

Bulletin de veille
Champs électromagnétiques
N°17 – Aout/Septembre 2026

Objectif : surveillance de la littérature scientifique concernant les impacts sur la santé humaine de l'exposition aux champs électromagnétiques

La validation des informations fournies (exactitude, fiabilité, pertinence par rapport aux principes de prévention, etc.) est du ressort des auteurs des articles signalés dans la veille. Les informations ne sont pas le reflet de la position de l'INRS.

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Exposition professionnelle

Kevlar reinforced carbon nanotube fabrics for EMI shielding: Scalable solutions for industrial and occupational protection,
Giri, P., Fang, Q., Kondapalli, V., Marzana, M., Mast, D., Shanov, V. and Schulz, M., *Synthetic Metals*, Oct 2026, Vol. 321.

Pristine carbon nanotube (CNT) fabric and Kevlar-reinforced CNT-silicone fabric were fabricated using a modified continuous floating catalyst chemical vapor deposition synthesis process. This scalable method produced fabrics measuring 25 cm & times; 90 cm, with thickness controlled via synthesis time. The CNT-based fabrics were flexible, electrically conductive, and reinforced with Kevlar yarn, fabric, or veil materials. Single-layer configurations exhibited electromagnetic interference (EMI) shielding effectiveness (SE) between 25 and 65 dB in the 8-12 GHz frequency range. Notably, multilayered assemblies of pristine CNT and CNT-silicone/ Kevlar composite fabrics achieved an EMI

SE of approximately 80 dB-one of the highest reported for CNT-based materials. These fabrics can be seamlessly incorporated into textiles and garments using conventional fabrication techniques. To demonstrate their practical applicability, an EMI shielding wallet was fabricated by stitching these fabrics together. Overall, this study presents high-performance EMI shielding fabrics with tunable specific shielding effectiveness ranging from 3700 to 70,000 dB & sdot;cm2/g, making them highly adaptable for various applications in defense, aerospace, communication, occupational safety, and industrial settings. Furthermore, the findings reinforce the notion that while electrical conductivity significantly influences EMI SE, it is not the sole determining factor. https://doi.org/10.1016/j.synthmet.2026.118262

Compact metasurface track-side PIS antenna-based occupational electromagnetic exposure research of inspectors in the metro tunnel,
Luo, M., Xu, J., Zhou, W., Li, X. and Lu, M., *Frontiers in Public Health*, Sep 3 2026, Vol. 14.

Introduction With the advancement of Smart Urban Rail construction, the electromagnetic environment has become increasingly complex inside metro tunnels. Track-side inspectors may experience occupational radio-frequency (RF) exposure when conducting professional inspections in such a closed electromagnetic environment.Methods In order to analyze the occupational electromagnetic exposure dose absorbed by the track-side inspectors,and explore a method to reduce the influence of RF electromagnetic radiation. We propose a compact metasurface track-side passenger information system (PIS) antenna at first, and verify its good radiation performance. Then we compare the electromagnetic exposure metrics in the track-side inspectors human model when they are exposed to the conventional track-side PIS antenna and the proposed track-side PIS antenna at 5.8 GHz.Results The simulation results show that, the peak local specific absorption rate (SAR) is reduced by at least 39.83% in the trunk, skull, brain, heart, liver, and testes after the antenna is miniaturized by 53%.Discussion The findings indicate that the proposed track-side PIS antenna can reduce the external radiation energy, thereby reducing its impact on the surrounding environment. This research provides a theoretical analysis for occupational RF exposure safety of track-side inspectors and offers a dosimetry reference for antenna design in metro tunnel communication systems. https://doi.org/10.3389/fpubh.2026.1893518

Editorial: Non-ionizing radiation: impacts on human health from exposures in occupational settings,
Modenese, A., Nogueira, C. and Wittlich, M., *Frontiers in Public Health*, Jul 13 2026, Vol. 14.
https://doi.org/10.3389/fpubh.2026.1880564

Occupational exposure to extremely low-frequency fields and cardiovascular consequences: a systematic review,
Raeisi, E., Maghare Dehkordi, S., Yazdanirad, S. and Mohammadian-Hafshejani, A., no. 0301-0422 (Print). 2026

OBJECTIVE: Exposure to extremely low-frequency (ELF) electromagnetic fields can have harmful effects on human health. The present systematic review study aimed to investigate the relationship between occupational exposure to ELF and cardiovascular outcomes. METHODS: Searches were conducted in six electronic bibliographic databases: Scopus, PubMed, Web of Science, Embase, MEDLINE, and Google Scholar. This search included records up to August 19, 2026. The search strategy used two sets of keywords. Following the selection of proper studies, relevant data were extracted by the reviewers. To assess the risk of bias in the included studies, the Joanna Briggs Institute checklist was used. RESULTS: Seven of fourteen studies (50 percent) showed that there is an association between ELF field exposure and cardiovascular outcomes. However, the available

evidence is insufficient to establish causality. Some of the outcomes reported in the studies included acute myocardial infarction, arrhythmia, hematological parameters, coronary heart disease, and hypertension. CONCLUSION: Exposure to ELF fields may be associated with some cardiovascular outcomes. However, the confirmation of this relationship remains ambiguous, and it requires further investigations in future research. https://doi.org/10.3389/phrs.2026.1609952

Occupational electromagnetic field exposure and sleep disturbances: The predominant role of high-frequency electric fields,
Soumillion, M., Remy, V., Petrovic, D., Dil, J. and Canu, I., *International Journal of Hygiene and Environmental Health*, Aug 2026, Vol. 277.

Electromagnetic fields (EMFs) are ubiquitous and include low-frequency magnetic fields (LF-MF) from alternating currents, low-frequency electric fields (LF-EF) from wiring and equipment, and high-frequency electric fields (HF-EF) from wireless technologies and broadcast antennas. Bus drivers are exposed to an EMF mixture and report higher rates of sleep disorders than the general population. This study aimed to examine associations between sleep disturbances and cumulative occupational EMF exposure over 12 months, considering individual components and the mixture. EMF exposure estimates from the Swiss bus-exposure matrix were matched to the occupational history of 351 TRAPHEAC study bus drivers. Sleep quality, insomnia, and excessive daytime sleepiness (EDS) were assessed using the Global Sleep Assessment Questionnaire. Associations with cumulative EMF exposure were evaluated using multivariable linear regression controlled for age, sex, occupational noise, and nightshift work, and heat exposure. Mixture effects were analyzed with Bayesian Kernel Machine Regression (BKMR), and the influence of non-occupational EMF exposure was examined via stratification. Multivariable linear regression showed positive associations of HF-EF, but not LF-EF or LF-MF, with insomnia and EDS, although models explained little variance. BKMR confirmed the predominance of HF-EF in the mixture effect, with a positive but statistically non-significant dose-response for the EMF mixture. Stratified analyses suggested stronger associations among drivers with low non-occupational EMF exposure. These findings suggest a dose-response relationship between occupational EMF mixture exposure and sleep disturbances, primarily driven by HF-EF. However, the overall variance explained by EMF exposure is small, highlighting the role of other risk factors in sleep disturbances among bus drivers. https://doi.org/10.1016/j.ijheh.2026.114886

Evaluation of the additional occupational risk for workers with orthopedic implants in MRI settings,
Zilberti, L., Arduino, A., Busoni, S., Camisa, V., Cannatà, V., Magistrelli, A., Miele, V., Oberhofer, N., Origgi, D., Pradella, S., Zanovello, U. and Bottauscio, O., *Annals of Work Exposures and Health*, Oct 2026, Vol. 70, no. 7.

Objective To provide quantitative information that can aid the relevant authority in deciding whether workers with metallic nonferromagnetic orthopedic implants can work in proximity to magnetic resonance imaging (MRI) scanners, including when the exam is being performed.Methods Virtual experiments in which the exposure of workers with and without prostheses is evaluated through numerical simulation of realistic human models, with reference to 4 physical effects: radiofrequency (RF)-induced heating, gradient-induced heating, gradient-induced peripheral nerve stimulation, and mechanical actions related to the Lenz effect.Results In the presence of the considered implants, the extent of RF-induced heating and of the electric field responsible for peripheral nerve stimulation is low and comparable to what is observed without the prostheses. The extent of gradient-induced heating and Lenz effect, which occur only in the presence of implants, is minimal.Conclusion As long as the body of the worker with passive non-ferromagnetic orthopedic implants remains outside the MRI scanner, the incremental risk posed by the presence of the implants is negligible. The Lenz effect

is weak even if the part of the worker's body with an implant enters the scanner bore. https://doi.org/10.1093/annweh/wxag067

Etudes épidémiologiques

Electrophysiology of vision after smartphone use,
El Mekkawy, L., Hussein, A., Maher, E., Mohammed, M. and Shalaby, M., *Egyptian Journal of Neurology Psychiatry and Neurosurgery*, Sep 3 2026, Vol. 62, no. 1.

Background Smart phones emit electromagnetic radiation and blue light which cause many effects on retina and CNS. The aim is to investigate MP usage effect on vision in healthy adults by using VEP and ERG and to correlate these effects with age and previous usage duration.Results 70 healthy participants were subjected to one hour exposure to a smart phone set at 30 cm distance from eyes. P-VEP and ERG (pattern, full field flash and multifocal) were recorded pre and post exposure. Correlations with age and with prior history of duration of usage were analyzed. Significant P100 latency delay was reported in P-VEP. No effect on P-ERG was observed. F-ERG showed a high statistically significant reduction in b wave amplitude. MF ERG showed a statistically significant P1 amplitude reduction and latency delay. P100 latency increase showed a positive correlation with age and a negative one with prior exposure duration. F-ERG showed significant negative change in (a) wave latency with age but no significant one with MP usage duration. Regarding MF ERG, there was significant negative correlation of P1 wave with age and with the duration of MP usage.Conclusion Practicing mindful mobile device utilization to minimize possible undesirable effects on vision is advised. These effects were more obvious in central retina. Long duration of previous use of MP increases tolerance of electro-diagnostic tests of vision to acute exposure though impairing basal function. ERG is more affected in young age, but VEP is more impaired in old age after acute MP exposure. https://doi.org/10.1186/s41983-026-01226-w

Maternal mobile phone use during pregnancy versus early childhood in relation to behavioral problems in preschool-aged children: A prospective cohort study,
Joo, H., Choi, J., Lim, H., Choi, H., Lee, A., Moon, J. and Ha, M., *Environmental Research*, Sep 15 2026, Vol. 306.

Evidence on the effect of maternal mobile phone use on child behavioral development remains inconsistent, particularly regarding the relative importance of the prenatal and early childhood exposure periods. We aimed to examine associations between maternal mobile phone call duration during pregnancy and early childhood and behavioral problems in preschool-aged children. We analyzed data from the Mothers and Children's Environmental Health (MOCEH) prospective birth cohort. Maternal mobile phone use was measured by questionnaire during pregnancy and at ages 3-5 years, and child behavioral problems were assessed using the Korean Child Behavior Checklist (K-CBCL) at ages 4, 5, and 6 years. Maternal daily call duration (minutes/day), used as a proxy indicator of mobile phone use, was calculated from daily call frequency and average duration per call. Associations with behavioral problem scores were estimated using linear mixed-effects models in sub-cohorts with available exposure information for the whole period (n = 780), pregnancy (n = 763), and early childhood (n = 418). Mutually adjusted models accounted for maternal mobile phone use during the other exposure period, with missing information treated as a separate category. Early childhood maternal mobile phone use was significantly associated with higher total ((3 = 1.37, 95% CI: 0.46-2.28) and externalizing ((3 = 1.44, 0.54-2.33) problem scores, whereas prenatal use was not. Sex-stratified analyses showed associations for total and externalizing problems in males and internalizing problems in females. These findings suggest that maternal mobile phone use during early childhood, rather than pregnancy, is associated with child behavioral problems, pointing to the caregiving

pathways, such as interruptions in parentchild interaction caused by technology use, as a plausible explanation. https://doi.org/10.1016/j.envres.2026.125314

Exposure to 5G Radiofrequency and Physiological Effects in Healthy Young Adults: Insights Into Heart Rate Variability and Salivary Stress Biomarkers,
Layla, J., Lisa, M., Stéphane, D., Raphaël, B., Laurent, H., Paul, M., Philippe, L., Tamara, B., Erwan, S. and Brahim, S., *Bioelectromagnetics*, Jul 2026, Vol. 47, no. 5.

This study investigated the potential impact of fifth-generation (5 G) radiofrequency (RF) on the autonomic nervous system (ANS). Electrocardiograms (n = 43) and salivary samples (n = 33) were collected from healthy young volunteers before, during, and after exposure to a 3.5 GHz frequency (electrical field intensity similar to 1-2 V/m) emitted by an antenna while participants were seated at rest. Heart-rate (HR) and heart rate variability (HRV) indices, including time and frequency domain measures, were analyzed from short-term epochs during both "real" and "sham" exposure sessions, under eyes-open (EO) and eyes-closed (EC) conditions. Initial variations in RR intervals and HR were observed during 5 G exposure; however, these effects were not confirmed by post-hoc analyses after correction for multiple comparisons, suggesting the absence of consistent exposure-related modulation. The only statistically significant result was a time-by-exposure interaction for the RMSSD parameter during the final exposure period. This effect was small in magnitude, limited to a single time point, and not supported by other parasympathetic indices, and should therefore be interpreted cautiously as it may reflect normal physiological variability or a statistical artifact. No consistent exposure-related effects were detected in salivary stress biomarkers, including cortisol, alpha-amylase, and chromogranin A. Although minor variations were observed in some measures, all values remained within normal physiological ranges, and their clinical relevance remains uncertain. These findings are restricted to the specific experimental conditions examined, namely short-term far-field exposure (25.5 min) at low specific absorption rate (SAR) levels (0.008 mW/kg in the brain). Overall, the results provide preliminary baseline human data at 3.5 GHz rather than confirmatory evidence of biological effects. Further studies involving larger cohorts and longer exposure durations are required to determine whether subtle or cumulative autonomic effects of 5 G exposure can be reliably detected. https://doi.org/10.1002/bem.70056

A systematic review of mobile phone use and pregnancy and fetal outcomes,
Wang, M., Zhang, Y., Angley, M., Kleiman, N., Wang, X. and Kahe, K., *Journal of Exposure Science and Environmental Epidemiology*, 2026.

Background Pregnancy is a crucial period characterized by profound maternal and fetal biological changes and increasing susceptibility to environmental influences. The widespread use of mobile phones has raised concerns regarding potential health effects during pregnancy. Mobile phones emit non-ionizing radiofrequency electromagnetic fields (RF-EMF), which could affect fetal development through thermal and non-thermal mechanisms. Research on mobile phone use during pregnancy remains limited and yields mixed findings.Objective This review systematically evaluated evidence on the associations between maternal mobile phone use-specifically frequency and duration-and pregnancy outcomes.Methods Comprehensive PubMed, Web of Science, and Google Scholar searches identified 20 studies meeting the predetermined inclusion criteria. Covidence was used for title and abstract screening.Results While several studies reported no significant health threat, others suggested an association with adverse pregnancy outcomes. The most consistent evidence emerged for alterations in fetal and neonatal cardiac function and increased risk of preterm birth, highlighting a need for further targeted research on system-specific vulnerabilities. https://doi.org/10.1038/s41370-026-00958-4

Evaluation de l'exposition

Citizen science-based mapping of radiofrequency electromagnetic field exposure in Europe: A proof-of-concept validation study,
Baruah, A., Sandoval-Diez, N., Belácková, L., Roga, L., Jalilian, H., Fröhlich, J., Thielens, A., Röösli, M. and Huss, A., no. 1096-0953 (Electronic). 2026

Characterising population-level radiofrequency electromagnetic field (RF-EMF) exposure from mobile telecommunications networks at fine spatial resolution has been limited by the cost and scale of conventional measurement methods. The ETAIN 5G Scientist app, developed within the ETAIN (Exposure To electromAgnetic fIelds and plaNetary health) project uses citizen science smartphone data to produce calibrated RF-EMF exposure maps for 4G/5G networks at 25 × 25 m(2) spatial resolution across Europe. As of 2026, the app had collected over 19 million measurements globally. We conducted a proof-of-concept validation of these exposure maps in two European cities with contrasting urban and network characteristics: Utrecht (Netherlands) and Basel (Switzerland). Walking measurement campaigns used the ETAIN app installed on smartphones and the ExpoM-RF4 reference exposimeter carried simultaneously in a backpack. App-derived exposure estimates were compared with spatiotemporally matched reference measurements at the grid-cell level. Validation was performed separately for 4G Long-Term Evolution (LTE) and combined 4G LTE and 5G New Radio (NR) environmental exposure estimates. 4G LTE exposure estimates correlated strongly with measured exposure in both Utrecht (r(s) = 0.87, 95% CI: 0.80-0.91, N = 127) and Basel (r(s) = 0.71, 95% CI: 0.63-0.78, N = 214; both p < 0.001). The combined 4G LTE and 5G NR exposure estimates correlated strongly in Utrecht (r(s) = 0.88, 95% CI: 0.81-0.92; 19.7% of grid cells with 5G NR detection) but showed moderate correlation in Basel (r(s) = 0.41, 95% CI: 0.29-0.53; 45.3% of grid cells with 5G NR detection). Sensitivity analyses showed map reliability stabilised at five or more observations per grid cell and improved when data from at least two network operators were combined. These results demonstrate that the ETAIN 5G Scientist application can produce validated, spatially continuous RF-EMF exposure maps at scale. The approach is well suited for characterising exposure trends as mobile networks continue to evolve. https://doi.org/10.1016/j.envres.2026.125886

Assessment of Electromagnetic Field Exposure from Multiple Sources Simultaneously in the High-Frequency Range Based on Safety Standards
Chutchavong, V., Aroonmitr, P. and Ieee (2025). 2025 SICE Festival with Annual Conference-SICE FES, Chiang Mai, THAILAND.

This study presents a method for evaluating electromagnetic field (EMF) exposure from multiple sources operating simultaneously across a wide range of frequencies, based on the guidelines defined by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) in its 2020 publication. The proposed approach adopts the normalized exposure ratio, which combines the exposure values from all relevant sources and frequency bands. A key issue addressed in this study is the lack of standardized measurement methods for absorbed power density (Sab) in high-frequency bands above 10 GHz, despite the existence of defined exposure limits. A comparison reveals that the difference between the limits for Sab and incident power density (Sinc) for the general public is relatively small when compared to the gap between the general public and occupational exposure limits. Therefore, the use of Sinc is proposed as a temporary surrogate for Sab in frequency ranges where direct measurement is not yet feasible. This approach enables comprehensive exposure assessment from multiple sources under both near-field and far-field conditions. It also serves as a practical alternative while Sab measurement techniques for high-frequency applications such as 5G, WiGig, and next-generation wireless technologies are still under development. https://doi.org/10.23919/SICEFES67750.2025.11236585

Low-frequency magnetic flux density levels in various exposure scenarios: a measurement-based study,
Dobruna, J., Ibrani, M., Maloku, H. and Fazliu, Z., *Radiation Protection Dosimetry*, 2026.

The increasing exposure to low-frequency electromagnetic fields has raised significant concerns regarding its potential effects on human health and the environment. At the same time, it has spurred growing interest in identifying low-exposure scenarios to support green and sustainable objectives. This study presents the results of in situ measurements of magnetic flux density across various exposure scenarios. Measurements were also conducted at close distances from different photovoltaic panels to summarize magnetic flux density exposure levels. Additionally, the study includes the measurement of magnetic flux density at various locations within electric, mild hybrid, and hybrid vehicles. To our knowledge, this is the first time such measurements have been reported for the region of Kosovo, providing initial valuable data for assessing exposure levels for both the general population and workers. The results offer a basis for comparative studies with other countries, contributing to the global understanding of electromagnetic field exposure. https://doi.org/10.1093/rpd/ncag104

Comparison of electromagnetic exposures from the positioning antenna of driverless vehicle in adult and child passengers,
Dong, X., Ren, Y. and Lu, M., *Archives of Electrical Engineering*, 2026 2026, Vol. 75, no. 2, p. 265–285.

With the rapid development of driverless systems technologies, the differences in electromagnetic exposure levels amongst passengers of different ages have become a research hotspot in this field. This study focuses on the electromagnetic exposure of adults and children inside an electric vehicle caused by positioning antennas of driverless systems. Based on the COMSOL Multiphysics software, an electromagnetic numerical calculation model is established, including a vehicle body model, an antenna model, and separate models for an adult and child. Considering the differences in body size and dielectric properties between adults and children, the finite element method is used to calculate exposure levels under the electromagnetic environment generated by the positioning antenna. The results reveal that the electromagnetic exposure level in a child's body is higher than that in an adult due to the former's smaller body size and higher dielectric parameters. This study facilitates the evaluation of the electromagnetic environment of positioning antennas in electric vehicle driverless systems, provides a basis for improving electromagnetic radiation safety standards inside electric vehicles, and promotes the rapid development of electric driverless technologies while ensuring public health and safety. https://doi.org/10.24425/aee.2026.158259

Human Exposure to Electromagnetic Fields in 6G Office Settings With RIS Technology,
Gallucci, S., Benini, M., Fiocchi, S., Chiaramello, E., Tognola, G. and Parazzini, M., *Ieee Journal of Electromagnetics Rf and Microwaves in Medicine and Biology*, 2026.

Objectives: This study evaluates human exposure to radiofrequency electromagnetic fields in an office environment equipped with Reconfigurable Intelligent Surfaces (RIS), a key technology for 6G networks. Method: Using a two-steps methodology combining raytracing for electric field estimation and Specific Absorption Rate (SAR) calculations, we assessed whole-body (wbSAR) and brain (brainSAR) exposure levels in female and male models under multiple beam configurations at 3.5 GHz. Two scenarios were investigated: RIS beam is intended to be i) directed toward workstations and ii) toward a hypothetical moving user. The analysis included spatial distribution mapping of exposure levels, peak SAR value assessment, and statistical analysis of anthropometric and posture-related differences across various beam configurations. Results: Results reveal that brainSAR peak values in most cases exceeds wbSAR peak values, with exposure levels being highly dependent on beam

configuration, subject posture, and its anatomical characteristics. The present study revealed that, in the simulated indoor scenario, the anatomy-related and posture-related differences in terms of exposure levels vary within the environment depending on the relative position of the human body and the RIS. Notably, non-users may experience higher exposure than intended users due to main beam interception at different heights. However, all the exposure levels found are well below the limits recommended by the ICNIRP guidelines. Clinical or Biological Impact: The exposure assessment demonstrates that EMF absorption from RIS technology varies based on individual anatomy and posture, with important implications for designing indoor 6G environments depending on diverse user profiles. https://doi.org/10.1109/jerm.2026.3719474

Levels of electromagnetic radiation from telecommunication towers in Dar es Salaam, Tanzania: implications for public exposure and regulatory compliance. LID - 1180 [pii] LID - 10.1007/s10661-026-16044-z [doi],
John, M. Z. and Macha, I. a.-O., no. 1573-2959 (Electronic). 2026

The rapid expansion of telecommunication infrastructure has intensified public concerns regarding exposure to radiofrequency electromagnetic fields (RF-EMFs). This study evaluates electromagnetic field (EMF) levels and power densities emitted by telecommunication towers in Dar es Salaam, Tanzania, and benchmarks them against international exposure standards. A cross-sectional design was employed involving 40 base transceiver stations. Electric field strength measurements were conducted using a calibrated Narda SRM-3006 frequency-selective radiation meter, while power density was computed using standardized propagation models. Statistical analyses were performed using SPSS (v23), including descriptive statistics, correlation analysis, and independent t-tests. The mean EMF and power density were 1.654 ± 0.457 V/m and 0.0073 W/m(2), respectively. No significant correlation was observed between field-measured EMF values and regulatory data (r = 0.031, p = 0.788), suggesting methodological and temporal discrepancies. All measured values were substantially below the ICNIRP exposure limits. However, comparison with more stringent national thresholds indicates potential long-term precautionary concerns. These findings advance the understanding of RF-EMF exposure and underscore the need for future research to prioritize emerging communication technologies, network densification, and evolving urban environments, where meaningful variations in exposure are more likely to occur, rather than routinely replicating measurements under comparable conditions. https://doi.org/10.1007/s10661-026-16044-z

Real-World Assessment of RF-EMF Exposure From 3G, 4G, and 5G Mobile Networks Across Different Urbanization Levels,
Lee, A., Jeon, S., Hong, S., Wang, S., Wiart, J., Samaras, T. and Moon, J., *Ieee Access*, 2026 2026, Vol. 14, p. 134636–134653.

As 5G mobile networks become increasingly widespread, realistic assessment of radio-frequency electromagnetic field (RF-EMF) exposure in modern mobile-network environments is becoming increasingly important. This study characterized real-world downlink (DL) and uplink (UL) RF-EMF exposure across different urbanization levels in South Korea using commercial 3G, 4G, and 5G mobile networks. DL electric-field strengths and UL transmit powers were simultaneously measured in urban and rural environments using frequency-selective field measurements and mobile-network logging systems. The measured exposure levels were used to calculate brain specific absorption rate (SAR) using anatomically realistic child and adult numerical models. The results showed that, under the measurement and dosimetric conditions considered in this study, brain SAR associated with DL exposure from base-station infrastructure was comparable to or exceeded that associated with UL exposure in most tested scenarios. Urban-rural differences in whole-brain-averaged SAR reached 6.2 dB for the child model and 5.7 dB for the adult model, whereas age-related differences were

substantially smaller. These findings indicate that environmental and network-infrastructure factors are major determinants of RF-EMF exposure variability in dense modern mobile-network environments. By integrating real-world measurements with anatomically realistic dosimetry, this study provides a practical framework for RF-EMF exposure assessment and characterization in evolving mobile communication networks. https://doi.org/10.1109/access.2026.3728447

Research Progress on High-Frequency Electromagnetic Environments in the Internet of Vehicles, Li, J., Lu, M. and Wang, S., *Electronics*, Aug 2 2026, Vol. 15, no. 15.

With the increasing demand for clean energy and low-carbon transportation, next-generation vehicles integrating high-frequency electronic systems have become more complex, raising concerns about in-vehicle electromagnetic exposure. This paper reviews high-frequency devices operating in the 30 kHz-300 GHz range and systematically analyzes the spatial distribution and key frequency characteristics of electromagnetic sources in vehicles. The results show that, even under worst-case conditions, electromagnetic exposure levels for occupants remain well below the safety limits defined by ICNIRP. For example, in a worst-case 5.9 GHz V2V communication scenario, the driver's head SAR10g reaches 0.981 W/kg (9.81% of the ICNIRP occupational limit), while the whole-body SAR is only 0.008728 W/kg with negligible temperature rise. Other systems, including 5G-V2X, automotive radar, and mobile phones, also produce exposure levels far below safety thresholds. These findings suggest that RF exposure levels for vehicle occupants remain low relative to current guideline limits under the assessed scenarios. However, key challenges remain, including limited studies on multi-source exposure, insufficient data on vulnerable populations, simplified simulation conditions, lack of standardized validation methods, and inadequate assessment of emerging technologies. This work provides a quantitative basis for future safety standards and highlights critical research directions. https://doi.org/10.3390/electronics15153418

A Georeferenced Dataset of Electromagnetic Field Exposure Measurements in Colombia, Ocampo-Rodríguez, D., Ramirez-Ramirez, D. and Correa-Alvarez, C., *Data*, Aug 21 2026, Vol. 11, no. 8.

This Data Descriptor presents a georeferenced dataset of electromagnetic-field exposure measurements collected in Colombia between 2 November 2023 and 30 June 2024. The records originate from the Sistema de Monitoreo de Campos of the Agencia Nacional del Espectro (ANE), which uses isotropic probes to monitor broadband radiofrequency electromagnetic fields from 100 kHz to 8 GHz and reports six-minute averages of incident power density in W/m(2). The comma-separated value file contains 1,286,346 timestamped records and seven source variables, including Well-Known Text (WKT) point geometry. The principal 2024 subset comprises 995,238 records from 24 monitoring stations. We provide a reproducible workflow for timestamp and coordinate parsing, structural and numeric validation, station-level aggregation, and spatial sensitivity analysis using inverse distance weighting with the mean, median, and 95th percentile. The dataset does not provide frequency-resolved measurements, calibration certificates, or measurement-uncertainty budgets; these omissions limit the use of the public file for formal regulatory-compliance assessment. The accompanying repository includes validated station-level summaries, descriptive tables, figures, and reproducible R code. The package supports environmental monitoring, geospatial analysis, methodological comparison, and reproducible reuse of electromagnetic-field exposure data. https://doi.org/10.3390/data11080211

Justification of sanitary protection zones for 0.4-330 kV overhead power lines based on magnetic field exposure and normalization of its levels,

Rozov, V., Dumanskyi, V., Pelevin, D. and Kundius, K., *Electrical Engineering & Electromechanics*, 2026 2026, no. 5, p. 85–95.

Problem. In Ukraine, the current sanitary protection zones (SPZ) and right-of-way (ROW) zones of overhead power lines (OHLs), within which the construction of residential buildings is prohibited, are established by regulatory legal acts solely based on the criterion of electric field (EF) strength, without taking into account magnetic field (MF) flux density. This situation poses a serious threat to the health of the population living near OHLs, since, unlike the EF, the MF has a significantly higher penetrating capacity and, under conditions of long-term exposure, exhibits carcinogenic properties. Furthermore, the features of MF distribution outside the current OHL ROW zones remain insufficiently studied. This creates risks of widespread population exposure exceeding the maximum permissible level of the MF. Goal. Substantiation of the boundaries of SPZ for designed 0.4-330 kV OHLs based on the regulatory MF flux density level of 0.5 mu T, and the development of rational methods for normalizing the MF level of existing OHLs. Methodology. A comprehensive combination of theoretical and experimental studies of the MF flux density distribution of 0.4-330 kV OHLs outside their current ROW zones, as well as a comparative sanitary and hygienic assessment of the obtained data. Results. The necessity of expanding the boundaries of ROW (SPZ) zones for 110-330 kV OHLs and utilizing developed & laquo;magnetically clean & raquo; OHLs to ensure the protection of public health from MFs has been substantiated. Scientific novelty. It has been theoretically proven and experimentally confirmed that it is the MFflux density, rather than the EF strength, that is the determining factor for establishing safe boundaries of OHL SPZ. The necessity of establishing the SPZ width at 30 m for 110 kV OHLs and 83 m for 330 kV OHLs is substantiated. The synthesis of & laquo;magnetically clean & raquo; OHLs based on the method of vector MF compensation has been performed. Practical value. Practical recommendations have been developed for normalizing OHL MF flux density by increasing the width of the SPZ (PZ) for 110-330 kV OHLs, and constructing synthesized & laquo;magnetically clean & raquo; OHLs for their local use in critical areas during the modernization of existing legacy OHLs. References 56, tables 3, figures 11. https://doi.org/10.20998/2074-272x.2026.5.11

Analytical Method for Calculation of Electromagnetic Fields From Armoured HVAC Cables, Rzempoluch, J., Goddard, K., Callender, G., Chaudhary, S., Dix, J. and Lewin, P., *Ieee Transactions on Power Delivery*, Aug 2026, Vol. 41, no. 4, p. 1771–1782.

With the proliferation of HVAC armoured cables in offshore wind applications, the provision of methods for the calculation of both magnetic and electric field effects from HV cables is of high importance for consenting processes associated with offshore wind development and biological experiments. Despite electro-reception of marine animals being a known phenomenon, the electric fields present outside of HVAC cables, mostly induced as a result of the time-varying magnetic vector potential, have not been thoroughly analysed in literature. The available methods for the calculation of magnetic fields are often complex and require an expert user. In this work, this knowledge gap is addressed through the development of an analytical method, with some parameters derived from simple numerical simulations, that can be applied to both magnetic and electric fields and by provision of MATLAB code for calculation of both effects. The presented method includes the impact of metallic sheaths, cable twist, and magnetic armour. For the development of electric field expressions, the impact of the insulating layer at the cable outer boundary is considered. The presented results are within 3% of the numerical solution for the magnetic and electric field norm and within 5% for the individual components of the fields. https://doi.org/10.1109/tpwrd.2026.3671454

Measurement of Public Ambient Non-Ionizing Radiation (NIR) Exposure Level at Selected Area Around Malaysia,

Sabri, N., Zailani, N., Zafar, S., Umar, R., Ghazali, M., Misbah, S., Tukiman, R. and Pang, N., *Jurnal Fizik Malaysia*, 2026 2026, Vol. 47, no. 1, p. 10121–10134.

The rapid expansion of telecommunication infrastructure has raised public concern regarding ambient non-ionizing radiation (NIR) exposure. This study quantifies ambient NIR exposure levels, in terms of electric field strength (V/m), at 14 specific points across 5 locations in Malaysia, categorized into populated and unpopulated areas. Measurements were conducted during the daytime using a Keysight Field Fox RF spectrum analyzer supporting frequencies up to 4 GHz, with the instrument positioned at an average human exposure height of 1.5 meters. Results demonstrated that denser human populations significantly increase exposure levels; populated areas recorded a maximum electric field strength of 12.33 V/m at an open football field, compared to a maximum of only 2.14 V/m at Bukit Bunga in unpopulated zones. The primary contributors to these ambient NIR levels were identified as the GSM 900, GSM 1800, UMTS 2100, and LTE 2600 MHz networks. Crucially, all measured electric field strengths safely fall far below the 61 V/m reference limit recommended by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) for the general public. These findings provide critical baseline data for future RF-EMF temporal monitoring and regulatory planning. https://jfm.ifm.org.my/vol_iss/24

Electromagnetic Field Exposure of Vulnerable Road Users to Stationary Road Side Units

Struck, T., Altinel, B., Bomkessel, C., Hein, M. and Ieee (2025). 2025 International Automated Vehicle Validation Conference-IAVVC, Baden-Baden, GERMANY.

Until to date, there is a lack of comprehensive risk assessment regarding electromagnetic exposure from automated and connected transportation, which might raise public concerns. Aiming to provide appropriate data for risk communication related to automated and connected vehicle ecosystems and associated electromagnetic emissions, we propose a mobile, time- and location-resolved field measurement approach based on ambient vehicle-to-everything communication (V2X) detection and data processing. Initial field measurements were performed in the living-lab environment of the city of Ilmenau, Germany, to investigate the electromagnetic field exposure from stationary roadside units to bypassing vulnerable road users. The maximum instantaneous V2X field exposure measured was found to be 98 dB(mu V/m) corresponding to 0.12% of the E-field reference level from the international ICNIRP98 guideline. As the electromagnetic exposure depends on the presence and varying density of transmitting V2X units as well as the wireless propagation channel, the results provide a snapshot of the respective communication environment. The proposed measurement approach bears great potential for any type of time- and location-resolved V2X field measurements. https://doi.org/10.1109/iavvc61942.2025.11219574

Experimental Mapping of the Human Exposure to Time Varying Magnetic Fields

Vergne, C., Nicolas, H., Hemm, S., Pascal, J., Madec, M., Lambert, M. and Ieee (2025). 2025 IEEE Sensors Conference-SENSORS, Vancouver, CANADA.

Evaluating experimentally the human exposure to time varying magnetic fields is often complex due to the strongly non-homogeneous magnetic field observed near electromagnetic devices. This study investigates the use of an in-house ac magnetic field camera (MFC) to map the exposure coefficients defined by standards and guidelines (ICNIRP and ICES). As a case study this paper reports on the spatial distribution of the magnetic field exposure coefficients of a neurosurgical tracking system. Although initial field strengths were low, the frequency analysis revealed that exposure coefficients exceeded recommended limits in worst-case scenarios. To mitigate this, a bandwidth limitation of the magnetic field generated by the tracking system was implemented effectively reducing exposure levels. These results highlight the importance of optimized system design and signal processing to ensure compliance with safety standards in surgical applications. https://doi.org/10.1109/sensors59705.2025.11330974

Research on the Electromagnetic Environment inside an Electric Vehicle under the Excitation of an Internal Radiation Source
Zhang, S., Zhao, Y., Zhao, H. and Ieee (2025). 2025 International Conference on Numerical Electromagnetic and Multiphysics Modeling and Optimization-NEMO-Annual, Tianjin, PEOPLES R CHINA.
With the widespread adoption of intelligent electric vehicles, studying their internal electromagnetic environment has become increasingly critical for ensuring electromagnetic compatibility and human safety. This paper studies a simplified vehicle and a single medium human body model, with an antenna mimicking an internal radiation source. Full-wave simulation software analyzes the electromagnetic environment at four points and on an observation plane. Results show that the human body can affect the electric field intensity, with its absorption of electromagnetic waves. The findings contribute to understanding the electric vehicle electromagnetic environment and related safety issues. https://doi.org/10.1109/nemo62710.2025.11215441

Toxicité

High Voltage, High Stakes Assessing Cardiovascular Effects of Electromagnetic Fields From Electric Vehicles,
Dewi, I., Anggitama, A., Yusrizal, T. and Dewi, K., *Jacc-Asia*, Aug 2026, Vol. 6, no. 8, p. 1692–1699.

Electric vehicles (EVs) are increasingly adopted worldwide as a sustainable alternative to internal combustion engine vehicles. Alongside their environmental advantages, concerns have emerged regarding the potential health impacts of electromagnetic field (EMF) exposure generated by EV components and charging processes. This review aims to summarize current evidence on cardiovascular effects associated with EMF exposure from EVs. Relevant studies from PubMed, ScienceDirect, and SCOPUS were evaluated for EMF exposure levels, cardiovascular outcomes, and potential interference with medical devices. Most studies confirm that EMF exposure from EVs remains within international safety standards. Some findings suggest possible biological effects, including oxidative stress and subtle electrocardiogram alterations, though no significant electromagnetic interference has been observed in patients with cardiac implants. Overall, no immediate cardiovascular risks have been identified. Nonetheless, the long-term effects of EV-related EMF exposure remain uncertain, highlighting the need for further longitudinal studies to assess chronic exposure and its potential consequences to support the development of comprehensive safety guidelines. https://doi.org/10.1016/j.jacasi.2025.09.012

Are 5 G radiofrequency electromagnetic fields and PARP1 interfering with the development of human iPSC-derived dopaminergic neurons?,
Ducray, A. D., Ben Chaabene, R., Jamaati, A., Capstick, M. and Mevissen, M., no. 1872-9711 (Electronic). 2026

The rapid expansion of wireless technologies has increased exposure to radiofrequency electromagnetic fields (RF-EMF), with evolving frequencies and network configurations complicating assessment of potential health risks. Although no conclusive evidence links RF-EMF exposure to adverse health outcomes, including neurodevelopmental disorders or neurodegeneration, some studies suggest possible effects on cognitive functions. In this study, we address the role of poly(ADP-ribose) polymerase 1 (PARP1), a protein involved in neuronal development and neurodegeneration, and evaluate potential effects of RF-EMF. Dopaminergic neurons derived from wild-type (WT) and PARP1-knockout (KO) human induced pluripotent stem cells (hiPSCs) were exposed to RF-EMF during differentiation. PARP1 levels in WT cells decreased between differentiation and maturation, supporting its role during early neuronal development. The absence of PARP1 resulted in a prominent

increase in dopaminergic phenotype at maturation when compared to differentiation, while protein levels of the dopaminergic progenitor marker decreased. Neuronal maturity was unaffected by genotype, while increased expression of the presynaptic marker synaptophysin suggests enhanced synaptic function in PARP1-KO cells compared to WT cells. Neuronal activity was developing over time in both WT and PARP1-KO cells. However, PARP1 deficiency was associated with selective changes in spike timing and burst-related properties, particularly at early and late differentiation stages. RF-EMF exposure did not alter the neuronal phenotype, development, synaptic integrity, or electrical activity in either genotype. Proteomic analysis further supports that genotype-dependent differences were greater than any RF-EMF-related exposure effects. Future studies should assess RF-EMF exposure at later developmental stages and investigate PARP1 function in disease-relevant models. In conclusion, PARP1 absence was associated with an enhanced dopaminergic phenotype, indicating that PARP1 may influence neuronal differentiation, maturation, and synaptic plasticity. Electrical activity increased with maturation time, consistent with progressive functional development of the neuronal culture. Overall, neuronal development was predominantly influenced by the genotype, whereas RF-EMF exposure produced only transient effects on the dopaminergic phenotype. Evidence of a genotype-dependent response to RF-EMF exposure was observed only for SYP and mTOR. https://doi.org/10.1016/j.neuro.2026.103591

Heart rate variability responses to 26 GHz millimeter-wave exposure in healthy young adults, Michelant, L., Jamal, L., Blanchard, E., Baz, T., Nizerolle, B., Hugueville, L., Leveque, P. and Selmaoui, B., *Electromagnetic Biology and Medicine*, 2026.

The ongoing expansion of 5 G networks, using millimeter waves like the 26 GHz frequency band, calls for a better understanding of their potential health effects. In this context, the acute effects of 26 GHz exposure on heart rate variability (HRV), a non-invasive marker of autonomic nervous system activity, were evaluated in healthy young adults. Using a triple-blind, randomized crossover design, 31 participants were exposed to both real and sham 26 GHz 5 G new radio modulated radiofrequency fields in a controlled, shielded environment. Exposure levels were set to reflect realistic upper environmental values (2 V/m at the head and 1 V/m at the torso). Throughout pre-exposure, exposure, and post-exposure phases, HRV was continuously measured under resting eyes-open and eyes-closed conditions. Analysis revealed no statistically significant differences across time- or frequency-domain HRV parameters between real and sham exposures at any phase of exposure. These data suggest that short-term exposure to 26 GHz millimeter waves at environmentally relevant intensities does not alter cardiac autonomic regulation in resting healthy adults. This aligns with the known limited tissue penetration of millimeter waves and the absence of clearly identified biological mechanisms affecting deeper autonomic control at these frequencies. Still, as the exposure duration was relatively brief and the population limited to healthy young individuals, further studies are needed to investigate longer exposures, potential effects during autonomic modulation such as orthostatic maneuvers, and responses in more diverse or vulnerable groups. However, these findings contribute valuable information indicating that no measurable acute physiological changes were observed under the specific environmental exposure conditions investigated; these findings do not address possible long-term or cumulative effects. https://doi.org/10.1080/15368378.2026.2730027

Evaluation of Specific Absorption Rate in Ear Tissue After Exposure to Electromagnetic Field from Cell Phone

Psenakova, Z., Smetana, M., Nevedel, J., Gombarska, D. and Ieee (2025). 26th International Conference on Computational Problems of Electrical Engineering-CPEE-Annual, Rasovice, CZECH REPUBLIC.

This article investigates the impact of electromagnetic fields (EMF) generated by mobile devices on the human ear through numerical simulations. Using CST Studio Suite, simulations were performed

on a detailed 3D ear model, as well as standardized voxel models representing an adult (HUGO) and a child, to determine the distribution of the Specific Absorption Rate (SAR) at frequencies of 1800 MHz, 2.4 GHz, and 5 GHz. The outcomes indicate that higher frequencies result in increased surface absorption and elevated SAR values, particularly in the auricle region; however, all simulated values comply with the ICNIRP 2020 safety guidelines. This study contributes to understanding the thermal effects of RF exposure from mobile devices and provides a basis for evaluating potential health implications. https://doi.org/10.1109/cpee67905.2025.11236759

Impact of Terahertz Electromagnetic Devices on Human Tissue: A Review of SAR and Safety Considerations,
Sharma, N., Kaur, A. and Sharma, S., *Radio Science*, Aug 13 2026, Vol. 61, no. 8.

Terahertz (THz) technology, operating in the 0.1-10 THz band, has gained increasing relevance in wireless communications, biomedical diagnostics, and wearable systems. Its ability to provide high-resolution imaging and non-invasive sensing has made it a promising tool in healthcare. However, strong absorption of THz waves by water-rich biological tissues raises critical concerns regarding biological safety. A key metric for evaluating electromagnetic exposure is the Specific Absorption Rate (SAR), which quantifies the rate of energy deposition in tissues. This review examines the role of THz antennas, sensors, and absorbers in shaping electromagnetic field distributions and their implications on SAR. While flexible and compact THz antennas and sensors demonstrate potential for applications such as COVID-19 detection, fall monitoring, and biosensing, most studies rely on simplified phantoms or simulations, limiting biological realism. Similarly, metamaterial absorbers enhance device sensitivity and control field localization but may inadvertently introduce resonant hotspots that increase localized SAR. Current research highlights a trade-off between device performance and biological safety, further constrained by incomplete dielectric data sets and lack of standardized measurement techniques. This review underscores the urgent need for experimental validation, localized SAR metrics, and updated safety frameworks to ensure the safe deployment of THz-enabled biomedical technologies. https://doi.org/10.1029/2025rs008496

The Effects of Non-Ionizing Radiation (NIR) Towards Cytoplasmic Activity and DNA Integrity in Acanthamoeba sp. Paradigmatic,
Wuzri, N., Halim, U., Manisekaran, T., Sabri, N., Misbah, S., Tajudin, A. and Hashim, F., *Malaysian Journal of Fundamental and Applied Sciences*, May–Jun 2026, Vol. 22, no. 3, p. 603–612.

Electromagnetic fields (EMFs) with low frequency, usually used in communication (known as radiofrequency, 30kHz-300GHz) and generated by electricity (called extremely lowfrequency, 3Hz-3kHz), known as the non-ionizing radiation (NIR) which lacks energy to induce ionization directly. In the current situation, the high exposure of NIR has been used for communication purposes. Wi-Fi is a wireless network that consists of at least one antenna, providing access to the internet and/or other wireless devices, such as laptops, computers, and mobile phones, which communicate wirelessly using Wi-Fi. The Wi-Fi produces different strengths of frequencies (3G, 4G and 5G). Acanthamoeba sp. is classified as an eukaryotic organism which is like human cells and acts as a good bioindicator for other eukaryotic organisms. Their morphological changes can be easily detected whether in healthy or unhealthy conditions. This study aims to investigate the effects of three different strengths of Wi-Fi frequency (3G, 4G and 5G) on the morphological changes in Acanthamoeba sp. The percentage of cell viability was observed by undergoing MTT assay technique. It was shown that the higher the frequency of NIR, 5G - the lower the cell viability counted. Light microscopy was used to observe morphological changes of the cell and cytoplasmic activity, under fluorescence microscopy and stain cells with the Acridine Orange and Propidium Iodide (AO/PI) dyes. Based on that, the frequencies of NIR are directly proportional to the cell death, autophagy and necrosis of Acanthamoeba sp. Precisely,

the cell with treatment of 5G frequency of NIR showed the highest number of necrotic cells compared to 3G and 4G frequencies. Treatment using NIR frequencies has the potential to affect cellular health, and its presence in the environment is detrimental to living organisms. DNA integrity was observed by gel electrophoresis systems to determine the DNA fragmentation occurred after exposure to different strengths. DNA fragments showed that late autophagy and necrosis modes of cell death in cell. https://doi.org/10.11113/mjfas.v22n3.5179

Méthodes

Decoder-Based Extrapolation Techniques for Human Exposure Assessment From 4G/LTE Base Stations: Experimental Challenges and Procedures for Reliable Estimations,
Bernieri, A., Betta, G., Capriglione, D., Cerro, G., Miele, G. and Suka, D., *Ieee Transactions on Instrumentation and Measurement*, 2026 2026, Vol. 75.

Nowadays, the accurate assessment of human exposure to electromagnetic fields (EMFs) radiated by mobile communication systems is fundamental, not only for safety reasons but also for assuring the proper operation and coexistence of such systems. As an alternative to classical exposure assessment methods, the extrapolation-based approach relies on the power consistency of the expected time-constant reference signal for estimating the maximum electric field. Nevertheless, several studies have shown that the hypothesis of constancy of the reference signal level cannot always be kept in practical situations, thus creating possible misleading estimations when comparing the measurement results with the applicable limits. To overcome such an issue, we propose a suitable approach to estimate a comparator offset (COF) value to robustly compare the extrapolated value with the reference applicable limits, to meet the requirements of the IEC 62232 (the standard in force for cellular base station (BS) EMF human exposure assessment). Through a wide experimental campaign, conducted at different test sites, this article also highlights some practical issues that could arise in estimating maximum E-field levels, based on dedicated decoder measurements, for different operators (OPs) and frequency bands in 4G networks. Such findings can be useful for technical standard committees, and practitioners and technicians involved in the EMF exposure assessment. https://doi.org/10.1109/tim.2026.3720853

Evaluation of neuronal activation thresholds for low-frequency electromagnetic exposure using morphologically realistic neuron models,
Gázquez, J., Cadena, C., He, W., Yamada, E., Alteköster, C., Soyka, F., Laakso, I., Hirata, A., Joseph, W., Tarnaud, T. and Tanghe, E., *Physics in Medicine and Biology*, Sep 28 2026, Vol. 71, no. 18.

Objective. International guidelines for low-frequency electromagnetic field exposure (LF EMF) are primarily intended to prevent substantiated adverse effects. In these frameworks, limits on internal electric fields are linked to external exposure levels through computational dosimetry. However, the relationship between internal electric fields and these adverse effects remains incompletely understood. In particular, current approaches often overlook the morphological complexity and diversity of cortical neurons, which may limit the realism of neuronal activation estimates used to support these assessments. This study aimed to evaluate LF EMF-induced neural activation using morphologically realistic neuron models representing all cortical layers. Approach. Twenty-five morphologically realistic neuron models were embedded within 11 detailed human head models. The internal electric fields were simulated for uniform magnetic field exposures (100 Hz-100 kHz) along the three anatomical directions, and excitation thresholds were computed using a multi-scale framework combining voxel-based dosimetry with biophysical neuron simulations. A real-world exposure scenario involving a child near an acousto-magnetic article-surveillance deactivator was also analyzed. Main results. Excitation thresholds varied across cell type, morphology, cortical

location, subject anatomy, frequency, and exposure direction, with L2/3 pyramidal, L4 basket, and L5 thick-tufted pyramidal cells showing the lowest thresholds. Despite this variability, all simulated thresholds were conservative with respect to the basic restrictions and dosimetric reference limits set by IEEE International Committee on Electromagnetic Safety and International Commission on Non-Ionizing Radiation Protection. The smallest margin occurred at 100 kHz, where the threshold remained a factor of 2.8 above the corresponding limit. Significance. These findings indicate that current LF EMF exposure limits remain conservative when evaluated using highly detailed, morphology-based central nervous system activation models. https://doi.org/10.1088/1361-6560/aea302

Analytical Approach to Uncertainty Evaluation of Exposure Index-Metric for Assessing Human Population Exposure Induced by a Wireless Cellular Network,
Koprivica, M. and Neskovic, A., *Electronics*, Aug 28 2026, Vol. 15, no. 17.

The rapid development of wireless technologies requires reliable assessment of electromagnetic radiation. Under the scope of the project LEXNET, a novel metric named the Exposure Index (EI) was defined to assess the mean exposure of a human population within a geographical area. The EI considers exposure from both base stations/access points and wireless user devices, thereby assessing the total exposure originating from the wireless cellular network. Considering that every measurement result should have an associated uncertainty, this paper proposes an analytical method for evaluating the uncertainty of the EI. Advancing beyond standard GUM evaluations that require scenario-specific derivations of complex partial derivatives, the proposed procedure provides a unified, first-order analytical approximation. Assuming that all input parameters are independent and have small relative standard uncertainties, this framework yields a closed-form relative expression to instantly calculate the combined relative standard uncertainty of the EI. Furthermore, if the determination of expanded uncertainty is required, we propose a method to estimate the probability distribution function of the EI. Assuming that all input parameters of the EI are normally distributed with small uncertainties, we demonstrate that the EI probability distribution can be considered normal. This method provides a highly convenient way to calculate the relative standard uncertainty of the EI and to determine the coverage factor for the relative expanded uncertainty. https://doi.org/10.3390/electronics15173886

Broadband dielectric characterization of liquid media at physiological cell-culture temperature (36.5 °C) with Debye-ionic modeling for RF exposure assessment,
Lee, H., Park, M., Woo, H., Jeong, N., Yook, J. and Hyun, K., *Results in Engineering*, Dec 2026, Vol. 32.

Unlike most existing dielectric databases, which primarily focus on biological tissues, water, saline solutions, or tissue-equivalent materials, this study establishes a validated dielectric dataset for widely used cell-culture media measured directly under physiological culture conditions. In this work, the dielectric properties of four liquid media (DI water, PBS, DMEM, and RPMI-1640) were experimentally characterized at the physiological cellculture temperature (36.5 degrees C) using a temperature-controlled chamber. The relative permittivity and loss tangent of each medium were measured over the frequency range of 0.3-20 GHz. To provide a physically interpretable description of the measured dielectric behavior, a Debye-ionic conduction model for the four media was developed. The corresponding model parameters-static permittivity (es), infinite-frequency permittivity (e infinity), relaxation time (tau), and ionic conductivity (sigma)-were extracted by fitting the measured data. The results demonstrate that the PBS, DMEM, and RPMI-1640 exhibit dielectric behavior characteristic of saline-based aqueous media. Although the differences in the real part of the relative permittivity (e ') among them are relatively small, the imaginary part of the relative permittivity (e '') and the ionic conductivity are substantially higher, reflecting the dominant

contribution of ionic conduction. These findings indicate that loss-related parameters are critical for predicting RF-induced power absorption and specific absorption rate (SAR) under otherwise identical local electric field conditions. Furthermore, by integrating uncertainty-quantified measurements with physically interpretable Debye-ionic conduction parameters, the proposed framework provides an engineering resource for reproducible RF dosimetry, reliable SAR estimation, and realistic in vitro bioelectromagnetic simulations. https://doi.org/10.1016/j.rineng.2026.112462

Numerical Design of a 26 GHz Exposure System for Real-Time Electrophysiological Experiments
Pisano, C., Dolciotti, N., Toschi, A., Paffi, A., Liberti, M., Apollonio, F. and Ieee (2025). 2025 Conference on Antenna Measurements and Applications-CAMA-Annual, France.
The rapid development of wireless technologies has led to the adoption of 5G networks particularly in highfrequency bands such as FR2, which operates in the millimeterwave (mmW) region. The addition of new frequencies, such as 26 GHz, has once again raised the issue of radiofrequency electromagnetic field (RF-EMF) exposure in both public and occupational environments. However, existing biological data on mmW frequencies are insufficient for thorough health evaluations. To bridge this gap, new in vitro studies are required. This work introduces the design and electromagnetic characterization of a 26 GHz exposure system tailored for realtime electrophysiological analysis of living cells. https://doi.org/10.1109/cama65664.2025.11335326

Methodology for assesment of induced voltage on human body in the vicinity of overhead electric lines
Radil, R., Janousek, L., Smetana, M., Smondrk, M. and Ieee (2025). 26th International Conference on Computational Problems of Electrical Engineering-CPEE-Annual, Rasovice, CZECH REPUBLIC.
The article focuses on non-thermal biological effects of the grid frequency electromagnetic field (EMF) generated in vicinity of high voltage electric overhead lines. More exactly, it deals with the assessment of voltages or charges induced on a surface of human's body in the area near extra high voltage overhead power lines. This problematic is a part of a methodology for assessment of the intersections of cycling communications with high voltage electric overhead lines. Cyclists crossing high voltage electric overhead lines usually undergo the risk of electroshock, which might lead to the loss of concentration or acute paralysis and secondary serious injuries. https://doi.org/10.1109/cpee67905.2025.11236784

Environmental and auto-induced RF-EMF adult and children far-field exposure simulations between 450 MHz and 26 GHz,
Wydaeghe, R., Stroobandt, B., Gallucci, S., Parazzini, M., Tognola, G., Wiart, J., Vermeeren, G., Guxens, M., Tanghe, E. and Joseph, W., *Physics in Medicine and Biology*, Sep 14 2026, Vol. 71, no. 17.

Objective. Children's exposure to radio-frequency electromagnetic fields above 6 GHz lacks characterization. No study spans sub-GHz cellular bands to millimeter wave while including child phantoms. This study quantifies the specific absorption rate (SAR) and absorbed power density (APD) in two adult and two child anatomical phantoms across 15 frequencies from 450 MHz to 26 GHz. Approach. We performed 550 finite-difference time-domain simulations covering environmental (plane-wave) and auto-induced (beamforming) exposure. SAR and APD were computed following IEC/IEEE 62 704-1 and IEC/IEEE 63 195-4, respectively. The simulations included, for the first time, whole-body dosimetry at 26 GHz in child and adult phantoms, and child APD across 7-15 GHz. Results were normalized to the international commission on non-ionizing radiation protection 2020 reference levels for general public exposure. Main results. Children show 1.5-1.9 times higher whole-body SAR than adults at all sub-6 GHz frequencies. A 6 year-old reaches 93% of the 80 mW kg -1 whole-body SAR limit at 2140 MHz, averaged over 12 plane-wave configurations, and 145% in the worst one. Whole-body SAR, not local SAR, determines compliance margins below 6 GHz. Brain SAR decreases by

96% from 450 MHz to 5.8 GHz as absorption shifts to the skin. Eye SAR drops 77-fold from 7 to 26 GHz as penetration depth falls below eyelid thickness. Under simplified maximum ratio transmission (MRT) beamforming, psSAR 10g at 3500 MHz exceeds the 2 W kg -1 head/torso limit for all four phantoms (131%-158%). APD at 7 GHz exceeds 20 W m -2 for a 6 year-old by 2.5%. Worst-case whole-body SAR agrees with the literature within 2%. Significance. The results identify frequency-phantom combinations where compliance margins narrow: 3500 MHz and 7 GHz under beamforming, and children near 2 GHz under environmental exposure. The organ-specific SAR data for brain, eyes, skin, and genitals support epidemiological exposure assessment and dose modeling across current and prospective wireless bands. https://doi.org/10.1088/1361-6560/ae97ac

Evaluating Human Body Model Fidelity for Vehicle Electromagnetic Compatibility Simulations
Zhang, J., Zhao, H., Zhao, Y., Sammut, C. and Ieee (2025). 2025 International Conference on Numerical Electromagnetic and Multiphysics Modeling and Optimization-NEMO-Annual, Tianjin, PEOPLES R CHINA.
This paper investigates the influence of human body model fidelity on electromagnetic field behaviour inside a vehicle cabin during exposure to external radiated sources. The study compares three simulation configurations: one involving a highly detailed anatomical human model, one with a homogeneous medium approximation, and one without any human presence. Time-domain signal analysis shows minimal discrepancies among the models, particularly in early-time responses. However, frequency-domain analysis highlights significant variations below 50 MHz due to the effects of internal anatomical complexity on near-field coupling. Spatial field distribution analyses further confirm that electromagnetic interactions at mid-to-high frequencies are predominantly governed by reflections at the body's outer surfaces. Our findings suggest that high-fidelity models are essential for low-frequency simulations but can be replaced with simplified models for efficient simulation at higher frequencies without compromising accuracy. This study provides quantitative and qualitative insights to support body model selection in vehicle EMC simulations. https://doi.org/10.1109/nemo62710.2025.11215303

ExposNet: A Deep Learning Framework for EMF Exposure Prediction in Complex Urban Environments,
Zhang, Y., Wang, S. and Wiart, J., *Ieee Transactions on Machine Learning in Communications and Networking*, 2026 2026, Vol. 4, p. 1229–1243.

The prediction of the electric field (E-field) plays a crucial role in monitoring radiofrequency electromagnetic field (RF-EMF) exposure induced by cellular networks. In this paper, a deep learning framework is proposed to predict E-field levels in complex urban environments. First, the drive test measurement in Paris and Lyon and publicly accessible databases used to construct the training dataset are introduced, with a detailed explanation provided on how these datasets are formulated and integrated to enhance their suitability for Convolutional Neural Networks (CNNs)-based models. Then, the proposed model, ExposNet, which is a lightweight CNN-based framework, is presented. Two variants of the network structure are proposed, enabling per-frequency prediction and total E-field prediction. Extensive experimental analyses are conducted, including the comparison with a standard U-Net baseline and a classical Kriging baseline. Moreover, a detailed ablation study is conducted to quantify the contribution of each input component, and additional generalization experiments are performed on different test subsets. The overall results indicate that, despite being trained and tested on real-world measurements, the model performs well and achieves better accuracy compared to previous studies. https://doi.org/10.1109/tmlcn.2026.3714431

Toxicité sur les animaux

Chronic 3.5 GHz radiofrequency exposure is associated with behavioral, molecular, and histopathological changes in the rat hippocampus,
Bektas, H., Cakir, S., Alizade, A., Dogu, S. and Altindag, F., *International Journal of Radiation Biology*, 2026.

Purpose Chronic exposure to mid-band radiofrequency (RF) electromagnetic fields at 3.5 GHz is increasingly relevant to modern wireless environments; however, its effects on hippocampal circuit stability under non-thermal conditions remain unclear. We investigated whether prolonged 3.5-GHz RF exposure is associated with anxiety-like behavior and hippocampal transcript-level changes consistent with excitatory-inhibitory (E/I) imbalance, and whether thymoquinone (TQ) or taurine (TAU) are associated with modulation of these responses.Materials and methods Adult male Wistar rats (n = 28) were assigned to Sham, RF, RF + TQ (20 mg/kg), or RF + TAU (20 mg/kg) groups (n = 7/group). Animals were exposed to a GSM-like 3.5-GHz RF signal (2 W; 2 h/day; 5 days/week; 10 weeks). Anxiety-like behavior and spatial learning were assessed using the Elevated Plus Maze (EPM) and Morris Water Maze (MWM). Hippocampal gene expression (bdnf, creb1, camk2a, th, tph2, gad1, slc17a7) was quantified by RT-qPCR, and histopathology by H&E staining.Results Dosimetry indicated whole-body SAR of 0.0383 W/kg and brain gray matter SAR of 0.3411 W/kg. RF exposure was associated with reduced open-arm time in the EPM. Expression of slc17a7 increased in the RF group, suggesting a shift toward excitation. Under RF co-exposure conditions, TQ and TAU were associated with changes in slc17a7 expression and with increases in bdnf, creb1, and camk2a, along with inhibitory and monoaminergic markers. RF-exposed hippocampi showed neuronal degeneration, less pronounced in antioxidant-treated groups.Conclusions Chronic non-thermal 3.5-GHz RF exposure is associated with anxiety-like behavior and a hippocampal molecular-structural profile consistent with E/I imbalance and tissue stress. TQ and TAU were associated with context-dependent changes under RF co-exposure conditions; however, due to the absence of antioxidant-only control groups, independent effects cannot be determined. These findings suggest that synaptic homeostasis may represent a potential target of prolonged mid-band RF exposure. https://doi.org/10.1080/09553002.2026.2708930

Effects of chronic single - and dual-band radiofrequency exposure on spatial learning and memory retention in growing male rats,
Boumaiza, S., Bouzidi, A., Bouharati, S., Ferahtia, A. and Abed, H., *Revista Cientifica-Facultad De Ciencias Veterinarias*, 2026 2026, Vol. 36, no. 3.

Radiofrequency electromagnetic fields have become increasingly present in daily life due to the widespread use of wireless technologies. However, their long-term effects on cognitive functions remain insufficiently understood, particularly under repeated multi-frequency exposure conditions. This study investigated the effects of chronic exposure to 800 MHz, 900 MHz, and sequential 800/900 MHz RF fields on spatial learning and memory in growing male Wistar rats. Animals were divided into four groups: sham-exposed, 800 MHz, 900 MHz, and sequential 800/900 MHz exposure. Exposures were administered 6 days per week for 4 months. Spatial learning and memory were assessed using the Morris water maze. During the acquisition phase, rats underwent four trials per day for five consecutive days, and escape latency was recorded. Memory retention was evaluated during the probe trial by measuring time spent in the target quadrant and platform-site crossings. Escape latency significantly decreased across training days in all groups, indicating preserved acquisition learning. No significant effect of exposure was observed during the acquisition phase. In contrast, probe trial analysis revealed a significant reduction in target-quadrant time in the sequential 800/900 MHz group compared with sham-exposed and 800 MHz animals, whereas platform-site crossings were not significantly affected. Overall, chronic radiofrequency exposure did not impair spatial learning

acquisition, but sequential exposure to 800 and 900 MHz was associated with reduced spatial memory retention. https://doi.org/10.52973/rcfcv-e363968

Effects of Prenatal Pulsed Electromagnetic Field and 27.12-Megahertz Radiofrequency Exposure on Fetal Development and Placental Stress Response in Rats,
Bozlu, G., Sezik, M., Taner, R., Asci, H., Milletsever, A., Ozmen, O., Ateser, H. and Cömlekci, S., *Journal of Fetal Medicine*, Jun 2026, Vol. 13, no. 02, p. 77–86.

Objectives Pulsed electromagnetic field (PEMF) and radiofrequency electromagnetic field (RF-EMF) stimulation promote neovascularization and angiogenesis and may have therapeutic potential for preventing or treating early-onset fetal growth restriction. We investigated the morphological and histopathological effects of PEMF and RF-EMF, administered separately or in combination, during early (gestational days 0-10) and late (days 10-20) pregnancy in a rat model. Materials and Methods Thirty-two pregnant Wistar albino rats were randomly assigned to eight experimental groups. Animals were exposed to PEMF, RF-EMF, or combined EMF protocols during either early or late gestation. Fetal biometric measurements at term, histopathological examination of fetal organs, and placental heat shock protein 70 (HSP-70) immunostaining were evaluated. Results Histopathological examination demonstrated normal brain, lung, liver, heart, intestine, and kidney tissues in all fetuses except for intracranial hemorrhage foci detected in two fetuses exposed to combined EMF treatment. Fetal weight-standardized head-crown length and biparietal diameter were significantly greater in fetuses exposed to RF-EMF during early pregnancy than in the other groups. Placental weights were similar among groups. Intense HSP-70 immunostaining was observed in placentas exposed to PEMF and RF-EMF during the first 10 days of gestation. No external malformations or skeletal abnormalities were identified. Conclusion At the exposure parameters used, PEMF and RF-EMF were not associated with significant teratogenic effects and appeared relatively safe for fetal development. Increased fetal growth despite unchanged placental weight may reflect enhanced uteroplacental perfusion or adaptive placental stress responses. However, the potential adverse effects of combined EMF exposure on the fetal brain warrant further investigation. Implications for Clinical Practice Carefully controlled exposure to PEMF or RF-EMF during pregnancy may be a relatively safe and nonteratogenic approach that could enhance fetal growth, but combined EMF modalities should not be used until potential fetal brain effects are better understood. https://doi.org/10.1055/s-0046-1827815

Testicular damage from electromagnetic radiation in rats and evaluation of protective agents,
Gözüküçük, A., Çakiroglu, B., Uyanik, B., Kiliç, H. and Çelik, I., *Urologia Journal*, 2026.

Background: Male infertility has been associated with various environmental, physiological, and genetic factors. In recent years, the widespread use of mobile phones has raised concerns regarding exposure to electromagnetic radiation (EMR). EMR emitted from mobile devices may adversely affect male reproductive function by inducing oxidative stress and impairing spermatogenesis. Objective: This study aimed to evaluate the potential protective effects of vitamin E and N-acetylcysteine (NAC) against EMR-induced testicular damage in rats.Methods: A total of 35 adult male Wistar rats were randomly divided into five groups (n = 7 per group): control, EMR exposure, EMR + NAC, EMR + vitamin E, and EMR + NAC + vitamin E. Rats were exposed to EMR generated by a mobile phone operating in the GSM frequency band (900/1800 MHz) in active call mode, positioned at a fixed distance of 15 cm from the cages, for 3 h daily over 28 days. The specific absorption rate (SAR) was based on manufacturer-reported values. Biochemical analyses were performed to assess total antioxidant capacity (TAC), glutathione peroxidase (GPX), superoxide dismutase (SOD), and malondialdehyde (MDA) levels. Data distribution was evaluated using the Shapiro-Wilk test, and group comparisons were conducted using the Kruskal-Wallis test with appropriate post-hoc analyses. Results: Significant differences were observed among groups in terms of total antioxidant capacity (TAC) ($p < 0.001$). TAC

levels were reduced in the EMR-only group compared to controls, whereas antioxidant supplementation (NAC and/or vitamin E) resulted in increased TAC levels. Post-hoc analyses demonstrated significant improvements in TAC in treatment groups compared to both control and EMR-only groups. However, no statistically significant differences were observed among groups for GPX, SOD, and MDA levels (p > 0.05). Conclusion: N-acetylcysteine (NAC) and vitamin E may exert partial protective effects against EMR-induced oxidative alterations in rat testes, particularly as reflected by improvements in total antioxidant capacity. However, given that other oxidative stress markers did not demonstrate statistically significant differences, these findings should be interpreted with caution. Further experimental and clinical studies with larger sample sizes and detailed histopathological evaluation are required to better elucidate the potential therapeutic role and clinical relevance of these antioxidant agents. https://doi.org/10.1177/03915603261448981

Differential Effects of 3.5 GHz and 24 GHz 5G Radiofrequency Exposure on Male Sexual Behaviour and Reproductive Endocrine Function in Rats,
Hairulazam, A., Ibrahim, S., Osman, K., Mokhtar, M., Zulkefli, A., Ros, M., Jamaludin, N., Taha, S., Vijay, S., Zakaria, Z., Bahar, A. and Jaffar, F., *International Journal of Molecular Sciences*, Aug 7 2026, Vol. 27, no. 16.

The rapid expansion of 5G technology has increased exposure to high-frequency radiofrequency electromagnetic fields (RF-EMF), raising concerns about male reproductive health. This study investigated the effects of 5G frequencies at 3.5 GHz and 24 GHz on male libido, reproductive hormones, the testosterone-to-oestrogen (T/E) ratio, and androgen receptor expression in rats. Eighteen male Sprague-Dawley rats were randomly assigned to Control, 3.5 GHz, and 24 GHz (n = 6/group). Exposed groups received 7 h/day RF-EMF exposure for 60 consecutive days, while the Control underwent sham exposure. During the final week of exposure, mating behaviours were assessed using mount frequency, mount latency, intromission frequency, ejaculation latency, and post-ejaculatory interval. Serum testosterone and oestrogen levels, the T/E ratio and androgen receptor expression in the testis and hypothalamus were evaluated. The 3.5 GHz group demonstrated statistically significantly prolonged ejaculation latency (3480 +/- 1576.956, p < 0.01, Hedges' g = 1.03) compared with the Control group. In contrast, 24 GHz exposure statistically significantly reduced mount frequency (4.80 +/- 0.837, p < 0.01, Hedges' g = -0.65) and prolonged the post-ejaculatory interval (588.83 +/- 206.41 s, p < 0.01, Hedges' g = 1.63) compared with the Control group. Hormonal analysis revealed statistically significant elevation of testosterone levels in the 3.5 GHz group, whereas the 24 GHz group showed statistically significant reductions in testosterone and oestrogen. Androgen receptor expression was unchanged. These findings suggest frequency-dependent effects of 5G RF-EMF on male libido and endocrine balance. https://doi.org/10.3390/ijms27167102

Effects of radiofrequency electromagnetic field exposure on cancer in laboratory animal studies, a systematic review (vol 199, 109482, 2025),
Mevissen, M., Ducray, A., Ward, J., Kopp-Schneider, A., Mcnamee, J., Wood, A., Rivero, T. and Straif, K., *Environment International*, Aug 2026, Vol. 214.

Background: More than ten years ago, the World Health Organization's (WHO) International Agency for Research on Cancer (IARC) published a monograph concluding there was limited evidence in experimental animals for carcinogenicity of Radio Frequency Electromagnetic Field (RF EMF). Objective: The objective of this review was to systematically evaluate the effects of RF EMF exposure on cancer in experimental animals. Methods: Eligibility criteria: Based on pre-established Populations, Exposures, Comparators, Outcomes, and Study Type (PECOS) criteria, studies in experimental animals of the following study types were included: chronic cancer bioassays, initiation-(co-)promotion studies, and studies with tumor-prone animals. Information sources: MEDLINE (PubMed), Science

Citation Index Expanded and Emerging Sources Citation Index (Web of Science), and the EMF Portal. Data abstraction and synthesis: Data are publicly available online as interactive visuals with downloadable metadata. We adapted the risk-of-bias (RoB) tool developed by Office of Health Assessment and Translation (OHAT) to include considerations pertinent to the evaluation of RF EMF exposure and cancer bioassays. Study sensitivity was assessed with a tool adopted from the Report on Carcinogens (RoC). We synthesized studies using a narrative approach. Effect size was calculated as the 1% Bayesian Average benchmark dose (BMD) of a respective study when dose response or a trend was identified (see Supplementary Data 3). Evidence Assessment: Certainty of the evidence (CoE) was assessed using the Grading of Recommendations, Assessment, Developing and Evaluations (GRADE) approach, as refined by OHAT. Evidence from chronic cancer bioassays was considered the most directly applicable to evaluation of carcinogenicity. Results: We included 51 studies with 10 chronic bioassays No studies were excluded based on risk of bias concerns. Studies were not considered suitable for meta-analysis due to heterogeneity in study design, species, strain, sex, exposure characteristics, and cancer outcome. No or minimal evidence of RF EMF exposure-related cancer outcomes was found in most systems or organs in any study (these included gastrointestinal/digestive, kidney, mammary gland, urinary, endocrine, musculoskeletal, reproductive, and auditory). For lymphoma (17 studies), with 5 chronic bioassays (2,186 mice, 2,500 rats) inconsistency between two chronic bioassays was not plausibly explainable, and the CoE for lymphoma was rated 'moderate'. For brain tumors (20 studies), including 5 chronic bioassays (2,575 mice, 8,840 rats), an increase in glial cell-derived neoplasms was reported in two chronic bioassays in male rats. The CoE for an increased risk in glioma was judged as high. The BMD analysis was statistically significant for only one study, and the BMD was 4.25 (95% CI 2.70, 10.24). For neoplasms of the heart (3 chronic bioassays), 3 studies were performed in rats (4,304 animals), and 1 in mice (1,386 animals). Based on 2 bioassays, statistically significant increases in malignant schwannomas were judged as high CoE for an increase in heart schwannomas in male rats. The BMDs from the two positive studies were 1.92 (95%CI 0.71, 4.145) and 0.102 (95%CI 0.056, 0.244), respectively. Ten studies reported neoplasms in the adrenal gland (5 chronic bioassays). The CoE for an increased risk in pheochromocytoma was judged as moderate. None of these findings were dose-dependent when compared to the sham controls. Fourteen studies investigated tumors of the liver with 5 of these being chronic bioassays.The CoE was evaluated as moderate for hepatoblastomas. For neoplasms of the lung (5 chronic bioassays), 4 studies were conducted in rats (2,176 animals) and 9 studies in mice (4,171 animals). In one chronic bioassay, a statistically significant positive trend was reported for bronchio-alveolar adenoma or carcinoma (combined), which was rated as moderate CoE for an increase in lung neoplasms with some evidence from 2 initiation-(co-)promotion studies. Discussion: Meta-analysis was considered inappropriate due to the heterogeneity in study methods. The GRADE/ OHAT CoE framework has not been frequently applied to animal studies and experience to date suggests refinements are needed. We deferred to standard methods in environmental health where CoE is framed in the context of strength of the evidence providing positive support for carcinogenicity. High CoE can be interpreted as the true effect is highly likely to be reflected in the apparent relationship. Moderate CoE indicates the true effect may be reflected in the apparent relationship. Cancer bioassays conducted in experimental animals are commonly used to identify potential human carcinogens. We note that the two tumor types with high CoE in animals in this systematic review are the same as those identified with limited evidence in humans by the IARC Working Group. However, even in cases where the animal evidence demonstrates high CoE, the extrapolation of risk from cancer bioassays to humans is particularly complex for RF EMF. Without a better understanding of the mechanism of the carcinogenicity of RF-EMF, the choice of exposure metric for risk extrapolation (whole body versus localized), intensity or cumulative exposure whether or not a monotonic dose response holds for carcinogenic effects, and whether SAR is the appropriate dose metric for adverse effects induced by RF-EMF may be critical. Other: This review was partially funded by the WHO radioprotection programme. The protocol for this review was registered in Prospero reg. no.

CRD42021265563 and published in Environment International 2022 (Mevissen et al., 2022). https://doi.org/10.1016/j.envint.2026.110368

Impact of extremely low-frequency magnetic fields on neuroinflammation and synaptic protein development in prenatal and postnatal rat brains,
Öztürk, H., Kiliç, M., Ercan, A. and Saribal, D., *Indian Journal of Experimental Biology*, Sep 2026, Vol. 64, no. 9, p. 835–845.

Brain development during prenatal and postnatal periods is critical, and external stressors such as electromagnetic fields can significantly influence this process. Although there are numerous studies on this topic, our understanding of how electromagnetic fields affect the central nervous system remains limited. In this study, we investigated the effects of extremely low-frequency magnetic fields (ELF-MF) on the developing brains of Sprague-Dawley rats. The rats were exposed to 50 Hz, 500 & micro;T ELF-MF during prenatal, postnatal, or both periods. Using ELISA, we assessed inflammatory markers and synaptic protein levels in two brain regions. Combined prenatal and postnatal exposure to ELF-MF significantly increased IL-17A levels in the hippocampus and cortex and elevated IFN-gamma levels in the cortex. However, there was no change in IL-4 levels. Additionally, in the combined prenatal and postnatal exposure group, ELF-MF significantly reduced PSD-95 levels in both the cortex and hippocampus, and Syn1 levels in the hippocampus. Our results suggest that ELF-MF may trigger inflammation in the brains of young rats, potentially impairing synaptic transmission, particularly in the hippocampus where reduced Syn1 may limit presynaptic neurotransmitter release. This study provides new insights into the impact of ELF-MF on brain development and underscores the need for further research in this field. https://doi.org/10.56042/ijeb.v64i09.28373

Chronic paternal Wi-Fi RF-EMR exposure impairs placental efficiency and fetal growth: Association with sex-dependent histone modification patterns in mice,
Wang, J., Gao, L., Jin, N., Yan, S., Lei, H., Ju, Y., Chen, S. and Wang, X., *Ecotoxicology and Environmental Safety*, Sep 15 2026, Vol. 323.

The widespread use of Wi-Fi-derived radiofrequency electromagnetic radiation (RF-EMR) has raised concerns regarding male reproductive health; however, whether paternal exposure exerts transgenerational effects on offspring development remains unclear. This study investigated the effects of chronic paternal 2.4 GHz Wi-Fi RFEMR exposure (whole-body SAR 0.125-0.5 W/kg, 4 h/day, 6 days/week for 20 weeks) on sperm quality in F0 male mice and placental development in F1 offspring, with a focus on epigenetic regulation. Paternal RF-EMR exposure significantly reduced sperm concentration and increased the sperm abnormality rate in F0 males. F1 offspring exhibited reduced fetal weight and placental efficiency, with more pronounced impairments in male offspring. Mechanistically, paternal exposure reduced the proportion of placental labyrinth layer and downregulated multiple nutrient transporters in a male-biased manner. Epigenetic analysis revealed sex-dependent histone modifications in placentas following paternal RF-EMR exposure: male placentas exhibited increased H3K9me2/3, H3K27me3, H3K27ac, and H3K4me2, whereas female placentas exhibited decreased H3K4me2. ChIP-qPCR targeting transporter promoters revealed sex-specific enrichment of repressive histone marks in placentas from exposed fathers. In male placentas, H3K27me3 was increased at the Atp1a1 and Slc22a3 promoters, and H3K9me3 was increased at the Atp1a1 and Slc2a1 promoters. In female placentas, H3K27me3 at the Slc3a2 promoter was significantly decreased. Collectively, chronic paternal Wi-Fi RF-EMR exposure impairs fetal growth and placental efficiency, with male offspring being more susceptible, and is associated with disrupted placental structure, impaired nutrient transport, and sex-dependent histone modifications in the offspring placenta. These findings underscore the importance of considering paternal RF-EMR exposure in reproductive risk assessment. https://doi.org/10.1016/j.ecoenv.2026.120751

Actualité, société et mesures de prévention

Cartoradio : carte de niveaux de l'exposition du public aux ondes électromagnétiques issues des stations de téléphonie mobile déployées en extérieur sur tout le territoire. ,
(2025),
Cartoradio est un outil cartographique permettant de présenter sur une même carte les antennes relais et les mesures du champ électromagnétiques qu'elles créent. Cartoradio permet, d'une part, de connaître l'emplacement des stations radioélectriques et, d'autre part, d'avoir accès, pour un site donné, aux résultats des mesures de champs électromagnétiques synthétisés par une fiche de mesures. Depuis octobre 2021, Cartoradio permet également de fournir des statistiques sur les sites radioélectriques implantés sur une zone : ville, département, région. Il est ainsi possible de savoir combien de sites 5G sont mis en service par les opérateurs mobile dans telle ou telle ville, avec des filtres par opérateur et bande de fréquences. La plateforme intègre depuis avril 2025 une carte de niveaux de l'exposition du public aux ondes électromagnétiques issues des stations de téléphonie mobile déployées en extérieur sur tout le territoire. www.cartoradio.fr

Appel à projets de recherche 2026 du PNR EST sur le thème "Radiofréquences et santé",
ANSES (16 juillet 2026),
L'Anses a lancé le 9 juillet 2026 un appel à projets de recherche 2026 sur le thème « Radiofréquences et santé ». Il est financé par les fonds confiés à l'Anses par le ministère de la transition écologique, de l'énergie, du climat et de la prévention des risques. Cet appel à projets de recherche (APR) est lancé dans le cadre du Programme National de Recherche Environnement-Santé-Travail (PNR EST) et porte sur quatre thèmes : mécanismes d'action au niveau moléculaire et cellulaire, effets physiologiques et sanitaires des radiofréquences, hypersensibilité électromagnétique, caractérisation des expositions. https://www.anses.fr/fr/appel-consultation/appels-candidature/appel-projets-recherche-2026-du-pnr-est-theme-radiofrequences

Communiqué de presse. Retrait du marché et rappel de téléphones à la suite d'un dépassement de la valeur limite de DAS,
ANFR (31 juillet 2026),
L'Agence nationale des fréquences (ANFR) a demandé aux sociétés WSJ PRODUCT LTD, APEX CE SPECIALISTS, TECHTRIBE, NOTHING TECHNOLOGY B.V et VALEX de procéder respectivement au retrait du marché français et au rappel des téléphones AGM Note N1, DOOGEE N55 PLUS, INFINIX SMART 9 (X6532), NOTHING PHONE 3A (A059) à la suite d'un dépassement de la limite de débit d'absorption spécifique (DAS) et du téléphone SAMSUNG A55 (SM-A556E/DS) pour défaut de marquage CE. Les distributeurs doivent prendre les mesures de retrait et de rappel de leur propre initiative en cas d'inaction du fabricant. https://www.anfr.fr/fileadmin/2026/CP_DAS_AGM__.pdf

Evaluation de l'exposition, débit d'absorption spécifique (DAS) des téléphones mobiles,
ANFR (juillet 2026),
Jeu de données mis à jour https://data.anfr.fr/explore/dataset/das-telephonie-mobile

Electromagnetic-Exposure Prevention and Mitigation Literacy Among Pre-Service Science Teachers: Behavioral Adaptation, Responsibility Attribution, and Governance Gaps,
Çalis, S., *Sustainability*, Aug 17 2026, Vol. 18, no. 16.

The expansion of wireless infrastructure has made anthropogenic non-ionizing electromagnetic fields (EMFs)-commonly described in public discourse as "electrosmog" or electromagnetic pollution-a pervasive feature of digitalized environments. This study examines how 81 pre-service science

teachers in T & uuml;rkiye conceptualized EMF-related sources, perceived risks, mitigation measures, and responsibility. A multi-source qualitative design combined inductive content analysis of nine open-ended questionnaire items with a document-informed deductive mapping based on authoritative EMF-exposure and risk-governance documents. The integrated framework distinguished diagnostic and risk-appraisal capacity, receiver-pathway-source intervention levels, governance and collective capacity, and responsibility attribution. Within a questionnaire primarily oriented toward awareness and daily-life action, responses concentrated strongly on receiver-level behavioral adaptation and attributed responsibility mainly to individuals and households. Source-level controls, monitoring, compliance, institutional responsibility, and evidence-based risk communication were not spontaneously articulated. Because these dimensions were not directly prompted, the findings do not establish a governance-literacy deficit; they define the boundaries of the mitigation repertoire elicited and generate a hypothesis for future research using explicit institutional and governance-oriented prompts. The study's contribution lies in applying an integrated exposure-management and responsibility-attribution framework to an understudied teacher-education population and identifying curriculum needs concerning evidence appraisal, multilevel responsibility, and uncertainty-sensitive risk communication. https://doi.org/10.3390/su18168381

EMC evaluation in radiation-emitting medical devices: regulatory limits and an integrated safety approach. LID - 10.1080/17434440.2026.2759441 [doi],
Censi, F., D'agostino, S., Apolinio, F., Masini, E. P. and Burriesci, G., 2026, no. 1745-2422 (Electronic).

INTRODUCTION: Electromagnetic compatibility (EMC) is a fundamental safety requirement for medical devices, ensuring both the limitation of electromagnetic emissions and adequate immunity to external electromagnetic disturbances. AREAS COVERED: Within the European regulatory framework, EMC is addressed in the Regulation 2017/745 (MDR), which requires manufacturers to minimize radiation emissions, prevent interference with other devices, and provide appropriate information in the instructions for use. The main technical reference standard for EMC is IEC 60,601-1-2, which defines test methods and limits for electromagnetic emissions and immunity. However, this standard evaluates radiated emissions only above 30 MHz, creating a regulatory gap for devices operating at lower frequencies. Moreover, it does not address the assessment of unintended or spurious emissions below this threshold. EXPERT OPINION: To address these limitations, additional standards and guidelines must be considered. IEC 62,311 provides methodologies for assessing human exposure to electromagnetic fields across the frequency range 0 Hz-300 GHz, while exposure limits can be derived from the ICNIRP guidelines and the European Directive 2013/35/EU. By combining EMC testing according to IEC 60,601-1-2 with exposure assessment based on IEC 62,311 and comparison with ICNIRP limits, manufacturers can demonstrate full regulatory compliance in terms of EMC. FAU - Censi, Federica https://doi.org/10.1080/17434440.2026.2759441

Health risks of radiofrequency electromagnetic fields, and the World Health Organization's programme,
Elwood, M. and Karipidis, K., *New Zealand Medical Journal*, Jul 17 2026, Vol. 139, no. 1638, p. 91–99.

Radiofrequencies (electromagnetic fields from 100kHz to 300GHz) are used for communications, such as mobile phones, radio and television broadcasting, and some other applications such as diathermy. Possible health effects have been studied extensively, especially whether the use of mobile phones increases the risk of brain cancer. The World Health Organization (WHO) has sponsored 13 extensive reviews of the scientific studies on health effects. For human epidemiological and some experimental studies on volunteers, the studies found no increased risk for most effects, with up to moderate confidence (the highest category for observational studies). Some results showed effects on cognitive performance and reduced sperm vitality, but with very low confidence. For animal studies, increases

in glioma and heart schwannoma in male rats were reported with high confidence. Increases in some other cancers, and reductions in foetal weight, pregnancy rate and sperm count, were found with moderate or low confidence. The relevance of the animal studies to humans is a key issue. These reviews will be used by the WHO in risk assessment and setting guidelines for exposure and good practice. https://doi.org/10.26635/6965.7477

Shielding the First 24 Postnatal Months of Life: A Proposal for a Prospective Cohort Study of Early-Life Electromagnetic Exposure and Autism Risk,
Garoli, A. and Greco, A., *Alpha Psychiatry*, Aug 24 2026, Vol. 27, no. 4.

Background: Autism Spectrum Disorder (ASD) involves Mirror Neuron System (MNS) dysfunction, driving core social and imitative impairments. Systemic physiological alterations such as autonomic dysregulation, mitochondrial dysfunction and neuroinflammation are known to impair synchronization and plasticity of neuronal clusters. A less-evident environmental cofactor, coinciding with rising ASD prevalence, is the considerable world-wide increase in electromagnetic radiation (EMR) overall exposure among children. Experimental evidence shows how low-intensity EMR influences cellular processes, via voltage-gated calcium channels (VGCCs), oxidative stress, and mitochondrial metabolism. The Resonant Convergence framework, allow to predict how chronic EMR exposure during the first 24 postnatal months of life can act as a factor in ASD pathogenesis. The best candidate mechanism is chronic Ion Cyclotron Resonance (ICR) detuning the Ca2+-calmodulin pathway, thus disrupting MNS synchronization.Methods and Analysis: A prospective observational pilot cohort study (24-month follow-up) proposes to enroll 1000 full-term newborns into two arms: an EMR-reduced cohort (n = 500, rest and sleep-phase Faraday shielding) and a standard exposure cohort (n = 500). Exposure is quantified via radiofrequency (RF)/extremely low frequency(ELF) measurements, proximity analysis, device inventories and wearable dosimetry. The primary endpoint is a continuous neurodevelopmental trajectory score (joint attention, language, electroencephalogram (EEG) mu-rhythm); binary ASD diagnosis (Autism Diagnostic Observation Schedule, Second Edition (ADOS-2), Autism Diagnostic Interview-Revised (ADI-R)) is a secondary, exploratory endpoint. Moreover, an optional genomic screening will evaluate gene-environment interactions within extremely low-frequency electromagnetic field (ELF-EMF) vulnerable pathways, including ASD-associated genes upregulated by RF via bromodomain and extraterminal protein (BET)-mediated epigenetic mechanisms. Analyses will employ risk ratios, Fisher's exact tests and logistic regression adjusted for confounders; mixed-effects and Bayesian modeling will evaluate longitudinal outcomes and exposure reduction effects. Given a 2-3% baseline prevalence, approximately 20-30 ASD cases are expected. The study is therefore powered for exploratory signal detection rather than definitive causal inference, providing the critical baseline data required to justify and design future confirmatory trials. Sex-stratified modeling will address the 4:1 male-to-female prevalence ratio.Ethics and Dissemination: Ethics committee approval is not yet sought; full protocol review and approval will be obtained prior to the study initiation, in strict accordance with the Declaration of Helsinki. Written parental informed consent will be mandatory for all participants prior to enrollment. Study findings and methodological milestones will be disseminated through peer-reviewed international scientific publications. This protocol provides a structured methodological framework for the first prospective investigation of sleep-phase EMR reduction as a potential modulator of ASD incidence during early neurodevelopment. Results will inform adequately powered confirmatory trials in electromagnetic neurodevelopmental epidemiology. https://doi.org/10.31083/ap53282

Impact of an Educational Intervention on Awareness, Knowledge, Preventive Practices, and Risk Perception Regarding Mobile Phone Radiation among Allied Health Sciences Students: A Quasi-experimental Study,

Lande, J., Saraf, A., Dabholkar, A. and Kaushik, P., *Journal of Clinical and Diagnostic Research*, Aug 2026, Vol. 20, no. 8, p. LC11–LC16.

Introduction: Mobile phones are in widespread use among students and are therefore an exposure source of Radiofrequency Electromagnetic Radiation (RF-EMR) which has raised concerns about health effects and safety procedures. Although students use cell phones extensively, little or no knowledge exists about radiation exposure, Specific Absorption Rate (SAR), and preventive measures. Educational activities can be used to increase awareness, perceptions and safe mobile phone usage practices. Aim: To assess the impact of an educational intervention on the levels of awareness, knowledge, and risk perception regarding mobile phone radiation among allied health sciences students. Materials and Methods: The present Institutional-based quasi-experimental (pre-post) study design was adopted with a sample of 213 students from Dr. D. Y. Patil School of Allied Health Sciences, Pune, Maharashtra, India between June-July 2025. A validated, self-administered questionnaire of 64 items was used with the aim of assessing awareness, knowledge, perceptions of risk, and preventive practices regarding the hazards of mobile phone radiation. The questionnaire was given pre-intervention and post-intervention. The intervention included an awareness and educational session on mobile phone radiation, its potential health effects, myths and misconceptions, and safety practices. The data collected was analysed using the chi-square statistical test. A p-value of less than 0.05 was considered statistically significant. Results: Improvements in various areas of radiation awareness and safety practices were statistically significant. These areas include an increase in awareness of preventive practices from 132 (62%) to 176 (82.6%), knowledge of methods to check SAR levels from 70 (32.9%) to 165 (77.5%), improvement in the practice of checking their phone's SAR levels among the students from 62 (29.1%) to 164 (77%), awareness of safe sleeping distance from 119 (55.9%) to 170 (79.8%), and awareness of radiation warning symbols from 91 (42.7%) to 144 (67.6%) (all p<0.001). Improvement in the perception of risks was observed, but belief in the impact of radiation on health did not change (p=0.613). Conclusion: Results show improvements in knowledge, awareness of preventative measures and perception of risk concerning mobile phone radiation following educational intervention among students. While things have certainly gotten better in each area, health effects data appear stagnant for some audiences, reinforcing the need to maintain awareness and educational efforts. https://doi.org/10.7860/jcdr/2026/89344.24016

Spotlight on EMF research: a literature review service by the German federal office for radiation protection,
Leymann, H., Astanin, A., Baaken, D., Belenki, D., Deser, A., Gernand, L., Geschwentner, D., Meyer, F., Pophof, B., Schmidt, J., Weiser, E., Wilsdorf-Koehler, H., Zang, M. and Kuhne, J., *Journal of Radiological Protection*, Sep 1 2026, Vol. 46, no. 3.

In the area of research on electromagnetic fields (EMFs) and health, decision makers and practitioners face an increasingly complex information landscape, characterised by high publication volumes, heterogeneous methods and the occasional spread of oversimplified claims. 'Spotlight on EMF Research', offered by the German Federal Office for Radiation Protection (BfS), wants to support the EMF-interested community by providing regular, structured assessments of selected scientific publications. Spotlight on EMF Research offers concise summaries and critical commentaries, brief Literature Suggestions, comprehensive literature lists, and a quarterly newsletter aimed at regulators, advisory bodies, scientists, and other expert users. This article describes the underlying rationale and workflow, including regular database searches, AI-assisted categorisation, and an interdisciplinary editorial and review process. It also presents descriptive data on the screened and featured literature and summarises early user feedback. We discuss the systematic limitations and potential selection biases of the format, its implications for risk communication in a changing media landscape, and how

Spotlight on EMF Research complements existing scientific EMF literature information services. https://doi.org/10.1088/1361-6498/ae8aff

A Ten-Country Study on Public Perceptions of 5G EMF Emissions: Who Feels Exposed, and Why?, Link, S., Grellier, J., Martin, L., Eggeling-Böcker, M., Abacioglu, F., Schulz, C., Vaupotic, N., White, M. and Boehmert, C., *Bioelectromagnetics*, Jul 2026, Vol. 47, no. 5.

Formal risk assessment considers characteristics such as proximity, dose, and vulnerability. However, public risk perception may also be influenced by other-possibly less relevant-factors such as visibility and novelty. The introduction of 5G and its associated infrastructure and radiofrequency electromagnetic fields (RF-EMF) may therefore change perceptions of RF-EMF from mobile communications in general. To explore this, we conducted an online survey in 10 European countries (n = 10,358) using a picture-based approach. Respondents perceived daily RF-EMF exposures as moderate but expected them to increase with 5G. A mobile phone at the ear was generally associated with higher perceived exposure than multiple base stations. Overall, distance to the RF-EMF source most strongly influenced perceived exposure, followed by the number of sources. 5G reception was linked to higher exposure perception than 4G or Wi-Fi reception. These patterns were consistent across most countries. We conclude that when assessing RF-EMF exposure, people rely on heuristics (e.g., more sources imply more exposure) that often guide them correctly. Understanding when and why people feel particularly exposed can help develop more effective communication about true levels of exposure and risk. https://doi.org/10.1002/bem.70058

Mobile Network Penetration in Italy: A Preliminary Space and Time Analysis
Solmonte, N., Franci, D., Marsico, G., Pasquino, N. and Ieee (2025). 2025 International Workshop on Metrology for Green Technologies Renewable Energy and Ecological Sustainability-MetroGREENST, Messina, ITALY.
The controversy about exposure to radiofrequency (RF) electromagnetic fields (EMFs) and their health risks is one of today's most significant environmental and health issues. The increase in telecommunication systems and RF emission sources has led to a rise in EMF levels, especially in urban areas. This study examines the spatial and temporal distribution of Base Stations (BSs) in some Italian regions by analyzing open datasets from the Istituto Superiore per la Protezione e la Ricerca Ambientale (ISPRA). Collected through systematic measurement and monitoring campaigns, these records enable the reconstruction of infrastructure and power dynamics over more than a decade (from 2010 to 2023). A set of infrastructure, technology, and demographic indicators is applied to capture different aspects of network development. Results show a general increase in BSs' density and power levels over time, driven by the progressive penetration of mobile technologies. The analysis also reveals a shift toward densification, with the reinforcement of existing sites prevailing over the creation of new ones. This measurementbased approach offers a longitudinal and integrated perspective on mobile network evolution, linking infrastructural growth with demographic and territorial characteristics and providing evidence for informed assessments of population exposure. https://doi.org/10.1109/metrogreenst67435.2025.11428905

Preparation and electromagnetic shielding properties of conductive/magnetic filler composite nylon fabric,
Yuan, J., Zhang, Y., Lou, L. and Liu, S., *Aatcc Journal of Research*, Jul 2026, Vol. 13, no. 4.

The rapid development of 5G communication and the Internet of Things (IoT) led to increasingly severe electromagnetic pollution, which posed a serious threat to the operation stability of electronic devices and human health. It was urgent to develop flexible, lightweight, eco-friendly, and high-efficiency electromagnetic interference (EMI) shielding fabrics for wearable electronic applications,

while existing materials were limited by complex preparation processes, high cost, and insufficient shielding performance. Herein, we fabricated a series of EMI shielding composite fabrics using nylon fabric as the substrate, eco-friendly waterborne polyurethane (WPU) as the matrix, and acetylene black (AB) and ferroferric oxide (Fe3O4) as conductive and magnetic functional fillers, via a facile coating method combined with a layer-by-layer pre-curing process. The effects of filler concentration, composite order and multi-layer gradient structure on the EMI shielding effectiveness (SE) of the composite fabrics were systematically investigated. The results showed that the optimal SE of single-filler coated fabrics reached 15.5 dB for the 5 wt% AB filled system and 3.5 dB for the 30 wt% Fe3O4 filled system, respectively. By constructing a vertical gradient structure (AB-Fe3O4 layered design), the SE of the binary composite fabric was enhanced to 19 dB, which realized a significant synergistic enhancement compared with single-filler systems. More importantly, after introducing conductive copper paint to form a three-layer gradient structure, the composite fabric achieved an excellent SE of EMI over 55 dB in the target frequency band. This work provided a facile and scalable strategy for the fabrication of high-performance flexible EMI shielding fabrics, and had promising application prospects in the field of wearable electronic protection. https://doi.org/10.1177/24723444261478658