatory Schumann resonance for colony survival

Favre D, Johansson O. (2025). Honeybees' Behavior in a Faraday-Shielded Hive: Mandatory Schumann Resonance for Colony Survival. *International Journal of Research - GRANTHAALAYAH*, 13(4), 25-38. <https://doi.org/10.29121/granthaalayah.v13.i4.2025.6023>

Various studies suggest that increased exposure to electromagnetic radiation from mobile phones and antennas probably contributes to the disturbance or decline of insect populations. In previous experiments, the authors were able to show that mobile phones and electromagnetic pollution induce the piping or whistling signal of worker bees in stressed colonies. A Faraday shield is a conductive housing that blocks electromagnetic fields by redistributing electrical charges. It is used to shield various objects, such as electronics, from interference. In some experiments, various animal species including rodents and birds, were placed in Faraday cages. Mice housed in Faraday cages exhibited elevated levels of cortisol (a stress hormone), disturbed sleep behavior, and a reduced ability to cope with stressors. These studies suggest that the presence or absence of EMFs can affect biological processes in different animal species differently. To assess the effects of such an environment on honeybees, experiments were conducted in which honeybee colonies were kept in shielded hives.

### Study design and implementation:

Faraday-shielded hives were constructed by surrounding standard hives on all sides with aluminum sheets (0.7 mm thick). The entrance slot for the honeybees was shielded separately by placing metal rods in front of it. The Faraday-shielded bee-hive was tested in an anechoic chamber at the Swiss Federal Institute of Technology (EPFL) to determine attenuation factors at 900 megahertz (MHz). Schumann resonance frequencies are typically 7.83 Hz and are associated with very low frequency (VLF) electromagnetic waves. This study of honeybee colonies kept in two Faraday hives took place in a rural area of Switzerland near Montreux, at an altitude of 960 meters. The experiments with honeybees kept in Faraday-shielded hives began in spring 2013 and ended in mid-2024.

### Results:

The analyses showed that the attenuation factors of the Faraday-shielded hive ranged from 8.6 to 28.8 dB, depending on which side was considered. This corresponds to a reduction in incoming EMF of 63–97%. During the first years (2013–2022) of studying the fate of honeybee colonies in Faraday-shielded hives, the colonies acted disoriented. The queen was no longer able to lay eggs and produce female worker bees, especially after

winter. Worker bees were unable to raise new queens by feeding young eggs royal jelly, and newly built queen cells were no longer observed. After winter, no new worker bees emerged from the hive. Instead, more and more drones (males) hatched from the hexagonal cells. This showed that some worker bees had begun to lay unfertilized eggs. The result was a decline in the overall population. To counteract the observed population decline, a mated queen from a reputable supplier was introduced to the hive. Unfortunately, this did not help maintain viable honeybee colonies. Inserting queen cells or virgin queens from another hive was also ineffective. The colonies were always provided with sufficient food, space, and protection from pests and diseases to ensure resilience and the ability to raise a new queen. Unfortunately, all these efforts and procedures were unsuccessful. Long-term colony survival, stability, and productivity were never achieved in a Faraday-protected hive. It eventually became apparent that the presence of a Schumann generator was critical to the long-term well-being of EMF-shielded honeybee colonies. In mid-April 2022, two honeybee colonies were relocated from “normal” hives to Faraday-shielded hives. Schumann generators were placed in these Faraday-shielded hives at the same time. This allowed the colonies to survive until mid-June 2024.

### Conclusions:

The honeybee was one of the first animal species for which the existence of a magnetic sense was proposed. Two main hypotheses explain how bee species detect the geomagnetic field (GMF): the ferromagnetic hypothesis and the biochemical hypothesis. Schumann resonance is a natural electromagnetic phenomenon in the Earth's atmosphere that occurs between the surface and the ionosphere. It consists of standing electromagnetic waves in the extremely low frequency (ELF) range. These natural electromagnetic fields actually appear to act as environmental stimuli that influence biological rhythms and the development of various organisms. An experimental setup with Faraday-shielded beehives significantly reduces the external electromagnetic field and provides good protection against Schumann resonance. The queen bee, the central reproductive organ of a bee colony, could experience effects in a Faraday cage due to the absence of geomagnetic input. Although the queen bee is less directly dependent on navigation than worker bees, the absence of geomagnetic fields in a Faraday cage could have cascading effects on her health, behavior, and reproductive performance. These effects could indirectly destabilize the entire colony because the queen's well-being is critical to the hive's functioning and survival.

### Editor's notes:

This study clearly shows that it would not be a good idea for concerned beekeepers with hives close to a mobile phone base station or high-voltage transmission line to heavily shield their hives with a Faraday cage, as used in this study, unless the hives are also equipped with Schumann resonance generators. (AT)



### Mobile phones alter brain activity

## Effects of mobile electromagnetic exposure on brain oscillations and cortical excitability: scoping review

Torkan A, Zoghi M, Foroughimehr N, Yavari A, Jaberzadeh S (2025). Effects of Mobile Electromagnetic Exposure on Brain Oscillations and Cortical Excitability: Scoping Review. *Sensors*, 25(9), 1–20. <https://doi.org/10.3390/s25092749>

Mobile phones have become an integral part of everyday life. With each new generation of mobile technology, transmission power and frequency ranges increase, extending into the millimeter wave spectrum (> 26 GHz). In this context, the question of whether and how mobile phone radiation influences brain function becomes increasingly important. This scoping review summarizes the current state of research on the effects of mobile phone exposure on brain oscillations (EEG) and cortical excitability (TMS) in healthy adults. Unlike a systematic review, no quantitative synthesis or meta-analysis was performed.

### Study design and implementation:

The authors searched four databases – MEDLINE, PubMed, Web of Science and Scopus – for primary studies in English on healthy adult humans. They excluded studies with animal models, patient cohorts, or studies lacking quantitative EEG or TMS endpoints. Exposure parameters were characterized by carrier frequency (0.45–3.5 GHz), transmission power or SAR, exposure duration (1 min to 8 h), study design (blinding, crossover), and experimental details (e.g. eyes open vs. closed). The outcomes of interest were EEG band amplitudes and connectivity, and corticospinal and corticocortical excitability, as assessed via TMS. A total of 80 relevant studies were identified: 78 EEG studies and only 2 TMS studies. Data extraction and presentation followed PRISMA guidelines.

### Results:

Of the 78 EEG studies, the authors distinguished between studies in which the subjects' eyes were open and studies in which the subjects' eyes were closed. Of the 33 studies conducted with subjects' eyes open, 22 reported significant alterations in brain oscillations during mobile phone exposure. Of the 48 studies conducted with the subjects' eyes closed, 35 observed significant effects. Depending on the study design, changes in EEG amplitude were heterogeneous, with both increases and decreases reported across all frequency bands. The most common changes were increases in alpha- and beta-band amplitudes. Overall, more increases than decreases were documented. Both TMS studies reported significant modulation of excitability (intracortical facilitation).

### Conclusions:

This scoping review suggests that mobile phone exposure can modulate neuronal oscillations and cortical excitability. The authors identified major gaps in the evidence base, particularly regarding risk assessments, non-thermal effects, and 5G millimeter wave applications. Hardly any experimental studies exist on these topics. They also highlight limitations, including the small number of TMS studies, which makes the evidence for changes in excitability inconclusive. In addition, the diversity of outcome parameters across EEG studies precluded meta-analysis. Other limitations include imprecise characterization of participants (e.g. age and sex) and the absence of predefined effect sizes and power calculations, which could compromise the interpretability of the results. The authors recommend the following improvements for future work: conducting more 5G studies (especially on millimeter waves), better stratifying subjects by demographic variables, and standardizing experimental parameters, such as field strengths, controls, blinding, crossover design, and technical details of EEG/TMS acquisition.

### Editor's note:

The use of PRISMA scoping criteria provides structure and transparency. This review's credibility is bolstered by its systematic categorization (which includes a detailed characterization of radiofrequency fields), its large proportion of double-blind primary studies, and its explicit acknowledgment of methodological limitations. (RH)



## A computational approach supports the mechanistic hypothesis

### Radical pair model for magnetic field effects on NMDA receptor activity

Nair PS, Zadeh-Haghighi H, Simon C (2024). Radical pair model for magnetic field effects on NMDA receptor activity. *Sci Rep* [Internet]. 2024 Feb 13;14(1):3628. Available from: <https://doi.org/10.1038/s41598-024-54343-y>

The effects of magnetic fields on biological systems have been investigated in the context of magnetoreception, circadian rhythm regulation, and genotoxicity. The radical pair mechanism (RPM), a quantum mechanical process, provides a plausible explanatory framework for some of these effects as well as several phenomena reported in the central nervous system. In this model, the electronic states of short-lived molecular radical pairs are modulated by quantum interactions, such as Zeeman and hyperfine effects. The pairs then occupy coherent superpositions of singlet and triplet spin states.

#### Editor's note:

In the singlet state, the two unpaired electron spins are antiparallel; in the triplet state, they are parallel. In organic systems, singlet configurations are typically more reactive than triplet configurations.) External magnetic fields alter the interconversion rates between these states, thereby changing reaction kinetics and product yields. This can account for the experimentally observed field effects. The RPM has previously been applied to model the effects of extremely weak magnetic fields on processes such as adult neurogenesis and microtubule reorganization. Previous *in vitro* studies reported that static magnetic fields can significantly increase intracellular  $\text{Ca}^{2+}$  levels and NMDA receptor density in neurons. Because NMDA receptors play a critical role in synaptic plasticity, learning, memory, and numerous neurological disorders, the authors propose that an RPM acting on specific ion radical pairs may provide a mechanistic explanation. Under an applied static field, the quantum spin dynamics of protein oxyradicals paired with hydrated magnesium radicals could shift toward reactive singlet configurations, thereby modulating downstream signaling.

#### Study design and implementation:

The authors computed the product yields of candidate radical pair reactions under static magnetic fields ranging from 0.15 to 100 mT. They then compared these calculations with previously published *in vitro* observations obtained at 100 mT. The authors assume that the experimentally observed increase in NMDA receptor activity, as measured by elevated intracellular  $\text{Ca}^{2+}$ , stems from increased enzymatic phosphorylation events catalyzed via an ion radical mechanism. To test this hypothe-

sis, they modeled serine- and tyrosine-derived oxyradicals, each paired with hydrated magnesium radicals as plausible radical pair partners. The authors then simulated the probability of conversion into the reactive singlet configuration as a function of field strength. Changes in the fractional singlet yield could explain the observed experimental results.

#### Results:

At 100 mT, the calculated singlet yield for both serine- and tyrosine-based radical pairs increased by a factor of 1.24. This magnitude is similar to the experimentally reported increases in mean intracellular  $\text{Ca}^{2+}$  concentration: 1.5 for continuous exposure and 1.4 for repetitive exposure. Incorporating the natural  $^{25}\text{Mg}$  isotope fraction produced modest yet measurable differences in the predicted singlet yield.

#### Conclusions:

The computed increase in RPM singlet yield is quantitatively comparable, though not identical, to the experimentally observed increase in intracellular  $\text{Ca}^{2+}$  in cultured neurons. The authors suggest that additional biological amplification steps inherent to ion influx and downstream signaling could exacerbate an initially modest change in radical pair chemistry. Thus, the radical pair mechanism is a plausible mechanistic hypothesis for how static magnetic fields might modulate NMDA receptor activity. However, the *in situ* formation and persistence of the proposed serine oxyradicals under physiological conditions has yet to be definitively demonstrated. Direct experimental detection of the putative radicals and demonstration of their field dependence are required to substantiate the model.

#### Editor's note:

These results lend support to the RPM hypothesis regarding the effects of electromagnetic fields on neuronal NMDA receptors. However, comprehensive experimental validation is essential. If confirmed, a radical pair-based mechanism would significantly advance our understanding of how electromagnetic fields interact with molecular and cellular neurobiology, potentially impacting learning and memory. (RH)



### Mechanisms of the biological effects of EMF

## A comprehensive mechanism of biological and health effects of anthropogenic extremely low frequency and wireless electromagnetic communication fields

Panagopoulos DJ, Yakymenko I, De Iuliis GN, Chrousos GP (2025). A comprehensive mechanism of biological and health effects of anthropogenic extremely low frequency and wireless communication electromagnetic fields. *Frontiers in Public Health*. 2025 Jun 4;13:1585441. <https://doi.org/10.3389/fpubh.2025.1585441>

Exposure to anthropogenic electromagnetic fields (EMF), especially those from wireless communications (WC) and mobile telephony (MT), has increased dramatically. This phenomenon is unprecedented in biological evolution because all anthropogenic EMFs are fully polarized and coherent. Especially EMFs from wireless communications significantly differ from natural EMFs. Several experimental studies have found a link between the exposure of laboratory animals or cells to anthropogenic ELF or WC EMF/EMR and oxidative stress (OS) due to the overproduction of reactive oxygen species (ROS) and genetic damage/alterations (DNA damage, chromosomal damage, and mutations). In several of these studies, OS and/or DNA damage, resulting in cell death, were observed in the reproductive cells of various animals, leading to reduced reproduction or embryonic death. This genetic damage in reproductive cells explains other findings that link EMF exposure to infertility in insects, birds, and mammals (including humans), as well as to miscarriages and declines in bird and insect populations (especially bees), over the last 20 years.

However, some studies have found no effects of ELF or WC EMF/EMR exposure, especially those that used signal generators with invariable parameters and no modulation. In contrast, effects were found in more than 95% of studies that used real MT/WC exposure from commercially available devices (mobile/wireless phones and Wi-Fi) with high signal variability. Regardless of whether the exposure was real or simulated, about 70% of experimental studies found effects with either radiofrequency (combined with ELF) or pure ELF-EMF. Human-made EMFs with frequencies down to the lower limit of infrared radiation cannot directly break chemical bonds or cause ionization. How, then, are human-made EMFs at environmental intensities able to ionize DNA and other biological molecules? What unique property enables human-made EMFs to cause adverse biological and health effects unlike natural EMFs, including sunlight? Studies have shown that this unique property lies in the polarization and coherence associated with low frequency variability (ULF/ELF).

In the present study, Panagopoulos and Yakymenko et al. provide an updated description of how human-made EMFs at

non-thermal levels trigger dysfunction in voltage-gated ion channels (VGICs) in cell membranes. This induces the overproduction of ROS and OS, which are responsible for most known adverse biological and health effects, including DNA damage and related pathologies.

### Biochemistry of radical oxygen species:

The electron transport chain (ETC) in the inner mitochondrial membrane is a major source of ROS in all cells and probably accounts for 50–90% of total cellular ROS production under normal conditions. In spermatozoa exposed to WC-EMF, electron leakage from the ETC was found to originate from complex III when tested alongside complex III inhibitors. When considering the mitochondrial causes of OS,  $\text{Ca}^{2+}$  plays a key role. While a physiological increase in mitochondrial  $\text{Ca}^{2+}$  can stimulate ATP production when energy demand is high, it can also lead to increased ROS formation. Excessive  $\text{Ca}^{2+}$  accumulation can lead to mitochondrial dysfunction, decreasing ATP production and more importantly further increasing ROS production and apoptotic factors.  $\text{Ca}^{2+}$  can affect mitochondria by regulating important mitochondria-specific dehydrogenases. Therefore, careful control of mitochondrial  $\text{Ca}^{2+}$  levels is essential for ROS homeostasis. EMF-induced disruption of  $\text{Ca}^{2+}$  channels can lead to ROS overproduction.

NADPH/NADH oxidases (NOXs) catalyze the production of free superoxide anions by transferring electrons from NAD(P)H to oxygen. NOXs are also activated by cytosolic  $\text{Ca}^{2+}$  and have a  $\text{Ca}^{2+}$ -binding site in addition to their  $\text{H}^+$  voltage-gated channel. NOXs can account for 10–30% of total ROS production in neurons under basal conditions. However, their contribution can increase significantly during neuronal activation or inflammation. NOXs have been identified as an important target for human-induced EMFs.

Nitric oxide synthases (NOS) are specific enzymes found in all animal and plant cells that produce nitric oxide free radicals ( $\text{NO}\cdot$ ). An increase in  $\text{Ca}^{2+}$  and  $\text{NO}^-$  concentrations in cells has been found to be triggered very rapidly (within a few seconds) by EMF exposure. The induction of DNA damage by peroxynitrite is blocked by NOS inhibitors and antioxidants.

Furthermore, disruption of voltage-gated  $\text{Na}^+$ ,  $\text{K}^+$ ,  $\text{Mg}^{2+}$  and  $\text{Ca}^{2+}$  ion channels (VGICs) impairs the function of  $\text{Na}^+/\text{K}^+$  pumps (ATPase) and  $\text{Ca}^{2+}$  pumps in plasma membranes of all cells. In addition to its role as an ion pump, the  $\text{Na}^+/\text{K}^+$ -ATPase acts as a signal regulator that transmits signals from the plasma membrane to intracellular organelles. It also normalizes the  $\text{Na}^+/\text{K}^+$  balance in cells, for example, after disruption of VGICs. It is well known that ELF EMFs affect the activity of  $\text{Na}^+/\text{K}^+$ -ATPase and that changes in its activity are related to ROS production in the mitochondria. Martin Pall found a link between EMF-induced dysfunction of voltage-gated calcium channels and  $\text{NO}\cdot/\text{ONOO}^-$  overproduction. In the presence of  $\text{H}^+$ , peroxynitrite can easily decompose to  $\text{OH}\cdot$  and  $\text{NO}_2^-$ .

The superoxide anion radical ( $O_2^{\bullet-}$ ), produced by mitochondria or NADH/NADPH oxidase (NOX) is catalyzed by superoxide dismutase (SOD) in the cytosol or mitochondria and converted to hydrogen peroxide ( $H_2O_2$ ).  $H_2O_2$  can reach any location in the cell, including the nucleus, where it can be converted to the highly potent hydroxyl radical ( $OH^{\bullet}$ ), which can damage any biological molecule, including DNA.

### **Anthropogenic EMFs and VGICs:**

Normally, voltage-gated ion channels (VGICs) switch between open and closed states in response to membrane voltage changes of  $\geq 30$  mV, which exert forces on their voltage sensors. More specifically, VGICs respond to changes between -30 and -100 mV. VGICs can also respond to very weak polarized, coherent, and slowly fluctuating EMFs down to  $\sim 10^{-5}$  V/m via the forced oscillation that such EMFs induce on moving ions in close proximity ( $< 1$  nm) to the sensors (ion forced oscillation: IFO). The IFO-VGIC mechanism postulates that biological activity is proportional to EMF intensity and inversely proportional to frequency. Thus, the effects reported in the literature are caused by low frequency (ULF/ELF/VLF) EMFs, not high frequency (pure radiofrequency/microwave) EMFs. In addition, pulsed EMFs are significantly more bioactive than their continuous (non-pulsed) counterparts. VGICs do not simply respond to the presence of an unchanging (static) electric field; otherwise, they would constantly open and close chaotically, and life could not be sustained. For this reason, the geomagnetic field (GMF) is not particularly bioactive under normal conditions but becomes bioactive when the normal intensity changes by about 20% during magnetic storms. Dysfunction of ion channels affects otherwise carefully controlled intracellular ion concentrations, disturbing the cell's electrochemical balance and homeostasis, including its intracellular redox status, an index of its ROS content. The ROS regulatory system is closely linked to the  $Ca^{2+}$  signaling system. Dysfunction of the  $Ca^{2+}$  channels in the plasma or mitochondrial membrane leads to an interruption of the signaling system and an increase in the ROS concentration in the cell. Therefore, ion channel malfunction leads to ROS overproduction, which further amplifies ion channel malfunction. Clearly, we are dealing here with a vicious cycle in which VGIC dysfunction leads to OS in cells, which disrupts the ion channels further and leads to even more pronounced OS.

### **Conclusions:**

All human-generated EMFs are fully polarized and coherent. In most cases, they have low frequency (ELF/ULF/VLF) intensity fluctuations, meaning they have net electric and magnetic fields oscillating in one direction and in phase at ELF/ULF/VLF rates. These conditions lead to parallel and coherent low frequency forced oscillations of mobile ions and other charged or polar molecules in living tissue. According to the IFO-VGIC mechanism, the non-thermal biological and health effects described in the literature are specifically induced by low frequency components of an RF signal, not the high frequency EMF itself. This explains why non-thermal effects previously attributed to RF EMFs disappear in the absence of low frequency modulation or pulsation. According to the authors, it follows that pure RF/

**The ROS regulation system is closely linked to the  $Ca^{2+}$  signalling system. A malfunction of the  $Ca^{2+}$  channels in the plasma or mitochondrial membrane leads to an interruption of the signalling system and an increase in the ROS concentration in the cell.**

microwave EMFs can only cause heating of biological tissue. For cells whose genomic DNA is irreparably damaged by EMF-induced ROS, the possible consequences are cell senescence or cell death, which can lead to aging, organic or neurodegenerative diseases, reproductive problems, cancer, or mutated offspring.

Human-made EMFs, especially the most harmful ones emitted by mobile phone antennas and devices and power lines, have become a new reality of modern life. Every day, billions of people are exposed to them. Although they are significantly less cytotoxic than radioactivity or certain toxic chemicals, human-made EMFs are an evolutionarily novel and extremely persistent daily cytotoxic agent against which existing repair mechanisms may not be effective enough. This is especially true for individuals who are already genetically or epigenetically damaged. According to the authors, a prerequisite for the therapeutic effect of applied EMFs is the simulation of natural EMFs or physiological endogenous cellular signals. Natural atmospheric electromagnetic "Schumann" resonances (7.83 Hz) and their harmonics are fundamental frequencies detected in human and animal brain activity. The physical parameters of electromagnetic brain activity and atmospheric flashes show striking similarities. Therefore, the authors hypothesize that pulsed EMFs should have optimal therapeutic effects at frequencies that match Schumann frequencies or endogenous ionic oscillations in cells. These frequencies should also be biologically compatible or beneficial.

### **Editor's note:**

If this assumption is correct, this could significantly reduce the toxic effects of ELF-pulsed EMFs by making the low frequency components of the signal as similar as possible to natural Schumann resonances. (AT)



### Basic EHS research

## Skin fibroblasts from individuals self-diagnosed as electrosensitive reveal two distinct subsets with delayed nucleoshuttling of the ATM protein in common.

Sonzogni L, Al-Choboq J, Combemale P, Massardier-Pilonchéry A, Bouchet A, May P et al. (2025). Skin Fibroblasts from Individuals Self-Diagnosed as Electrosensitive Reveal Two Distinct Subsets with Delayed Nucleoshuttling of the ATM Protein in Common. *International Journal of Molecular Sciences*. 2025 May 16;26(10):4792. <https://doi.org/10.3390/ijms26104792>

Electromagnetic hypersensitivity (EHS) and its causal relationship with radiofrequency radiation are important public health issues. The term “electromagnetic hypersensitivity” was first proposed to describe a group of symptoms that some individuals attribute to exposure to electromagnetic fields (EMF). To date, the consensus in the literature is that EMF, as non-ionizing radiation, transfers much less energy to living matter than ionizing radiation. The WHO recommends that every clinical study on EHS include a self-assessment with a graded intensity of symptoms or complaints by means of a questionnaire. The authors favor using skin fibroblasts because they have several advantages over lymphocytes and other cell types: fibroblasts are the most representative; skin biopsies are easy to perform; fibroblasts are stable and long-lived in cell culture. Since cellular and clinical radiosensitivity have both been shown to be associated with impaired DNA double-strand break (DSB) repair, which depends on the ATM kinase protein (a key player in the stress response), investigating the functionality of ATM-dependent DSB recognition and repair pathways in skin fibroblasts from EHS patients is of great interest. To obtain the first molecular definition of EHS, a medical study called DEMETER (the French acronym for “Molecular Definition of Human Electrosensitivity”) was conducted with a cohort of 26 self-diagnosed electrosensitive volunteers.

### Study design and implementation:

As part of the DEMETER clinical trial, 26 adult volunteers diagnosed with EHS agreed to complete a self-assessment questionnaire and undergo a skin biopsy to establish a primary fibroblast cell line. Skin samples were collected from the volunteers between 2018 and 2021. Fibroblast cell lines from a laboratory called COPERNIC and an associated radiobiology database from cancer patients treated with radiotherapy (RT) who did not report EHS symptoms in their questionnaires were used as non-EHS controls. Of the COPERNIC donors, 10 were classified as radioresistant non-EHS controls (Group I), meaning they

showed minimal signs of genetic damage after 2 Gy of X-ray irradiation (75-85% of the normal population is radioresistant), and 186 were classified as radiosensitive non-EHS controls (Group II). Both DEMETER and COPERNIC cells were cultured at the same location and under the same conditions.

Irradiation was performed using a clinical 6-megavolt X-ray machine at the Léon-Bérard Cancer Research Center in Lyon, France. The dose was 2 Gy and the dose rate 6 Gy/min. The hydrogen peroxide treatment consisted of adding the indicated concentration of H<sub>2</sub>O<sub>2</sub> directly into the culture medium for 30 minutes. The authors assessed the number of spontaneous double-strand breaks (DSB), the primary form of DNA damage, and the number of spontaneous micronuclei (MN), a primary indicator of genomic instability, in each DEMETER fibroblast cell line. Spontaneous DSB were analyzed by immunofluorescence. The number of MN per 100 cells was determined using the same microscopic slides. Finally, the conclusions drawn from the first two steps (questionnaire and biological data) were combined to identify the specific molecular features of EHS. This report only presents data from the self-assessment questionnaire and data obtained after exposing DEMETER and COPERNIC cells to X-rays and H<sub>2</sub>O<sub>2</sub>, two well-documented inducers of DNA strand breaks.

### Results:

The DEMETER study was based on a cohort of 26 people with EHS.

1. The questionnaire and biological data yielded two subgroups of donors (1 and 2). The donors were assigned to two phenotypes: one with low background symptoms and high sensitivity to EMF (low background highly responsive, LBHR) and the other with high background symptoms and low sensitivity to EMF (HBLR). The groups were quantitatively defined by the intensity of self-reported symptoms in association with different EMF sources.
2. The questionnaire on symptoms after exposure to sources other than EMF (e.g. food and chemicals) revealed that the HBLR phenotype is associated with immune deficiency. The questionnaire also showed that the HBLR phenotype is particularly associated with fatigue, sleep disturbances, and decreased intellectual capacity, while the LBHR phenotype is particularly associated with cardiac and digestive system impairments, mood lability, nervousness, headaches, tinnitus, and skin reactions. The LBHR group had significantly fewer micronuclei and double-strand breaks than the HBLR group.
3. Two subgroups of DEMETER volunteers, namely A and B, were defined based on the number of spontaneous double-strand breaks (DSB) or micronuclei (MN) as endpoints. The same EHS subjects consistently showed either elevated

DSB and MN, or both in the lower/normal range. In addition, subgroups A and B were found in one of the two aforementioned subgroups 1 and 2, with a match rate of 64%.

4. Since DEMETER fibroblasts associated with the HBLR phenotype exhibit very high levels of spontaneous DNA breaks, the authors investigated whether these fibroblasts exhibit perinuclear ATM crowns, a marker of aging. This was confirmed. After irradiation with X-rays, all 26 DEMETER fibroblasts exhibited delayed radiation-induced ATM nucleoshuttling (RIANS). Delayed RIANS is a cellular response characterized by a systematic delay in the movement of ATM protein to sites of DNA double-strand breaks after radiation exposure. Using RIANS biomarkers, the authors showed that the two aforementioned phenotypes corresponded to DEMETER donors at a high risk for cancer (LBHR) or accelerated aging (HBLR). These results suggest that EHS may be systematically associated with delayed RIANS. They also imply that some X-proteins, ATM substrates, should be overexpressed in the cytoplasm of all DEMETER cells. Mutations could be responsible for harmful X-proteins and thus be a possible cause of EHS. EHS may be related to the management of DNA strand breaks.
5. The molecular definition of subgroups A and B was confirmed by other biomarkers. Subgroup A was associated with the early formation of radiation-induced MRE11 foci. Meanwhile, subgroup B was associated with both spontaneous formation of perinuclear pATM crowns and the late formation of radiation-induced MRE11 foci (92.3% overlap). These results suggest that subgroup A consists of individuals at high risk for cancer, while subgroup B consists of individuals at high risk for accelerated aging.
6. Treatment with H<sub>2</sub>O<sub>2</sub> can cause single-strand breaks (SSB) and double-strand breaks (DSB) in DEMETER cells, resulting in severe cell damage. These cells have been shown to represent the final step of perinuclear pATM crowns. Differences observed with H<sub>2</sub>O<sub>2</sub> treatment between subgroup B (HBLR phenotype) and controls significantly decreased with the application of antioxidant treatment, again supporting the model that EHS may be related to SSB and/or DSB management.

### Conclusions:

The results of this study are based on a small cohort of 26 EHS patients (DEMETER cohort). However, the finding that all 26 EHS patients had delayed radiation-induced ATM nuclear transfer (RIANS) suggests that a larger cohort would not drastically alter this conclusion. The presence of spontaneous SSB, DSB, or MN in EHS patient cells likely reflects tremendous oxidative stress and significant genomic instability. While a high spontaneous rate of DSB or MN is not specific to EHS, fibroblasts of DEMETER subgroup B can induce higher endogenous stress, resulting in more DSB per cell (HB phenotype) than fibroblasts of subgroup A (LB phenotype), suggesting more severe impairment in coping with and repairing SSB and/or DSB.

These results are consistent with immunodeficiency responses observed specifically in the HBLR subgroup, but also with the efficacy of an antioxidant drug after H<sub>2</sub>O<sub>2</sub> treatment. The radiobiological characterization performed in this report strongly suggests that all DEMETER fibroblasts exhibited delayed RIANS. This cannot be attributed to chance, considering the biological and mathematical constraints associated with delayed RIANS. This RIANS status implies that EHS patients undergoing radiotherapy for cancer may be at high risk for adverse tissue reactions following treatment. Findings from cells irradiated with X-rays indicate that DEMETER donors are at risk for grade 2–4 tissue reactions after radiotherapy. These secondary effects should not be overlooked. Further studies are needed to verify whether exposure of cells from EHS individuals to EMF corresponds to an X-ray dose; such studies are already underway. (AT)



### Can mobile phone radiation disrupt thermoregulation?

## Electromagnetic fields from mobile phones: A risk for maintaining energy homeostasis?

Seewooruttun C, Mai TC, Corona A, Delanaud S, Seze R de, Bach V, Desailoud R, Pelletier A (2025). Electromagnetic fields from mobile phones: A risk for maintaining energy homeostasis? *Annales d'Endocrinologie*, 86(3), 101782. <https://doi.org/10.1016/j.ando.2025.101782>

The widespread use of mobile phones and other wireless communication devices results in constant exposure to low-intensity radiation from these devices. While high SAR values are well documented to induce thermal effects, the ability of low SAR values, as encountered in everyday mobile phone use, to trigger non-thermal mechanisms remains controversial. This narrative review addresses the comparatively understudied phenomenon of mobile phone-dependent thermoregulation. The literature provides evidence that mobile radiation can trigger cold responses in animal models, thereby affecting energy balance.

### Study design and implementation:

This review does not take a systematic approach. Rather, it provides a narrative summary of experimental animal studies. The aim is to provide an overview of the physiological and molecular mechanisms through which mobile phone radiation could affect thermoregulatory functions.

### Results:

Although mobile phone radiation is generally associated with tissue heating and existing guidelines are designed to prevent this effect, animal experiments have paradoxically shown that low-intensity radiofrequency exposure can induce cold responses. Compared with controls, the exposed animals exhibited lower tail temperatures accompanied by increased vasoconstriction. In thermal preference tests, the exposed animals selected areas that were warmer than those selected by the controls. Even rats exposed to a SAR of 0.16 W/kg (well below thermal thresholds, editor's note) showed an increase in core body temperature. At the cellular level, changes in thermogenesis were observed. Brown adipose tissue (BAT) is the principal site of non-shivering thermogenesis. Analyses of BAT revealed no consistent changes in classical thermogenic markers such as UCP1 or PGC1- $\alpha$ . However, several biomarkers indicated the conversion of white adipose tissue into brown adipose tissue ("browning").

### Conclusions:

Behavioral and physiological tests, as well as biochemical marker tests, suggest that low-intensity mobile phone radiation disturbs thermal homeostasis. This imbalance can result in an actual increase in core body temperature. The combination of altered behavior (thermal preference), autonomic adjustments (vasoconstriction), and molecular changes (fat tissue transformation) indicates modulation of energy homeostasis. According to the authors, these adaptive responses do not appear to adversely affect health in the short term. However, data from long-term studies are extremely scarce. Overall, the researchers call for closer investigation of the thermoregulatory effects, particularly with reference to the thyroid gland. Thyroid hormones regulate systemic metabolism, including processes that govern cellular energy production and heat generation through thermogenesis.

### Editor's note:

By definition, this narrative review lacks the capacity to quantify its key findings and does not adhere to the PRISMA guidelines. However, generating quantitative evidence was not the aim. Rather, the authors aimed to provide an overview of an intriguing and underexplored research field. Notably, evidence of altered energy homeostasis was found at three levels: behavior, autonomic regulation, and molecular markers. As the authors recommend, a more in-depth investigation appears well justified. (RH)



## Commentary on the Evaluation of the Study by Bozok et al.

By Klaus Scheler

### Introduction

The study by Bozok et al. (2023) [1] titled “The Effects of Long-term Prenatal Exposure to 900, 1800 and 2100 MHz Electromagnetic Field Radiation on Myocardial Tissue of Rats,” was the first to investigate the long-term effects of exposing pregnant Sprague Dawley rats (white rats) to common mobile phone frequencies on the myocardial tissue of their male offspring.

Six groups (n = 3) of pregnant Sprague Dawley rats were used in this study: Group 1: controls (no exposure); Group 2: 900 MHz, 24 h/day; Group 3: 1800 MHz, 6 h/day; Group 4: 1800 MHz, 12 h/day; Group 5: 1800 MHz, 24 h/day; Group 6: 2100 MHz, 24 h/day.

The animals were exposed for 20 days. After 60 days, the offspring were sacrificed, and their myocardial tissue was examined histopathologically and biochemically. The researchers observed atypical myocardial morphology in young animals from the exposed groups, including pyknotic nuclei (degenerated cell nuclei), cytoplasmic vacuolization [2], eosinophilic cytoplasm, and enlargement of myocardial fibers.

Notably, myocardial damage increased with increasing frequency (900, 1800, 2100 MHz) at an equal exposure duration (24 h/day) and with increasing exposure duration (6 h/day, 12 h/day, 24 h/day) at 1800 MHz. These results suggest a dose-response relationship. Young animals in the control group showed no damage; their myocardial tissue showed a typical structure with intact cell boundaries and endomysium.

The study was reviewed in ElektrosmogReport 3/2023 [3], where the results were evaluated as a constructive contribution to the understanding of the effects of radiofrequency electromagnetic field (RF-EMF) on heart muscle. However, shortly after the study was listed in the EMF Portal [4], the Competence Centre for Electromagnetic Fields (KEMF) of the German Federal Office for Radiation Protection (BfS) published a critical evaluation [5] that dismissed the study entirely. The evaluation concluded: “For this reason, the study does not provide a reliable contribution to the current state of knowledge regarding RF-EMF effects on the heart.”

However, the reasons given for dismissing the study do not address its purpose or findings. Therefore, this criticism must be rejected, as shown below.

### Misrepresentation of Published Facts

1. The BfS claims that it is unclear whether the pregnant rats were randomly assigned to the various exposure groups. This is incorrect. The study is explicitly described as a “randomized study” in the “Methods” section, in line with standard procedures to avoid bias.
2. Furthermore, the BfS claims that the pregnant rats were distributed among the cages. This is false: a male rat was assigned to each female rat cage for mating purposes. As a result, pregnancies began at different times. Exposure only began once pregnancy was confirmed. Therefore, the following criticism by the BfS is also unfounded: “It is not mentioned ... if exposure of the animals took place at the same time.” [5]. The procedure is indirectly described in the study.
3. The BfS also claims that it is unclear whether the unexposed animals were kept under the same environmental conditions as the exposed ones. This can be inferred from the section “Animal Care and Welfare,” especially since the Health Guidelines for the Care and Use of Laboratory Animals are referenced.
4. Another point of criticism is the small sample size, but it is well justified in the study’s “Discussion” section: “However, animal welfare should not be ignored in these animal studies. Thus, we used a minimal number of pregnant rats (n:3) per exposure group and we examined a minimal number of male pups (n:6) from these litters in our study.”

### Neglect of the Overall Context

The BfS criticizes the use of malondialdehyde (MDA), a biomarker for lipid peroxidation, and glutathione (GSH), an antioxidant, as invalid biomarkers of reactive oxygen species (ROS), concluding that “based on the methods and data, it cannot be deduced that RF EMFs play a role in the formation of oxidative stress, as stated by the authors.”

However, this criticism fails to acknowledge the contextual relevance of MDA and GSH within the study. This will be briefly outlined below.

As previously mentioned, the authors’ criticized statement is based on their research findings regarding a dose-response relationship between RF-EMF exposure and various types of heart muscle damage that do not occur in the absence of exposure. In addition, the consistency of these findings with similar results from other studies was demonstrated. These findings fulfill the essential Bradford Hill criteria [6] and thus largely confirm that RF-EMF exposure can be considered the cause of heart muscle damage. In other words, a causal relationship can be assumed.

Since other studies have repeatedly identified increased levels of ROS in organs exposed to RF-EMF, the authors examined

corresponding ROS markers, such as MDA and GSH, at the biochemical level to further confirm the causal relationship. The MDA and GSH findings showed (with one exception) a (statistically significant) dose–response relationship analogous to the heart muscle damage: The MDA value, which indicates lipid peroxidation (cell membrane damage), increased significantly with exposure duration (dose), while the GSH value, which indicates antioxidant glutathione concentration in cells, decreased accordingly.

However, the BfS criticized the study, stating that MDA is primarily a marker for lipid peroxidation, not necessarily ROS, as MDA can also be produced in other ways [7]. Therefore, one cannot automatically conclude that MDA is an ROS marker. However, one can conclude that ROS is a lipid peroxidation marker and, consequently, a marker for corresponding MDA values. The situation is similar with GSH values because GSH is only considered a valid ROS biomarker in *in vitro* experiments.

Therefore, the authors' statement that RF-EMF promotes ROS formation cannot be formally derived from the MDA/GSH data alone (!), meaning in isolation from the aforementioned findings. This was not the authors' sole basis for their claim. However, given that no heart muscle cell damage or lipid peroxidation occurred in the control group and that the exposed groups and the control group were otherwise exposed to the same test conditions, RF-EMF remains the only relevant factor that can explain the measured MDA and GSH values, as well as the dose–response relationship. Thus, the findings are consistent with the authors' assumption that RF-EMF exposure leads to an increase in ROS.

Since the BfS dismisses the authors' conclusion without considering the overall context of the argument, the BfS's criticism is incomprehensible and unjustified.

### **Failure to Consider the Relevance of Influencing Factors**

The BfS also criticizes the omission of information regarding blinding, the age of the pregnant rats, cage placement, and whether the control group's cage had a deactivated antenna. The BfS could have obtained these details from the study's authors. The BfS's conclusion that “a substantial risk of bias” [5] cannot be ruled out is suggestive and biased: The existence of a risk of bias cannot be assessed if nothing is known about how these influencing factors were considered. Conversely, one could easily conclude that, despite the undocumented influencing factors, the study is highly relevant.

In principle, a lack of information only justifies a neutral conclusion, such as “Cannot be conclusively assessed without further details.” A lack of information does not justify downgrading the study. It is entirely possible that all concerns could be resolved with more information.

Every study may omit certain factors. While this could be grounds for criticism, an essential aspect of evaluating a study's significance is often overlooked: Not all influencing factors car-

ry the same weight in determining a study's significance. Their actual impact may range from significant to negligible.

A balanced assessment must consider the relevance of both documented and undocumented factors. As long as the relevance of the various influencing factors is not explained and their weighting for an assessment is not carried out, the BfS's evaluation cannot be considered impartial.

Downgrading a study solely because of missing methodological details – without assessing their actual impact or acknowledging constructive findings – is like dismissing a flower that has not yet bloomed.

### **Summary**

1. Some of the BfS's criticism is unfounded and invalid because it ignored facts that were clearly presented in the study.
2. The BfS criticism disregards the study's overall logic. The authors' conclusions are questioned by taking isolated aspects out of context. Only through such dissection does the BfS manage to construct a misleading criticism.
3. Furthermore, the BfS dismisses the study based on a few missing methodological details. The BfS does not know whether or how these details were considered. However, the BfS assumes that they are highly relevant to the study's validity. The BfS acknowledges that the missing information on these influencing factors is necessary “to adequately assess the study's quality” [5]. Despite this lack of information, the BfS negatively assesses the study's validity. Pretending to be ignorant in order to discredit findings is logically misleading and deceptive.
4. A proper evaluation must consider and weigh the relevance of all influencing factors, both documented and undocumented. A few missing pieces of information do not justify dismissing the results.

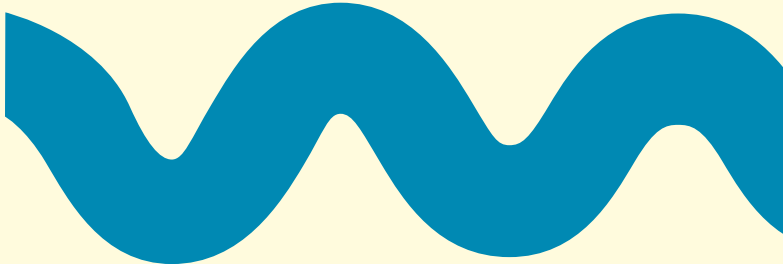
Thus, the BfS's final conclusion is based on pseudo-arguments. Moreover, its evaluation framework is all-or-nothing and maximalist. It dictates:

- a) which variables must be addressed,
- b) which correlations must be proven by which methods, and
- c) that a study must be downgraded if one or more influencing factors are not considered or documented, or if correlations are not proven with absolute certainty.

This method disregards established principles of balanced scientific evaluation, resulting in biased, questionable, and susceptible judgments. It also opens the door to misuse for partisan purposes.

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## Addresses for additional reliable information

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<http://www.biomedcentrum.sav.sk/research-departments/departments-of-radiobiology/?lang=en>

Shortened Link: [kurzlinks.de/belyaev](http://kurzlinks.de/belyaev)

Blog by Prof. Darius Leszczynski (Finland):

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## Databases:

[www.emfdata.org](http://www.emfdata.org)

[www.emf-portal.de](http://www.emf-portal.de)

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