Bulletin de veille
Champs électromagnétiques
N°6 - Février/Mai 2024

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.

Les liens mentionnés dans le bulletin donnent accès aux documents sous réserve d'un abonnement à la ressource.

Exposition professionnelle, études épidémiologiques

Evaluation of neonatal outcomes according to the specific absorption rate values of phones used during pregnancy,
BÜYÜKEREN M. and F. K. YAMAN,
Journal of the Turkish-German Gynecological Association 25, no. 1 (Mar 2024): 7-12,
Objective: The aim was to compare neonatal outcomes according to cell phone specific absorption rate (SAR) levels and daily time spent on cell phones by pregnant women. Material and Methods: Women who gave birth at Konya City Hospital between September 2020 and February 2021 were included in this retrospective study. Gestational ages, birth weight, birth length, head circumference, sex, 5 -minute APGAR scores, neonate postpartum resuscitation requirement, delivery type, the model of phone used by the pregnant women, and the average time spent on the phone during a day were recorded. To determine the relation between the SAR values of the phones used and delivering a small for gestational age (SGA) baby, receiver operating characteristic curve analysis was performed. Results: In total 1495 pregnant women were included. The rate of delivering a SGA fetus was significantly higher in women who used phones with higher SAR values (p=0.001). The cut-off value for the SAR level was 1.23 W/kg with 69.3% sensitivity and 73.0% specificity (area under the curve: 0.685; 95% confidence interval: 0.643-0.726). No correlation was found between time spent on the phone and SGA birth rate. Although both phone SAR values and

time spent on the phone were higher in the symmetrical SGA group compared to the asymmetrical SGA group, the difference was not significant (p>0.05). Although the women who had preterm delivery had higher phone SAR values and had spent more time on the phone compared to those who had term deliveries, the difference was again not significant (p>0.05). Conclusion: As the SAR values of cell phones used during pregnancy increased, there was a trend towards delivering a SGA baby. https://doi.org/10.4274/jtgga.galenos.2023.2022-10-1

Effects of Radiofrequency Electromagnetic Field (RF-EMF) exposure on pregnancy and birth outcomes: A systematic review of experimental studies on non-human mammals,
CORDELLI E., L. ARDOINO, B. BENASSI, C. CONSALES, P. ELEUTERI, C. MARINO, M. SCIORTINO, P. VILLANI, M. H. BRINKWORTH, G. D. CHEN, J. P. MCNAMEE, A. W. WOOD, L. BELACKOVA, J. VERBEEK and F. PACCHIEROTTI,
Environment International 180 (Oct 2023),
Background: The World Health Organization is coordinating an international project aimed at systematically reviewing the evidence regarding the association between radiofrequency electromagnetic field (RF-EMF) exposure and adverse health effects. Within the project, 6 topics have been prioritized by an expert group, which include reproductive health outcomes.Objectives: According to the protocol published in 2021, a systematic review and meta-analyses on the adverse effects of RF-EMF exposure during pregnancy in offspring of experimental animals were conducted.Methods: Three electronic databases (PubMed, Scopus and EMF Portal) were last searched on September 8 or 17, 2022. Based on predefined selection criteria, the obtained references were screened by two independent reviewers. Studies were included if they met the following criteria: 1) original, sham controlled experimental study on non-human mammals exposed in utero, published in peer-reviewed journals, 2) the experimental RF-EMF exposure was within the frequency range 100 kHz-300 GHz, 3) the effects of RF-EMF exposure on fecundity (litter size, embryonic/fetal losses), on the offspring health at birth (decrease of weight or length, congenital malformations, changes of sex ratio) or on delayed effects (neurocognitive alterations, female infertility or earlyonset cancer) were studied. Study characteristics and outcome data were extracted by two reviewers. Risk of bias (RoB) was assessed using the Office of Health Assessment and Translation (OHAT) guidelines. Study results were pooled in a random effects meta-analysis comparing average exposure to no-exposure and in a dose-response meta-analysis using all exposure doses, after exclusion of studies that were rated at "high concern" for RoB. Subgroup analyses were conducted for species, Specific Absorption Rate (SAR) and temperature increase. The certainty of the evidence was assessed using the Grading of Recommendations, Assessment, Development and Evaluations (GRADE) approach.Results: Eighty-eight papers could be included in this review. Effects on fecundity. The meta-analysis of studies on litter size, conducted at a whole-body average SAR of 4.92 W/kg, did not show an effect of RF-EMF exposure (MD 0.05; 95% CI -0.21 to 0.30). The meta-analysis of studies on resorbed and dead fetuses, conducted at a wholebody average SAR of 20.26 W/kg, showed a significant increase of the incidence in RF-EMF exposed animals (OR 1.84; 95% CI 1.27 to 2.66). The results were similar in the dose-response analysis. Effects on the offspring health at birth. The meta-analysis of studies on fetal weight, conducted at a whole-body average SAR of 9.83 W/kg, showed a small decrease in RF-EMF exposed animals (SMD 0.31; 95% CI 0.15 to 0.48). The meta-analysis of studies on fetal length, conducted at a whole-body average SAR of 4.55 W/kg, showed a moderate decrease in length at birth (SMD 0.45; 95% CI 0.07 to 0.83). The meta-analysis of studies on the percentage of fetuses with malformations, conducted at a whole-body average SAR of 6.75 W/kg, showed a moderate increase in RF-EMF exposed animals (SMD -0.45; 95% CI -0.68 to -0.23). The meta-analysis of studies on the incidence of litters with malformed fetuses, conducted at a whole-body average SAR of 16.63 W/kg, showed a statistically significant detrimental RF-EMF effect (OR 3.22; 95% CI 1.9 to 5.46). The results were similar in the dose-response analyses. Delayed effects on the offspring health. RF-EMF exposure

was not associated with detrimental effects on brain weight (SMD 0.10; 95% CI -0.09 to 0. 29) and on learning and memory functions (SMD -0.54; 95% CI -1.24 to 0.17). RF-EMF exposure was associated with a large detrimental effect on motor activity functions (SMD 0.79; 95% CI 0.21 to 1.38) and a moderate detrimental effect on motor and sensory functions (SMD -0.66; 95% CI -1.18 to -0.14). RF-EMF exposure was not associated with a decrease of the size of litters conceived by F2 based on few studies, which suffered of lack of independent replication deriving from only few laboratories. attributed a moderate certainty to the evidence of a lack of delayed effects on the offspring brain weight. For most of the other endpoints assessed by the meta-analyses, detrimental RF-EMF effects were shown, however the evidence was attributed a low or very low certainty. The body of evidence had limitations that did not allow an assessment of whether RF-EMF may affect pregnancy outcomes at exposure levels below those eliciting a wellknown adverse heating impact.In conclusion, in utero RF-EMF exposure does not have a detrimental effect on fecundity and likely affects offspring health at birth, based on the meta-analysis of studies in experimental mammals on litter size and fetal weight, respectively. Regarding possible delayed effects of in utero exposure, RF-EMF probably does not affect offspring brain weight and may not decrease female offspring fertility; on the other hand, RF-EMF may have a detrimental impact on neurobehavioural functions, varying in magnitude for different endpoints, but these last findings are very uncertain.Further research is needed on the effects at birth and delayed effects with sample sizes adequate for detecting a small effect. Future studies should use standardized endpoints for testing prenatal developmental toxicity and developmental neurotoxicity (OECD TG 414 and 426), improve the description of the exposure system design and exposure conditions, conduct appropriate dosimetry characterization, blind endpoint analysis and include several exposure levels to better enable the assessment of a dose-response relationship.
https://doi.org/10.1016/j.envint.2023.108178

Mobile phone use and brain tumour risk - COSMOS, a prospective cohort study,
FEYCHTING M., J. SCHÜZ, M. B. TOLEDANO, R. VERMEULEN, A. AUVINEN, A. H. POULSEN, I. DELTOUR, R. B. SMITH, J. HELLER, H. KROMHOUT, A. HUSS, C. JOHANSEN, G. TETTAMANTI and P. ELLIOTT,
Environment International 185 (Mar 2024),
Background: Each new generation of mobile phone technology has triggered discussions about potential carcinogenicity from exposure to radiofrequency electromagnetic fields (RF-EMF). Available evidence has been insufficient to conclude about long-term and heavy mobile phone use, limited by differential recall and selection bias, or crude exposure assessment. The Cohort Study on Mobile Phones and Health (COSMOS) was specifically designed to overcome these shortcomings. Methods: We recruited participants in Denmark, Finland, the Netherlands, Sweden, and the UK 2007-2012. The baseline questionnaire assessed lifetime history of mobile phone use. Participants were followed through population -based cancer registers to identify glioma, meningioma, and acoustic neuroma cases during follow-up. Non -differential exposure misclassification was reduced by adjusting estimates of mobile phone call -time through regression calibration methods based on self -reported data and objective operator -recorded information at baseline. Hazard ratios (HR) and 95% confidence intervals (CI) for glioma, meningioma, and acoustic neuroma in relation to lifetime history of mobile phone use were estimated with Cox regression models with attained age as the underlying time -scale, adjusted for country, sex, educational level, and marital status. Results: 264,574 participants accrued 1,836,479 person -years. During a median follow-up of 7.12 years, 149 glioma, 89 meningioma, and 29 incident cases of acoustic neuroma were diagnosed. The adjusted HR per 100 regression -calibrated cumulative hours of mobile phone call -time was 1.00 (95 % CI 0.98-1.02) for glioma, 1.01 (95 % CI 0.96-1.06) for meningioma, and 1.02 (95 % CI 0.99-1.06) for acoustic neuroma. For glioma, the HR for >= 1908 regression -calibrated cumulative hours (90th percentile cut -point) was 1.07 (95 % CI 0.62-1.86). Over 15 years of mobile phone use was

not associated with an increased tumour risk; for glioma the HR was 0.97 (95 % CI 0.62-1.52). Conclusions: Our findings suggest that the cumulative amount of mobile phone use is not associated with the risk of developing glioma, meningioma, or acoustic neuroma.
https://doi.org/10.1016/j.envint.2024.108552

Association of prolonged occupational co-exposures to electromagnetic fields, noise, and rotating shift work with thyroid hormone levels,
KHOSRAVIPOUR M., F. GHARAGOZLOU, M. G. KAKAVANDI, F. NADRI, A. BARZEGAR, K. EMAMI and H. V. ATHAR,
Ecotoxicology and Environmental Safety 270 (Jan 2024),
The purpose of this study was to determine the association of prolonged occupational co-exposure to extremely low-frequency electromagnetic fields (ELF-EMFs), noise, and rotating shift work with the levels of thyroid hormones (triiodothyronine (T3), thyroxine (T4), and thyroid-stimulating hormone (TSH). From 2016 to 2017, we enrolled all male workers without a history of thyroid disorders and followed them until 2020. To measure ELF-EMFs and noise exposures, we calculated the 8-hour equivalent sound pressure levels (Leq) and the 8-hour average of ELF-EMFs, respectively. Shift work schedules involved 8-hr fixed day and 8-hr clockwise 3-rotating night schedules. The participant's thyroid hormone levels were obtained from blood test results in their medical records. The percentage change in the levels of T3, T4, and TSH was estimated by using different mixedeffects linear regression models. The TSH levels were significantly elevated per a 10-dB increment of noise. The levels of T4 hormone were significantly changed per a unit increase in the levels of ELF-EMFs. Compared to the fixed-day workers, we observed workers exposed to shift work had a significantly lower T4 level. For T4 and TSH hormones, we found significant interactions among noise, ELF-EMFs, and shift work variables. In summary, this study warranted that prolonged exposure to ELF-EMFs, noise, and rotating shift work might be associated with thyroid dysfunction.
https://doi.org/10.1016/j.ecoenv.2023.115837

Mobile phone specific radiation disturbs cytokinesis and causes cell death but not acute chromosomal damage in buccal cells: Results of a controlled human intervention study,
KUNDI M., A. NERSESYAN, G. SCHMID, F. EIBENSTEINER, M. MISÍK and S. KNASMÜLLER,
Environmental Research 251 (Jun 2024),
Several human studies indicate that mobile phone specific electromagnetic fields may cause cancer in humans but the underlying molecular mechanisms are currently not known. Studies concerning chromosomal damage (which is causally related to cancer induction) are controversial and those addressing this issue in mobile phone users are based on the use of questionnaires to assess the exposure. We realized the first human intervention trial in which chromosomal damage and acute toxic effects were studied under controlled conditions. The participants were exposed via headsets at one randomly assigned side of the head to low and high doses of a UMTS signal (n = 20, to 0.1 W/kg and n = 21 to 1.6 W/kg Specific Absorption Rate) for 2 h on 5 consecutive days. Before and three weeks after the exposure, buccal cells were collected from both cheeks and micronuclei (MN, which are formed as a consequence of structural and numerical chromosomal aberrations) and other nuclear anomalies reflecting mitotic disturbance and acute cytotoxic effects were scored. We found no evidence for induction of MN and of nuclear buds which are caused by gene amplifications, but a significant increase of binucleated cells which are formed as a consequence of disturbed cell divisions, and of karyolitic cells, which are indicative for cell death. No such effects were seen in cells from the less exposed side. Our findings indicate that mobile phone specific high frequency electromagnetic fields do not cause acute chromosomal damage in oral mucosa cells under the present experimental conditions. However, we found clear evidence for disturbance of

the cell cycle and cytotoxicity. These effects may play a causal role in the induction of adverse long term health effects in humans. https://doi.org/10.1016/j.envres.2024.118634

Safety of Magnetic Resonance Imaging in Pregnancy,
MARALANI P. J., V. PAI and B. B. ERTL-WAGNER,
Radiologie 63, no. 1 (Jan 2023): S34-S40,
Magnetic resonance imaging is being increasingly used to diagnose and follow up a variety of medical conditions in pregnancy, both for maternal and fetal indications. However, limited data regarding its safe use in pregnancy may be a source of anxiety and avoidance for both patients and their healthcare providers. In this review, we critically discuss the main safety concerns of Magnetic Resonance Imaging (MRI) in pregnancy including energy deposition, acoustic noise, and use of contrast agents, supported by data from animal and human studies. Use of maternal sedatives and concerns related to occupational exposure in pregnant personnel are also addressed. Exposure to gadolinium-based contrast agents and sedation for MRI during pregnancy should be avoided whenever feasible. https://doi.org/10.1007/s00117-023-01207-7

Thermoluminescence dosimetry (TLD) in a 3 T magnetic resonance imaging (MRI) environment: implications for personnel exposure monitoring,
MEHRARA E.,
Biomedical Physics & Engineering Express 10, no. 4 (Jul 2024),
Thermoluminescent dosimeters (TLDs) serve as compact and user-friendly tools for various applications, including personal radiation dosimetry and radiation therapy. This study explores the potential of utilizing TLD-100 personal dosimetry, conventionally applied in PET/CT (positron emission tomography/computed tomography) settings, in the PET/MRI (magnetic resonance imaging) environment. The integration of MRI into conventional radiotherapy and PET systems necessitates ionizing radiation dosimetry in the presence of static magnetic fields. In this study, TLD-100 dosimeters were exposed on the surface of a water-filled cylindrical phantom containing PET-radioisotope and positioned on the patient table of a 3 T PET/MRI, where the magnetic field strength is around 0.2 T, aiming to replicate real-world scenarios experienced by personnel in PET/MRI environments. Results indicate that the modified MR-safe TLD-100 personal dosimeters exhibit no significant impact from the static magnetic field of the 3 T PET/MRI, supporting their suitability for personal dosimetry in PET/MRI settings. This study addresses a notable gap in existing literature on the effect of MRI static magnetic field on TLDs. https://doi.org/10.1088/2057-1976/ad470c

Environmental Pollution and Risk of Childhood Cancer: A Scoping Review of Evidence from the Last Decade,
NAVARRETE-MENESES M., C. SALAS-LABADÍA, F. GÓMEZ-CHÁVEZ and P. PÉREZ-VERA,
International Journal of Molecular Sciences 25, no. 6 (Mar 2024),
The long-term effects of environmental pollution have been of concern as several pollutants are carcinogenic, potentially inducing a variety of cancers, including childhood cancer, which is a leading cause of death around the world and, thus, is a public health issue. The present scoping review aimed to update and summarize the available literature to detect specific environmental pollutants and their association with certain types of childhood cancer. Studies published from 2013 to 2023 regarding environmental pollution and childhood cancer were retrieved from the PubMed database. A total of 174 studies were eligible for this review and were analyzed. Our search strategy brought up most of the articles that evaluated air pollution (29%) and pesticides (28%). Indoor exposure to chemicals (11%), alcohol and tobacco use during pregnancy (16%),

electromagnetic fields (12%), and radon (4%) were the subjects of less research. We found a particularly high percentage of positive associations between prenatal and postnatal exposure to indoor (84%) and outdoor (79%) air pollution, as well as to pesticides (82%), and childhood cancer. Positive associations were found between leukemia and pesticides and air pollution (33% and 27%); CNS tumors and neuroblastoma and pesticides (53% and 43%); and Wilms tumor and other rare cancers were found in association with air pollution (50%). Indoor air pollution was mostly reported in studies assessing several types of cancer (26%). Further studies are needed to investigate the mechanisms underlying the potential associations between indoor/outdoor air pollution and pesticide exposure with childhood cancer risk as more preventable measures could be taken. https://doi.org/10.3390/ijms25063284

Effect of Mobile Phone Usage During Pregnancy on Total Oxidant and Antioxidant Levels in Cord Blood,
ÖZEN G., D. KAHVECIOGLU, I. BULUT, O. EREL, S. NESELIOGLU, Y. ÜSTÜN and M. A. TASAR,
Journal of Behcet Uz Childrens Hospital 13, no. 3 (2023): 177-184,
Objective: Although cell phones are considered to have non-ionizing radiation, they have many adverse health effect. Non-ionizing radiation causes oxidant stress when the balance between the production of free oxygen radicals and their elimination by antioxidants is disrupted. The effects of mobile phone usage during pregnancy on the growing fetus is an important problem that needs to be resolved. We aimed to investigate the effects of using mobile phone during pregnancy on cord blood oxidant-antioxidant levels. Method: Cell phone usage features of 67 healthy pregnant women without additional risk factors were recorded. Total antioxidant status, total oxidant status (TOS), ischemia modified albumin (IMA), total thiol, native thiol, disulfide levels and disulfide/total thiol, disulfide/native thiol, native thiol/total thiol ratios evaluated in umblical cord blood. Results: A negative correlation was found between daily talking duration by mobile phone and IMA levels; a positive correlation was found between daily talking duration and native thiol, total thiol levels ($p<0.05$). TOS, native thiol and total thiol levels were higher in the mothers who have another mobile phone in their bedroom at night ($p<0.05$). Conclusion: Our study is the first clinical study that investigates the effects of using mobile phone during pregnancy on cord blood oxidant and antioxidant levels. Mobile phone exposure during pregnancy could have an important potential to cause oxidative stress in cord blood. Therefore, we think that it is important for pregnant women to protect themselves and the fetus by staying away from mobile phones as much as possible during pregnancy. https://doi.org/10.4274/jbuch.galenos.2023.70845

The effects of radiofrequency electromagnetic fields exposure on tinnitus, migraine and non-specific symptoms in the general and working population: A systematic review and meta-analysis on human observational studies,
RÖÖSLI M., S. DONGUS, H. JALILIAN, J. EYERS, E. ESU, C. M. ORINGANJE, M. MEREMIKWU and X. BOSCH-CAPBLANCH,
Environment International 183 (Jan 2024),
Background: Applications emitting radiofrequency electromagnetic fields (RF-EMF; 100 kHz to 300 GHz) are widely used for communication (e.g. mobile phones), in medicine (diathermy) and in industry (RF heaters).Objectives: The objective is to systematically review the effects of longer-term or repeated local and whole human body radiofrequency electromagnetic field (RF-EMF) exposure on the occurrence of symptoms. Primary hypotheses were tinnitus, migraine and headaches in relation to RF-EMF exposure of the brain, sleep disturbances and composite symptom scores in relation to whole-body RF-EMF exposure.Methods: Eligibility criteria: We included case-control and prospective cohort studies in the general population or workers estimating local or whole-body RF-EMF exposure for at least one week. Information sources: We conducted a systematic literature

search in various databases including Web of Science and Medline. Risk of bias: We used the Risk of Bias (RoB) tool developed by OHAT adapted to the topic of this review. Synthesis of results: We synthesized studies using random effects meta-analysis. Results: Included studies: We included 13 papers from eight distinct cohort and one case-control studies with a total of 486,558 participants conducted exclusively in Europe. Tinnitus is addressed in three papers, migraine in one, headaches in six, sleep disturbances in five, and composite symptom scores in five papers. Only one study addressed occupational exposure. Synthesis of results: For all five priority hypotheses, available research suggests that RF-EMF exposure below guideline values does not cause symptoms, but the evidence is very uncertain. The very low certainty evidence is due the low number of studies, possible risk of bias in some studies, inconsistencies, indirectness, and imprecision. In terms of non-priority hypotheses numerous exposure-outcome combinations were addressed in the 13 eligible papers without indication for an association related to a specific symptom or exposure source.Discussion: Limitations of evidence: This review topic includes various challenges related to confounding control and exposure assessment. Many of these aspects are inherently present and not easy to be solved in future research. Since near-field exposure from wireless communication devices is related to lifestyle, a particular challenge is to differentiate between potential biophysical effects and other potential effects from extensive use of wireless communication devices that may compete with healthy behaviour such as sleeping or physical activity. Future research needs novel and innovative methods to differentiate between these two hypothetical mechanisms.Interpretation: This is currently the best available evidence to underpin safety of RF-EMF. There is no indication that RF-EMF below guideline values causes symptoms. However, inherent limitations of the research results in substantial uncertainty.Other: Funding: This review was partially funded by the WHO radioprotection programme. Registration: The protocol for this review has been registered in Prospero (reg no CRD42021239432) and published in Environment International (Ro center dot o center dot sli et al., 2021)
https://doi.org/10.1016/j.envint.2023.108338

Electromagnetic Environment Assessment and Safety Research of Electrified High-Speed Railway Carriages,
SHI L., J. Y. LIANG, Y. Z. LIU, Y. Y. ZHAO and X. R. LI,
Electronics 13, no. 4 (Feb 2024),
With the advent of modern, high-speed electrified rail systems, there has been increasing concern about electromagnetic safety in rail carriages. The aim of this study was to assess the electromagnetic safety of passengers on trains by utilizing advanced 3D electromagnetic simulation software. A comprehensive model of the electromagnetic environment experienced by passengers on a CR400AF train, specifically under the influence of catenary radiation, was constructed. We analyzed the magnetic field strength, electric field strength, and current density in the brains of 20 passengers in various positions in the train. The findings revealed that among the 20 passengers analyzed, the maximum and minimum magnetic induction intensity recorded in the brain were 8.41 and 0.01 mu T, respectively. The maximum and minimum induced electric field intensities were 1110 and 10 mu V/m, respectively. Lastly, the maximum and minimum induced current densities were 1200 and 10 mu A/m2, respectively. The results show that when people ride on the CR400AF train, the magnetic induction intensity, induced electric field strength, and induced current density in the brain are below the recommended basic limits of exposure to power frequency electromagnetic fields in the guidelines of the International Committee on Non-Ionizing Radiation Protection. The power frequency magnetic field generated by the catenary can be effectively shielded by the aluminum alloy car body. The final result of this study indicates that the electromagnetic exposure from the contact wire at the level 25 kV does not pose a threat to the health of passengers on the CR400AF train. https://doi.org/10.3390/electronics13040740

New developments in cosmetic applications of electromagnetic fields: Client and occupational hazard assessment,
STAM R.,
Bioelectromagnetics (2024 Mar 2024),
Energy-based devices are used to improve features of appearance for aesthetic reasons while avoiding more invasive methods. Examples of treatment targets are the reduction of wrinkles, sagging, unwanted skin lesions, body hair and excess fatty tissue, and the enhancement of muscle tissue. One treatment modality is the use of electromagnetic fields (EMF, 0-300 GHz). The present work aims to give an up-to-date survey of cosmetic applications of EMF for professional use with an assessment of client and worker exposure and possible adverse effects. A systematic search was conducted for peer-reviewed articles (2007-2022), patents, premarket notifications, manufacturer data, and adverse effects reports. Five categories of cosmetic EMF device with increasing frequency were identified: sinusoid low frequency magnetic fields for lipolysis; pulsed low frequency magnetic fields for skin rejuvenation; pulsed low frequency magnetic fields for muscle building; radiofrequency EMF for lipolysis or skin rejuvenation; microwaves for hair removal or hyperhidrosis. In the vicinity of the last four device categories, there is a potential for exceeding the occupational exposure limits in the European Union EMF Directive, which could lead to nerve or muscle stimulation, burns or overheating. There are also potential hazards for clients or workers wearing active or passive medical devices. The severity of reported adverse effects increases with EMF frequency. The present review aims to systematically evaluate the literature on devices using electromagnetic fields (EMF; 1 Hz to 300 GHz) for cosmetic purposes, focusing on exposure levels and the potential for adverse effects in clients or operators. A systematic search was conducted for peer-reviewed articles, patents, premarket notifications, manufacturer data and adverse effects reports, and data on EMF strength and potential adverse effects were extracted. Five categories of cosmetic EMF device with frequencies ranging from extremely low frequency to microwaves were identified with the stated cosmetic aims of lipolysis, skin rejuvenation, muscle building, hair removal or reducing excessive sweating. For four device categories, there is a potential for exceeding occupational exposure limits in their vicinity and for adverse effects related to electrical stimulation or heating in clients. For all five device categories, there are also potential hazards for clients or operators wearing active or passive medical devices. https://doi.org/10.1002/bem.22503

Headache in the international cohort study of mobile phone use and health (COSMOS) in the Netherlands and the United Kingdom,
TRAINI E., R. B. SMITH, R. VERMEULEN, H. KROMHOUT, J. SCHÜZ, M. FEYCHTING, A. AUVINEN, A. H. POULSEN, I. DELTOUR, D. C. MULLER, J. HELLER, G. TETTAMANTI, P. ELLIOTT, A. HUSS and M. B. TOLEDANO,
Environmental Research 248 (May 2024),
Headache is a common condition with a substantial burden of disease worldwide. Concerns have been raised over the potential impact of long-term mobile phone use on headache due to radiofrequency electromagnetic fields (RF-EMFs). We explored prospectively the association between mobile phone use at baseline (2009-2012) and headache at follow-up (2015-2018) by analysing pooled data consisting of the Dutch and UK cohorts of the Cohort Study of Mobile Phone Use and Health (COSMOS) (N = 78,437). Frequency of headache, migraine, and information on mobile phone use, including use of hands-free devices and frequency of texting, were selfreported. We collected objective operator data to obtain regression calibrated estimates of voice call duration. In the model mutually adjusted for call-time and text messaging, participants in the high category of call-time showed an adjusted odds ratio (OR) of 1.04 (95 % CI: 0.94-1.15), with no clear trend of reporting headache with increasing call-time. However, we found an increased risk of weekly headache (OR = 1.40, 95 % CI: 1.25-1.56) in the high category of text messaging, with a clear

increase in reporting headache with increasing texting. Due to the negligible exposure to RF-EMFs from texting, our results suggest that mechanisms other than RF-EMFs are responsible for the increased risk of headache that we found among mobile phone users.
https://doi.org/10.1016/j.envres.2024.118290

Evaluation de l'exposition

Physics-Informed Machine Learning Modelling of RF-EMF Exposure in Massive MIMO Systems, BILSON S., T. H. LOH, F. HÉLIOT and A. THOMPSON, *Ieee Access* 12 (2024): 69410-69422,
Beamforming and massive multiple-input-multiple-output (mMIMO) technologies are key features of base stations (BSs) in the fifth-generation (5G) of mobile networks. This technology is used to focus more radio frequency (RF) energy towards actively connected users to improve their connection/performance, resulting in high variations in the radio frequency electromagnetic fields (RF-EMFs). This paper proposes a new methodology for modelling the RF-EMF exposure for 5G new radio (NR) mMIMO BS by means of a physics-informed machine learning (ML) approach using empirical measurement data. More precisely, the main focus of our work is to develop a suitable traceable RF-EMF exposure prediction tool in the context of 5G mMIMO BSs that can serve multiple mobile users (i.e. multiple-user MIMO (MU-MIMO)) within realistic real-world environments and scenarios. Our RF-EMF prediction tool relies on empirical measurement data acquired via a user-controllable mMIMO beamforming testbed and traceable RF-EMF measurement capability, where both indoor and outdoor RF-EMF measurement campaigns have been carried out. During the measurement campaigns various factors such as number of users, position of users and data duty cycles were considered. Using an ensemble of gradient boosted decision trees, we show that a physics-informed approach can improve predictive performance of RF-EMF compared with a purely data-driven approach, with the ability to extrapolate values of RF-EMF exposure to larger distances. Results show a coefficient of determination value of 0.86 on a 10-fold cross-validated experimental dataset. We also compare the sensitivity of RF-EMF exposure to various factors in the model, and show that model predictions become isotropic for large numbers of beam configurations, simplifying the exposure measurement methodology of 5G systems.
https://doi.org/10.1109/access.2024.3398992

Electromagnetic field exposure boundary analysis at the near field for multi-technology cellular base station site,
ELBASHEIR M. S., R. A. SAEED and S. EDAM, *Iet Communications* 18, no. 1 (Jan 2024): 11-27,
Mobile networks are expanding quickly as a result of significant advancements in wireless technologies and solutions, especially with the recent introduction of the Fifth Generation New Radio. The growth in mobile networks requires the installation of massive numbers of base stations that bring concerns about increasing overall electromagnetic field (EMF) radiation exposure levels. The International Commission on Non-Ionizing Radiation Protection (ICNIRP) has published guidelines that have been adopted by many regulators in many countries to control the overall radiation emitted from EMF transmitters. This paper studies the compliance boundary for a single site operating with multiple technologies including from the second generation (2G) to 5G colocated in the same site. The analysis is performed using a typical site configuration setup for the boundary calculations in the form of the Compliance Distance (CD). The calculation uses the power reduction factor and system load for more realistic results, and in situ measurements are conducted to validate the calculation's formula. The study also investigated the CD for four types of sites, macro, micro, small cell, and indoor sites. Additionally, the study analyzed the power densities (PDs) and total exposure ratio (TER) for the general public and occupational workers at

each site. The results show that CD has shorter distances when the power factor is considered, and 5G makes the highest contribution to the TER at the CD in the main directions of the antenna. Deployment of mobile networks involves the installation of base stations which causes an increase in total electromagnetic field exposure. The accurate analysis must identify the compliance boundary for the accumulated exposure from multi-technology co-existence.image https://doi.org/10.1049/cmu2.12711

Human exposure to EMF from 5G base stations: analysis, evaluation and comparison of different assessment methods,
EXPÓSITO I., C. HAKIZIMALI, M. G. SÁNCHEZ, I. CUIÑAS and J. VERHAEVERT, *Measurement* 229 (Apr 2024),
5G networks deployment poses new challenges when evaluating human exposure to electromagnetic fields. Fast variation of the user load and beamforming techniques may cause large fluctuations of 5G base stations field level. They may be underestimated, resulting in compliance of base stations not fitting the requirements. Apparently, broadband field meters would not be adequate for measuring such environments. However, we analyze the feasibility of confidently using broadband field meters and compare their performance with alternative equipment. Measurements based on the synchronization signals power level, using spectrum analyzers or drive test scanners, may be valid, if gain differences between the signaling and data radiation patterns are characterized. These methods lead to good results but require more time and knowledge. Nevertheless, using broadband field meters is still possible if the measurement results are corrected considering the base station load. Under specific conditions, explained here, fast assessment of 5G compliance could be provided.
https://doi.org/10.1016/j.measurement.2024.114434

Assessment of Exposure to Spatially Varying Magnetic Fields in MRI Environments: Modeling Analysis for Simulation Tools,
HARTWIG V., M. CIANFAGLIONE, F. CAMPANELLA, M. A. D'AVANZO, C. SANSOTTA and G. ACRI, *Ieee Access* 12 (2024): 11492-11499,
Magnetic resonance imaging (MRI) is a non-invasive diagnostic technique widely used in medicine with more than 60 million exams per year performed worldwide. MRI personnel are always exposed to static and spatially heterogeneous magnetic fields (fringe or stray fields) and motion-induced time-varying magnetic fields during the working day. This kind of exposure can evoke vertigo and other sensory perceptions such as nausea, visual sensations, and a metallic taste which are not considered hazardous per se, but can be disturbing and may impair working ability. Up to now, no standardized procedures have been available in the literature for the assessment of occupational exposure in an MRI environment. The goal of this paper is to give some indications about the analytical models underlying the development of digital tools for occupational exposure assessment in MRI environments, to have easy but interactive educational tools, for educating MRI staff to avoid higher-risk conditions, and to draw up the best practices. Analysis of the models for the estimation of the magnetic field spatial distribution and the representation of the workers' movements is described and finally, some recommendations for an accurate methodology to use in simulation tools for exposure assessment are given. https://doi.org/10.1109/access.2024.3355191

Spatially Averaged Epithelial/Absorbed Power Density for Nonplanar Skin Models Exposed to Antenna at 10-90 GHz,
LI K., S. KODERA, D. POLJAK, Y. L. DIAO, K. SASAKI, S. ZHANG, M. YAO, A. KAPETANOVIC, C. S. LI, T. N. WU, T. LIEBIG, W. SIMON and A. HIRATA, *Ieee Access* 12 (2024): 15379-15389,
International guidelines and standards for human protection from electromagnetic fields have been revised recently. The epithelial/absorbed power density (APD) has been used as a new physical quantity for local exposure to frequencies > 6 GHz, related to the temperature rise in the superficial

layer. The assessment methods of APD for practical exposure scenarios are crucial for realistic exposures. This study investigates averaging methods for APD in nonplanar skin models for local electromagnetic field exposure from 10 to 90 GHz. Eight research groups compared the calculated APDs using distinct numerical approaches and postprocessing techniques. The intercomparison aimed to clarify the primary causes of variations in aspects, such as APD averaging methods, skin model structure, and types of exposure antennas. Statistical analyses reveal that the maximum differences in relative confidence intervals (RCI) due to different average methods and skin models are within 9.4% and 5.1%, respectively. In contrast, when the distance between the antenna and skin is set to 5 mm, the discrepancy attributed to the exposure antenna reaches 59.4% at 10 GHz. This difference does not exceed 9.2% under other computational conditions. Additionally, the spatially averaged APD appears to have a linear relationship with the maximum skin surface temperature elevation, based on regression analysis. The findings indicate that the variances in the spatially averaged APD are largely independent of both the APD averaging methods and skin model structures. However, they slightly depend on the antenna types used as exposure sources.
https://doi.org/10.1109/access.2024.3358109

Assessment of public awareness on the effects of exposure to non-ionizing radiation sources in Tanzania,
NYAKYI C. P., S. C. MPESHE and M. A. DIDA, *Journal of Radiation Research and Applied Sciences* 17, no. 1 (Mar 2024),
Devices, equipment and facilities producing Non-Ionizing Radiation (NIR) are all around human environment. Exposure to NIR has effects to humans. Humans need to be aware of such effects as they are working with NIR sources and are working and living close to them. The objective of this research was to study public awareness on possible effects of exposure to NIR. The research was conducted in Mwanza, Dodoma and Dar es salaam regions in Tanzania. Through survey, respondents were approached and voluntarily requested to complete a structured questionnaire. Descriptive statistics was employed in data analysis and frequencies were computed to determine the counts and their percentages, and Chi-Square test of independence determined the existence of significant relationship between awareness statements and demographic variables. The research involved 600 respondents (314 (52.3%) males, 286 (47.7%) females). Results show that most respondents were aware of the effects of exposure to NIR and females were more aware than males. Awareness did not differ across education levels and respondents with no/low education showed the same level of awareness as those with higher education. Based on age, respondents of all age groups demonstrated awareness of NIR effects. However, some practices like mobile phone use, watching TVs, conducting activities or living near NIR sources, are exposing people to NIR. To make people more aware of NIR exposure effects, it is recommended awareness campaigns and training be provided to the public; to minimize NIR exposure, policies, regulations and guidelines be enforced by regulatory bodies and be observed by organs owning sources producing NIR. The essence is to ensure cases of effects due to NIR exposure are minimized.
https://doi.org/10.1016/j.jrras.2023.100770

A PRELIMINARY STUDY OF AMBIENT ELECTROMAGNETIC RADIATION AT BASE TOWER STATIONS IN RESIDENTIAL AREAS IN KUALA NERUS,
SENAFI N. M., N. ABDULLAH, N. S. MOHAMED, R. TUKIMIN and N. WAN, *Jurnal Teknologi-Sciences & Engineering* 86, no. 1 (Jan 2024): 83-93,
Introduction: Mobile communications have developed into an integral component of our daily life. The growing demand for mobile communication services in Kuala Nerus has seen an increase in the installation of base station towers (BST) in residential areas, as well as near schools, and hospitals. Kuala Nerus was selected as a study location because it is a newly developed district in Terengganu, hence, it is crucial to perform electromagnetic radiation (EMR) measurements in the early stages. Mobile service providers typically expand the number of base stations to improve signal reception

in anticipation of increasing demand. Objective/aim: This study aimed to measure the RF EMR exposure level in residential areas in Kuala Nerus by measuring the strength of its electric field (EF) strength and power density (PD) value while comparing it with the International Commission on Non-Ionizing Radiation Protection (ICNIRP)'s standard guidelines which is 61 (V/m) or 1000 (mu W/cm2). This study also developed a GIS map showing EMR exposure levels in residential areas at selected BSTs in Kuala Nerus. Materials and methods: Measurements were made using NARDA NBM 550, connected to a probe that could detect frequencies from 100kHz to 6GHz since Kuala Nerus only comply with 2G, 3G and 4G network. The data collection period for each point was approximately 6 minutes during daytime. Results: Average radiation levels in terms of EF strength at all locations were found to vary between 0.26 (V/m) to 3.35 (V/m) equivalent to (PD value about 0.02 mu W/cm2 to 2.97 mu W/cm2). The highest level was measured at Surau Kg Pok Tuyu, which was 5.48%. This ambient is 18 times lower than the Malaysian Communications and Multimedia Commission (MCMC) exposure limit for public areas and all the peak recorded levels were within the limits mentioned in the standard guidelines. The EMR saturation value was used to develop the GIS mapping by applying the Inverse Distance Weighted (IDW) Interpolation technique and a colour-code map of Kuala Nerus was produced. Conclusion: The RF value obtained does not exceed the standard limit, which in turn contributes indirectly to health monitoring initiatives for public NIR exposure. This study found that exposure levels in selected BSTs in residential areas in Kuala Nerus were within the standard guideline limits. https://doi.org/10.11113/jurnalteknologi.v86.20331

SDR-Based Portable System for Evaluating Exposure to Ambient Electromagnetic Fields,
TUTA L., F. PANAIT-RADU, F. ARDELEAN, D. GORGOTEANU and G. ROSU, *Electronics* 12, no. 24 (Dec 2023),
This paper discusses the need to accurately determine the population's exposure to low-intensity radio-frequency electromagnetic fields (RF-EMF) from modern technologies like mobile networks, Wi-Fi, and IoT and proposes a practical solution for this assessment. There is no scientific consensus on the biological effects, mostly due to challenges in conducting accurate biological experiments. Recent research suggests that real-life exposure sources trigger stronger biological responses than laboratory-generated RF-EMF. However, there is a lack of research comparing the effects of these sources. This paper introduces a portable system for assessing and monitoring EMF exposure in urban areas. Employing a Software-Defined Radio (SDR) platform to ensure adaptability, the system incorporates two measurement configurations. The initial version concentrates on determining the average power within a 20 MHz Wi-Fi channel, whereas the subsequent configuration augments its functionality by introducing a frequency sweep. This sweep broadens the scrutinized bandwidth, thereby enriching the captured data content through the storage of spectrum sweeps corresponding to each average power value. These data can be used to create EMF profile maps based on individuals' geographical coordinates. Compared to current limited-performance commercial exposimeters, the proposed system offers expanded capabilities by broadening the frequency bandwidth, georeferencing measurements, and storing data in an SQL database. Compared to high-performance commercial exposimeters, the major advantage of the system is its ability to detect short-term fluctuations in signal spectra and store the corresponding data for subsequent analysis. https://doi.org/10.3390/electronics12245003

Toxicité

Electromagnetic Modulation of Cell Behavior: Unraveling the Positive Impacts in a Comprehensive Review,

BAHMANPOUR A., S. M. GHOREISHIAN and A. SEPAHVANDI, *Annals of Biomedical Engineering* (2024 Apr 2024),
There are numerous effective procedures for cell signaling, in which humans directly transmit detectable signals to cells to govern their essential behaviors. From a biomedical perspective, the cellular response to the combined influence of electrical and magnetic fields holds significant promise in various domains, such as cancer treatment, targeted drug delivery, gene therapy, and wound healing. Among these modern cell signaling methods, electromagnetic fields (EMFs) play a pivotal role; however, there remains a paucity of knowledge concerning the effects of EMFs across all wavelengths. It's worth noting that most wavelengths are incompatible with human cells, and as such, this study excludes them from consideration. In this review, we aim to comprehensively explore the most effective and current EMFs, along with their therapeutic impacts on various cell types. Specifically, we delve into the influence of alternating electromagnetic fields (AEMFs) on diverse cell behaviors, encompassing proliferation, differentiation, biomineralization, cell death, and cell migration. Our findings underscore the substantial potential of these pivotal cellular behaviors in advancing the treatment of numerous diseases. Moreover, AEMFs wield a significant role in the realms of biomaterials and tissue engineering, given their capacity to decisively influence biomaterials, facilitate non-invasive procedures, ensure biocompatibility, and exhibit substantial efficacy. It is worth mentioning that AEMFs often serve as a last-resort treatment option for various diseases. Much about electromagnetic fields remains a mystery to the scientific community, and we have yet to unravel the precise mechanisms through which wavelengths control cellular fate. Consequently, our understanding and knowledge in this domain predominantly stem from repeated experiments yielding similar effects. In the ensuing sections of this article, we delve deeper into our extended experiments and research. https://doi.org/10.1007/s10439-024-03519-8

Effects of 3.5-GHz radiofrequency radiation on energy-regulatory hormone levels in the blood and adipose tissue,
BEKTAS H., S. DASDAG, F. ALTINDAG, M. Z. AKDAG, K. YEGIN and S. ALGUL, *Bioelectromagnetics* (2024 Feb 2024),
In recent years exposure of living beings to radiofrequency radiation (RFR) emitted from wireless equipment has increased. In this study, we investigated the effects of 3.5-GHz RFR on hormones that regulate energy metabolism in the body. Twenty-eight rats were divided into four groups: healthy sham (n = 7), healthy RFR (n = 7), diabetic sham (n = 7), and diabetic RFR (n = 7). Over a month, each group spent 2 h/day in a Plexiglas carousel. The rats in the experimental group were exposed to RFR, but the sham groups were not. At the end of the experiment, blood and adipose tissues were collected from euthanized rats. Total antioxidant, total oxidant, hydrogen peroxide, ghrelin, nesfatin-1, and irisin were determined. Insulin expression in pancreatic tissues was examined by immunohistochemical analysis. Whole body specific absorption rate was 37 mW/kg. For the parameters analyzed in blood and fat, the estimated effect size varied within the ranges of 0.215-0.929 and 0.503-0.839, respectively. The blood and adipose nesfatin-1 ($p = 0.002$), blood and pancreatic insulin are decreased, ($p = 0.001$), gherelin ($p = 0.020$), irisin ($p = 0.020$), and blood glucose ($p = 0.040$) are increased in healthy and diabetic rats exposed to RFR. While nesfatin-1 are negatively correlated with oxidative stress, hyperglycemia and insulin, ghrelin and irisin are positively correlated with oxidative stress and hyperglycemia. Thus, RFR may have deleterious effects on energy metabolism, particularly in the presence of diabetes. 3.5 GHz radiofrequency radiation (RFR) may induce alterations in hormones regulating energy metabolism. 3.5 GHz RFR may lead to alterations in total antioxidant, total oxidant, and hydrogen peroxide levels. Particularly in conjunction with diabetes, 3.5 GHz RFR may result in adverse effects on energy metabolism. Although there were changes of the hormone levels in the exposed group, the actual values remained for both sham and exposed groups within the normal range.
https://doi.org/10.1002/bem.22498

EXTREMELY LOW-FREQUENCY ELECTROMAGNETIC FIELD (ELF-EMF) INDUCED ALTERATIONS IN GENE EXPRESSION AND CYTOKINE SECRETION IN CLEAR CELL RENAL CARCINOMA CELLS,
CIOS A., M. CIEPIELAK, K. LIETO, D. MATAK, S. LEWICKI, M. PALUSINSKA, W. STANKIEWICZ and L. SZYMANSKI, *Medycyna Pracy-Workers Health and Safety* (2024 May 2024),
Background: The study aimed to investigate the influence of extremely low-frequency electromagnetic fields (ELF-EMF) on clear cell renal cell carcinoma (ccRCC) by assessing alterations in gene expression and the secretion of cytokines and chemokines. Material and Methods: Three ccRCC cell lines (786-O, 769-P, and CAKI-1) and a healthy HEK293 cell line were subjected to ELF-EMF exposure (frequency 50 Hz, magnetic field strength 4.5 mT) for 30 min daily for 5 days. The study examined the expression of ADAM28, NCAMI, and VEGFC genes, along with the secretion of 30 cytokines and chemokines. Results: Notably, primary tumor-derived cell lines, but not those from metastatic sites, exhibited ADAM28 gene expression, which increased following ELF-EMF exposure. A statistically significant reduction in VEGFC gene expression was observed in 769-P cells after ELF-EMF exposure. Additionally, NCAMI gene expression was upregulated in HEK293, 769-P, and 786-O cells, representing normal embryonic kidney cells and primary tumor cells, but not in CAKI-1 cells, which model metastatic sites. After EMF exposure, there was a statistically significant decrease in transforming growth factor (31 (TGF-(31) concentration in the cell culture supernatants of HEK293 and CAKI-1 cell lines, with no other significant changes in the secretion of tested cytokines. Conclusions: Given the study's findings and available research, caution is warranted when drawing conclusions about the potential inhibitory effect of ELF-EMF on ccRCC progression. Standardization of experimental models is imperative when assessing the effects of EMF in a human context. Med Pr Work Health Saf. 2024;75(2) https://doi.org/10.13075/mp.5893.01476

Effects of radiofrequency electromagnetic field (RF-EMF) exposure on male fertility: A systematic review of experimental studies on non-human mammals and human sperm in vitro,
CORDELLI E., L. ARDOINO, B. BENASSI, C. CONSALES, P. ELEUTERI, C. MARINO, M. SCIORTINO, P. VILLANI, M. H. BRINKWORTH, G. D. CHEN, J. P. MCNAMEE, A. W. WOOD, L. BELACKOVA, J. VERBEEK and F. PACCHIEROTTI, *Environment International* 185 (Mar 2024),
Background: The World Health Organization is coordinating an international project aimed at systematically reviewing the evidence regarding the association between radiofrequency electromagnetic field (RF-EMF) exposure and adverse health effects. Reproductive health outcomes have been identified among the priority topics to be addressed. Objectives: To evaluate the effect of RF-EMF exposure on male fertility of experimental mammals and on human sperm exposed in vitro. Methods: Three electronic databases (PubMed, Scopus and EMF Portal) were last searched on September 17, 2022. Two independent reviewers screened the studies, which were considered eligible if met the following criteria: 1) Peer -reviewed publications of sham controlled experimental studies, 2) Non -human male mammals exposed at any stage of development or human sperm exposed in vitro, 3) RF-EMF exposure within the frequency range of 100 kHz -300 GHz, including electromagnetic pulses (EMP), 4) one of the following indicators of reproductive system impairment: center dot decrease of fertility: rate of infertile males, rate of nonpregnant females, litter size and in vitro fertilization rate; center dot effects on semen quality: in animal studies sperm count, in both animal and in vitro studies sperm vitality, morphology and DNA/chromatin alterations; center dot reproductive organ toxicity: testis-epididymis weight, testis or epididymis histology, testis histomorphometry, testicular cell death, estimated testicular cell production; center dot hormonal effects: testosterone level. Two reviewers extracted study characteristics and outcome data. We assessed risk of bias (RoB) using the Office of Health Assessment and Translation (OHAT) guidelines. We categorized studies into 3 levels of overall RoB: low, some or high concern. We pooled study results in a random effects meta-analysis comparing average exposure to no -exposure and in a dose-response meta -analysis using all exposure doses. For experimental animal studies, we conducted subgroup analyses for species, Specific Absorption Rate (SAR) and temperature increase. We grouped studies on human sperm exposed in vitro by the fertility status

of sample donors and SAR. We assessed the certainty of the evidence using the GRADE approach after excluding studies that were rated as "high concern" for RoB. Results: One -hundred and seventeen papers on animal studies and 10 papers on human sperm exposed in vitro were included in this review. Only few studies were rated as "low concern" because most studies were at RoB for exposure and/or outcome assessment. Subgrouping the experimental animal studies by species, SAR, and temperature increase partly accounted for the heterogeneity of individual studies in about one third of the meta -analyses. In no case was it possible to conduct a subgroup analysis of the few human sperm in vitro studies because there were always 1 or more groups including less than 3 studies. Among all the considered endpoints, the meta -analyses of animal studies provided evidence of adverse effects of RF-EMF exposure in all cases but the rate of infertile males and the size of the sired litters. The assessment of certainty according to the GRADE methodology assigned a moderate certainty to the reduction of pregnancy rate and to the evidence of no -effect on litter size, a low certainty to the reduction of sperm count, and a very low certainty to all the other meta -analysis results. Studies on human sperm exposed in vitro indicated a small detrimental effect of RF-EMF exposure on vitality and no -effect on DNA/chromatin alterations. According to GRADE, a very low certainty was attributed to these results. The few studies that used EMP exposure did not show effects on the outcomes. A low to very low certainty was attributed to these results. Discussion: Many of the studies examined suffered of severe limitations that led to the attribution of uncertainty to the results of the meta -analyses and did not allow to draw firm conclusions on most of the endpoints. Nevertheless, the associations between RF-EMF exposure and decrease of pregnancy rate and sperm count, to which moderate and low certainty were attributed, are not negligible, also in view of the indications that in Western countries human male fertility potential seems to be progressively declining. It was beyond the scope of our systematic review to determine the shape of the dose-response relationship or to identify a minimum effective exposure level. The subgroup and the dose-response fitting analyses did not show a consistent relationship between the exposure levels and the observed effects. Notably, most studies evaluated RFEMF exposure levels that were higher than the levels to which human populations are typically exposed, and the limits set in international guidelines. For these reasons we cannot provide suggestions to confirm or reconsider current human exposure limits. Considering the outcomes of this systematic review and taking into account the limitations found in several of the studies, we suggest that further investigations with better characterization of exposure and dosimetry including several exposure levels and blinded outcome assessment were conducted. Protocol registration: Protocols for the systematic reviews of animal studies and of human sperm in vitro studies were published in Pacchierotti et al., 2021. The former was also registered in PROSPERO (CRD42021227729 https://www.crd.york.ac.uk/prospero/display_record.php?RecordID = 227729) and the latter in Open Science Framework (OSF Registration DOI https://doi.org/10.17605/OSF.IO/7MUS3). https://doi.org/10.1016/j.envint.2024.108509

Effects of Exposure to Radiofrequency at 2.45 GHz on Structural Changes Associated with Lipid Peroxidation in Prepubertal Rat Testicular Tissue,
KARADAYI A., N. A. UNAL, E. G. MUTLU, B. K. ENGIZ, A. AKKOCA and S. VAROL, *European Journal of Therapeutics* 29, no. 4 (Dec 2023): 846-855,
Objective: The increasing use of electronic devices, accompanied by advancing technologies, has led to heightened exposure to non-ionizing electromagnetic radiation (EMR). This exposure instigates the accumulation of free radicals and oxidative damage in tissues, consequently impacting biological systems. Notably, the testis is among the tissues adversely affected by EMR. Numerous studies have highlighted the pivotal role of the testis in sperm production, emphasizing the potential implications of any damage on the reproductive system. This study aims to assess the levels of lipid peroxidation through histological evaluation in the testicular tissue of prepubertal male rats exposed to electromagnetic radiation at varying electric field intensities within the 2.45 GHz radiofrequency (RF) range. Methods: The experimental group comprises six subdivisions,

including a sham control group, as well as groups exposed to varying electric field strengths (EFS) of 0.6 V/m, 1.9 V/m, 5 V/m, 10 V/m, and 15 V/m, respectively. Excluding the sham control group, the remaining subgroups were subjected to a daily 2.45 GHz RF exposure for 1 hour starting immediately after fertilization. This exposure to different electric field intensities continued for 45 days post-birth. Results: The samples obtained from the RF radiation-exposed rats exhibited elevated malondialdehyde (MDA) values and decreased glutathione (GSH) values in the testicular tissue. Furthermore, a comparative analysis between the microwave radiation-exposed group and the control group revealed distinct histological alterations in the testicular tissue. Conclusion: In conclusion, our findings indicate that exposure to microwave radiation at an electric field intensity of 15 V/m can lead to significant histopathological and oxidative parameter changes in Wistar rats. These results underscore the potential effects of such exposure on human health.
https://doi.org/10.58600/eurjther1875

Detrimental impact of cell phone radiation on sperm DNA integrity,
KOOHESTANIDEHAGHI Y., M. A. KHALILI, F. DEHGHANPOUR and M. SEIFY, *Clinical and Experimental Reproductive Medicine-Cerm* 51, no. 1 (Mar 2024): 13-19,
Radiofrequency electromagnetic radiation (RF-EMR) from various sources may impact health due to the generation of frequency bands. Broad pulses emitted within frequency bands can be absorbed by cells, influencing their function. Numerous laboratory studies have demonstrated that mobile phones- generally the most widely used devices-can have harmful effects on sex cells, such as sperm and oocytes, by producing RF-EMR. Moreover, some research has indicated that RF-EMR generated by mobile phones can influence sperm parameters, including motility, morphology, viability, and (most critically) DNA structure. Consequently, RF-EMR can disrupt both sperm function and fertilization. However, other studies have reported that exposure of spermatozoa to RF-EMR does not affect the functional parameters or genetic structure of sperm. These conflicting results likely stem from differences among studies in the duration and exposure distance, as well as the species of animal used. This report was undertaken to review the existing research discussing the effects of RF-EMR on the DNA integrity of mammalian spermatozoa.
https://doi.org/10.5653/cerm.2023.06121

Interactions between electromagnetic radiation and biological systems,
LIU L. Y., B. HUANG, Y. X. LU, Y. Y. ZHAO, X. P. TANG and Y. G. SHI, *Iscience* 27, no. 3 (Mar 2024),
Even though the bioeffects of electromagnetic radiation (EMR) have been extensively investigated during the past several decades, our understandings of the bioeffects of EMR and the mechanisms of the interactions between the biological systems and the EMRs are still far from satisfactory. In this article, we introduce and summarize the consensus, controversy, limitations, and unsolved issues. The published works have investigated the EMR effects on different biological systems including humans, animals, cells, and biochemical reactions. Alternative methodologies also include dielectric spectroscopy, detection of bioelectromagnetic emissions, and theoretical predictions. In many studies, the thermal effects of the EMR are not properly controlled or considered. The frequency of the EMR investigated is limited to the commonly used bands, particularly the frequencies of the power line and the wireless communications; far fewer studies were performed for other EMR frequencies. In addition, the bioeffects of the complex EM environment were rarely discussed. In summary, our understanding of the bioeffects of the EMR is quite restrictive and further investigations are needed to answer the unsolved questions.
https://doi.org/10.1016/j.isci.2024.109201

ICNIRP Statement on Short Wavelength Light Exposure from Indoor Artificial Sources and Human Health,

MILLER S., C. CAJOCHEN, A. GREEN, J. HANIFIN, A. HUSS, K. KARIPIDIS, S. LOUGHRAN, G. OFTEDAL, J. O'HAGAN, D. H. SLINEY, R. CROFT, E. VAN RONGEN, N. CRIDLAND, G. D'INZEO, A. HIRATA, C. MARINO, M. RÖÖSLI, S. WATANABE and ICNIRP, *Health Physics* 126, no. 4 (Apr 2024): 241-248,
Concerns have been raised about the possibility of effects from exposure to short wavelength light (SWL), defined here as 380-550 nm, on human health. The spectral sensitivity of the human circadian timing system peaks at around 480 nm, much shorter than the peak sensitivity of daytime vision (i.e., 555 nm). Some experimental studies have demonstrated effects on the circadian timing system and on sleep from SWL exposure, especially when SWL exposure occurs in the evening or at night. The International Commission on Non-Ionizing Radiation Protection (ICNIRP) has identified a lack of consensus among public health officials regarding whether SWL from artificial sources disrupts circadian rhythm, and if so, whether SWL-disrupted circadian rhythm is associated with adverse health outcomes. Systematic reviews of studies designed to examine the effects of SWL on sleep and human health have shown conflicting results. There are many variables that can affect the outcome of these experimental studies. One of the main problems in earlier studies was the use of photometric quantities as a surrogate for SWL exposure. Additionally, the measurement of ambient light may not be an accurate measure of the amount of light impinging on the intrinsically photosensitive retinal ganglion cells, which are now known to play a major role in the human circadian timing system. Furthermore, epidemiological studies of long-term effects of chronic SWL exposure per se on human health are lacking. ICNIRP recommends that an analysis of data gaps be performed to delineate the types of studies needed, the parameters that should be addressed, and the methodology that should be applied in future studies so that a decision about the need for exposure guidelines can be made. In the meantime, ICNIRP supports some recommendations for how the quality of future studies might be improved.
https://doi.org/10.1097/hp.0000000000001790

Effects of 2.4 GHz radiofrequency electromagnetic field (RF-EMF) on glioblastoma cells (U-118 MG),
NOWAK-TERPILOWSKA A., R. GÓRSKI, M. MARSZALEK, S. WOSINSKI, R. PRZESMYCKI, M. BUGAJ, L. NOWOSIELSKI, M. BARANOWSKI and J. ZEYLAND, *Annals of Agricultural and Environmental Medicine* 30, no. 4 (2023): 763-772,
Introduction. Mobile phones and Wi- Fi are the most commonly used forms of telecommunications. Initiated with the first generation, the mobile telephony is currently in its fifth generation without being screened extensively for any biological effects that it may have on humans or on animals. Some studies indicate that high frequency electromagnetic radiation emitted by mobile phone and Wi- Fi connection can have a negative effect upon human health, and can cause cancer, including brain tumour. Objective. The aim of the study was to investigate the influence of 2.4 GHz radiofrequency electromagnetic field (RF-EMF) on the proliferation and morphology of normal (human embryonic kidney cell line Hek-293) and cancer cells (glioblastoma cell line U-118 MG). Materials and method. The cell cultures were incubated in RF- EMF at the frequency of 2.4 GHz, with or without dielectric screen, for 24, 48 and 72h. In order to analyse the influence of the electromagnetic field on cell lines, Cytotoxicity test Cell Counting Kit-8 was performed. To protect cells against emission of the electromagnetic field, a dielectric screen was used. Results. It was found that 2.4 GHz RF electromagnetic field exposure caused a significant decrease in viability of U-118 MG and Hek-293 cells. The impact of the electromagnetic field was strongest in the case of cancer cells, and the decrease in their survival was much greater compared to the healthy (normal) cells of the Hek-293 line. Conclusions. Results of the study indicate that using a radio frequency electromagnetic field (2.4 GHz) has a clearly negative effect on the metabolic activity of glioblastoma cells. RF-EMF has much less impact on reducing the viability of normal cells (Hek -293) than cancer cells. https://doi.org/

Revue – microbiote intestinal et champs électromagnétiques

ROUSSEL A.-G. (2024).
Plusieurs maladies neuropsychiatriques, telles que la dépression, l'autisme, l'épilepsie, ou encore la maladie d'Alzheimer, ont été associées à des dysfonctionnements du microbiote intestinal (Kelly et al. 2017 ; Bastiaanssen et al. 2019) en même temps qu'elles ont été associées à l'exposition à des champs électromagnétiques non naturels de fréquence extrêmement basse et/ou de radiofréquence (voir Pall 2016 pour une revue). Dans le courant de recherches sur l'électrohypersensibilité (EHS) pour la préparation d'une revue précédente (« Mécanismes biologiques de l'électrohypersensibilité et de conditions associées »), il est apparu que celle-ci se caractérise par une étiologie au moins en partie intestinale, impliquant des signes et symptômes apparentés à l'allergie alimentaire et/ou à l'intolérance alimentaire et/ou au syndrome du côlon irritable (SCI). Au vu des différentes données disponibles au sujet de ces différentes conditions (dépression, autisme, épilepsie, maladie d'Alzheimer, et EHS), et au vu de l'implication conjointe de l'exposition à des champs électromagnétiques non naturels et du microbiote intestinal dans leur pathogenèse, il semblait nécessaire de rechercher comment des champs électromagnétiques exogènes pourraient affecter ce microbiote et/ou le mucus intestinal, où le microbiote réside, de façon particulière. Le but de cette revue a donc été de rassembler les différentes données disponibles relatives à l'électrophysiologie du microbiote et du mucus intestinal, et aux effets possibles de champs électromagnétiques non naturels sur cette dernière.
10.13140/RG.2.2.23814.18243

Static magnetic fields as a factor in modification of tissue and cell structure: a review,
SALETNIK B., A. PUCHALSKA-SARNA, A. SALETNIK, T. LIPA, B. DOBRZANSKI, JR. and C. PUCHALSKI,
International Agrophysics 38, no. 1 (2024): 43-75,
This review is intended to contribute to the evidence of the effects of static magnetic field on cells and tissue, as well as to present research results that will elucidate the com-plex matters involved in the formation and remodeling of cells. The cell characteristics studied in the papers that are reviewed include cell viability and proliferation, aggregation and their differentiation, structure and membrane potential. A moderate static magnetic field in the most commonly used range of 2-80 mT has potential application in the formation and remodeling of plant and human cells. However, in the case of cancer cells, the range of fields commonly used was 0.2-9 T. Magnetism promotes changes in plant cell growth, which prompts the cell to proliferate, thereby ensuring an increased rate of biomass production. Some researches presented the enhancement of the differentiation of plant cells and skeletal muscle tissue by over 30% at 80 mT static magnetic field. Changes in the cell cycle and growth reflect directly on the cell number and viability and provide useful information to detect modifications in the cell machinery. Static magnetic field, depending on its intensity, enhances cell proliferation and thus may improve, among other processes, tissue regeneration, wound healing and the inhibition of cancer cell proliferation. Researchers showed, among other things, that cells under the influence of static magnetic field changed their shape, had a larger chloroplast, stiffer cell wall, density of the cytoskeleton and cytoplasm contained several mitochondria. Numerous studies also discussed the behavior of the cell membrane of plant and animal organisms, including humans, under the influence of an static magnetic field. The effects of static magnetic field on the cell membrane of plant and human cells were similar. The research results indicate that static magnetic fields can significantly change membrane depolarization and its potential that regulates ion movement and thus can have a significant impact on the properties and biological functionality of the cell. Studies have shown that continuous application of static magnetic field caused deformation and damage of cell membrane. Based on the theoretical analyses presented also in this review, it can be concluded that static magnetic field affects cells and tissue, giving them changes in properties and behaviors and modulates, e.g. in the activity of ion channels. Thus it may produce effects leading to changes in the functioning of the cell. It is possible to formulate directions for further research aimed at using static magnetic fields for the

non-invasive remodeling and formation of plant and human cells.
https://doi.org/10.31545/intagr/176998

Hypomagnetic Conditions and Their Biological Action (Review),
SARIMOV R. M., D. A. SEROV and S. V. GUDKOV, *Biology-Basel* 12, no. 12 (Dec 2023),
Simple Summary The Earth's magnetic field is vital for life to exist. If the field becomes weaker, it's known as hypomagnetic conditions. Studying the impact of hypomagnetic conditions on living beings is significant for multiple reasons. Firstly, it helps us comprehend the biological consequences and learn more about how the magnetic field interacts with living organisms. Secondly, understanding the impact of hypomagnetic conditions on human health is important for preparing for extended space missions. This report outlines the influence of hypomagnetic conditions on various objects such as animals, humans, plants, bacteria, and individual molecules. It explains the effects at both a cellular and organismal level, and lists and characterizes the most likely mechanisms that account for biological responses to magnetic fields. Over the past century, scientists have gathered extensive data on the impacts of hypomagnetic conditions. We aimed to investigate the effect of experimental methods and type of exposure on the observed effects. Our findings indicate that hypomagnetic conditions primarily affect cellular processes such as gene expression and protein synthesis, as well as the functioning of the nervous system including neuron development and behavioral reactions.Abstract The geomagnetic field plays an important role in the existence of life on Earth. The study of the biological effects of (hypomagnetic conditions) HMC is an important task in magnetobiology. The fundamental importance is expanding and clarifying knowledge about the mechanisms of magnetic field interaction with living systems. The applied significance is improving the training of astronauts for long-term space expeditions. This review describes the effects of HMC on animals and plants, manifested at the cellular and organismal levels. General information is given about the probable mechanisms of HMC and geomagnetic field action on living systems. The main experimental approaches are described. We attempted to systematize quantitative data from various studies and identify general dependencies of the magnetobiology effects' value on HMC characteristics (induction, exposure duration) and the biological parameter under study. The most pronounced effects were found at the cellular level compared to the organismal level. Gene expression and protein activity appeared to be the most sensitive to HMC among the molecular cellular processes. The nervous system was found to be the most sensitive in the case of the organism level. The review may be of interest to biologists, physicians, physicists, and specialists in interdisciplinary fields.
https://doi.org/10.3390/biology12121513

Electromagnetic field (50 Hz) enhance metabolic potential and induce adaptive/reprogramming response mediated by the increase of N6-methyladenosine RNA methylation in adipose-derived mesenchymal stem cells in vitro,
SENDERA A., J. ADAMCZYK-GROCHALA, B. PIKULA, M. CHOLEWA and A. BANAS-ZABCZYK,
Toxicology in Vitro 95 (Mar 2024),
Background: Electromagnetic fields (EMF) have an impact on numerous cellular processes. It can positively and negatively affect adipose-derived stem cells (ASCs) thus their fate through the influence of specific factors and protein secretion. EMF can be a great factor for preconditioning ASCs for regenerative medicine purposes, however, understanding the cell's biological response to its effects in vitro is essential.Methods: ASCs were exposed to the EMF (50 Hz; 1.5 mT) for 24 and 48 h, and then cell biological response was analyzed.Results: 24 h exposure of ASCs to EMF, significantly increased N6-methyladenosine (m6A) RNA methylation, indicating epitranscriptomic changes as an important factor in ASCs preconditioning. Furthermore, the expression of stem cell markers such as Nanog, Oct-4, Sox-2, CD44, and CD105 increased after 24 h of EMF exposure. Besides, western blot analysis showed upregulation of p21 and DNMT2/TRDMT1 protein levels compared to control cells with no differences in the p53 profile. Moreover, after 24 h of exposure

to EMF, cell membrane flexibility, the metabolic potential of cells as well as the distribution, morphology, and metabolism of mitochondria were altered.Conclusion: ASCs undergo a process of mobilization and adaptation under the EMF influence through the increased m6A RNA modifications. These conditions may "force" ASCs to redefine their stem cell fate mediated by RNA-modifying enzymes and alter their reprogramming decision of as differentiation begins. https://doi.org/10.1016/j.tiv.2023.105743

A study on effects of cell phone tower-emitted non-ionizing radiations in an Allium cepa test system,
SHARMA A., S. SHARMA, S. BAHEL and J. K. KATNORIA, *Environmental Monitoring and Assessment* 196, no. 3 (Mar 2024),
Considering enormous growth in population, technical advancement, and added reliance on electronic devices leading to adverse health effects, in situ simulations were made to evaluate effects of non-ionizing radiations emitted from three cell phone towers (T1, T2, and T3) of frequency bands (800, 1800, 2300 MHz), (900, 1800, 2300 MHz), and (1800 MHz), respectively. Five sites (S1-S5) were selected near cell phone towers exhibiting different power densities. The site with zero power density was considered as control. Effects of radiations were studied on morphology; protein content; antioxidant enzymes like ascorbate peroxidase (APX), superoxide dismutase (SOD), glutathione-S-transferase (GST), guaiacol peroxidase (POD), and glutathione reductase (GR); and genotoxicity using Allium cepa. Mean power density (mu W/cm(2)) was recorded as 1.05, 1.18, 1.6, 2.73, and 12.9 for sites 1, 2, 3, 4, and 5, respectively. A significant change in morphology, root length, fresh weight, and dry weight in Allium cepa was observed under the exposure at different sites. Protein content of roots showed significant difference for samples at all sites while bulbs at sites S4 and S5 when compared to control. Antioxidant activity for root in terms of APX, GST, and POD showed significant changes at S4 and S5 and GR at site S5 and SOD at S1, S2, S3, S4, and S5. Similarly, bulbs showed significant changes at sites S4 and S5 for APX while at sites S3, S4, and S5 for POD and S2, S3, S4, and S5 for SOD and S5 for GR and GST. Genotoxicity study has shown induction of abnormalities at different stages of the cell cycle in Allium cepa root tips. The samples under exposure to radiation with maximum power density have shown maximum induction of oxidative stress and genotoxicity. https://doi.org/10.1007/s10661-024-12435-2

Impact of Long-Lasting Environmental Factors on Regulation Mediated by the miR-34 Family,
STEFÁNIK P., M. MOROVÁ and I. HERICHOVÁ, *Biomedicines* 12, no. 2 (Feb 2024),
The present review focuses on the interactions of newly emerging environmental factors with miRNA-mediated regulation. In particular, we draw attention to the effects of phthalates, electromagnetic fields (EMFs) and a disrupted light/dark cycle. miRNAs are small non-coding RNA molecules with a tremendous regulatory impact, which is usually executed via gene expression inhibition. To address the capacity of environmental factors to influence miRNA-mediated regulation, the miR-34 family was selected for its well-described oncostatic and neuro-modulatory properties. The expression of miR-34 is in a tissue-dependent manner to some extent under the control of the circadian system. There is experimental evidence implicating that phthalates, EMFs and the circadian system interact with the miR-34 family, in both lines of its physiological functioning. The inhibition of miR-34 expression in response to phthalates, EMFs and light contamination has been described in cancer tissue and cell lines and was associated with a decline in oncostatic miR-34a signalling (decrease in p21 expression) and a promotion of tumorigenesis (increases in Noth1, cyclin D1 and cry1 expressions). The effects of miR-34 on neural functions have also been influenced by phthalates, EMFs and a disrupted light/dark cycle. Environmental factors shifted the effects of miR-34 from beneficial to the promotion of neurodegeneration and decreased cognition. Moreover, the apoptogenic capacity of miR-34 induced via phthalate administration in the testes has been shown to negatively influence germ cell proliferation. To conclude, as the oncostatic and positive neuromodulatory functions of the miR-34 family can be strongly influenced

by environmental factors, their interactions should be taken into consideration in translational medicine. https://doi.org/10.3390/biomedicines12020424

Effects of 700 and 3500 MHz 5G radiofrequency exposure on developing zebrafish embryos, TORRES-RUIZ M., O. J. SUÁREZ, V. LÓPEZ, P. MARINA, A. SANCHIS, I. LISTE, M. DE ALBA and V. RAMOS, *Science of the Total Environment* 915 (Mar 2024),
Telecommunications industries are rapidly deploying the fifth generation (5G) spectrum and there is public concern about the safety and health impacts of this type of Radio Frequency Radiation (RFR), in part because of the lack of comparable scientific evidence. In this study we have used a validated commercially available setting producing a uniform field to expose zebrafish embryos (ZFe) to unmodulated 700 and 3500 MHz frequencies. We have combined a battery of toxicity, developmental and behavioral assays to further explore potential RFR effects. Our neurobehavioral profiles include a tail coiling assay, a light/dark activity assay, two thigmotaxis anxiety assays (auditory and visual stimuli), and a startle response - habituation assay in response to auditory stimuli. ZFe were exposed for 1 and 4 h during the blastula period of development and endpoints evaluated up to 120 hours post fertilization (hpf). Our results show no effects on mortality, hatching or body length. However, we have demonstrated specific organ morphological effects, and behavioral effects in activity, anxiety -like behavior, and habituation that lasted in larvae exposed during the early embryonic period. A decrease in acetylcholinesterase activity was also observed and could explain some of the observed behavioral alterations. Interestingly, effects were more pronounced in ZFe exposed to the 700 MHz frequency, and especially for the 4 h exposure period. In addition, we have demonstrated that our exposure setup is robust, flexible with regard to frequency and power testing, and highly comparable. Future work will include exposure of ZFe to 5G modulated signals for different time periods to better understand the potential health effects of novel 5G RFR. https://doi.org/10.1016/j.scitotenv.2023.169475

Effects of electromagnetic radiation on neurogenesis and gene expression in amniocytes, UZUN C., N. ERDAL, O. I. AY, U. KARAKAS, D. D. YILDIRIM, H. DURUKAN, M. B. AKDAG and M. E. ERDAL, *Toxicological and Environmental Chemistry* (2024 Jan 2024),
The aim of the study was to investigate the genetic effects of commonly used radiofrequency on the amniocytes of pregnant women by examining the changes in the expression of genes related to signal transduction and neurogenesis induced by electromagnetic fields of radiofrequencies of 1800 and 2100 MHz by real-time PCR. Upon exposure of the amniocytes to electromagnetic radiation of 2100 MHz at high field strength, the expression levels of genes with important functions in the Wnt signaling pathways as well as neurogenesis-related genes were increased. The findings suggest that radiofrequency at high field strengths can have genotoxic effects during pregnancy.
https://doi.org/10.1080/02772248.2024.2304014

Electromagnetic Immunity of Pacemakers and Implantable Defibrillators to Wireless Power Transfer Systems for Automotive: A Provocative Study,
VIVARELLI C., F. CENSI, G. CALCAGNINI, F. FRESCHI, L. GIACCONE, A. CANOVA and E. MATTEI, *Ieee Transactions on Electromagnetic Compatibility* 66, no. 1 (Feb 2024): 97-107,
Wireless power transfer (WPT) in automotive is an emerging technology that utilizes coupled coils to transfer power through time-varying magnetic fields, enabling the charging of electric vehicles. Like any electromagnetic field source, WPT systems can potentially interfere with other electronic devices, impacting their proper functioning. This risk requires evaluation, especially when the affected device is a cardiac implantable electronic device (CIED), as malfunctioning can pose serious hazards to the patient's safety. Currently, WPT technology is in its early stages and has not been explicitly considered during the drafting of current CIED regulations. Consequently, predicting the behavior of a CIED when in proximity to a WPT system is not straightforward, and new experimental data are necessary. The objective of this article is to conduct in-vitro testing on a

representative sample of pacemakers (PMs) and implantable cardioverter/defibrillators exposed to a magnetic field at the frequency of WTP systems, with field levels gradually increasing up to ICNIRP occupational reference levels. Compared to previous studies, the main novelty is to assess, on 11 commercial CIEDs, a safety margin for the exposure to the magnetic field dispersed by a WPT system, under worst-case exposure condition. Over a total of 51 conducted tests 24 interfering events were observed: only 1 occurred with a magnetic field at 50 mu T while all the others were observed with higher field levels, at 75 and 100 mu T. Thus, the results of this research demonstrate that the risk of interference is very low. Electromagnetic interference phenomena were observed only under worst-case conditions (e.g., maximum sensitivity of the device, maximum lead loop area, pulsed modulation, and unipolar configuration for PMs) and at exposure levels above the ICNIRP general population reference levels.
https://doi.org/10.1109/temc.2023.3338453

Thermal effects of metal implants embedded in different layers of human tissues exposed to electromagnetic fields,
WESSAPAN T. and P. RATTANADECHO, *Case Studies in Thermal Engineering* 53 (Jan 2024),
Metal implants are typically used in medicine and body modifications to repair or replace damaged tissues, bones, or organs. However, they can cause complications, such as pain, inflammation, and tissue damage, when exposed to strong electromagnetic fields. This study is performed to examine the effect of high-intensity near-field electromagnetic exposure on the thermal effects of metal implants in human tissues. Maxwell's equations and a bioheat model are employed in a numerical simulation to determine the electromagnetic field and temperature distributions in implants and surrounding tissues during exposure to high-intensity electromagnetic fields in close proximity. Various factors are examined, including the implant shape, size, material, and insertion depth. A physical model comprising layers of tissue and metal implants is employed, which is subjected to an alternating electromagnetic field generated by an induction coil. Results show that the implant shape, size, and depth affect tissue heating. Stainless steel 410 implants result in higher tissue temperature increases owing to their greater sensitivity to electromagnetic induction compared with Ti-6Al-4V implants. The findings from this study provide valuable insights into the thermal behavior and electromagnetic interactions of metal implants in human tissues, thus contributing to the advancement of implant design and human safety in electromagnetic environments.
https://doi.org/10.1016/j.csite.2023.103771

Low-frequency electromagnetic fields influence the expression of calcium metabolism related proteins in leukocytic cell lines,
WÓJCIK-PIOTROWICZ K., J. KASZUBA-ZWOINSKA, P. PISZCZEK, B. NOWAK, P. GUZDEK, K. GIL and E. ROKITA, *Environmental Toxicology and Pharmacology* 104 (Nov 2023),
Our study aimed to verify the hypothesis concerning low-frequency magnetic fields (LF-MFs)-related changes in cell viability through the biomechanism(s) based on calcineurin (CaN)-mediated signaling pathways triggered via ROS-like molecules. For experiments, Mono Mac 6 and U937 leukocytic cell lines were chosen and exposed to various LF-MFs and/or puromycin (PMC). The protein expression level of key regulatory proteins of calcium metabolism was examined by Western Blot analysis. In turn, the reactive oxygen species (ROS) and cell viability parameters were evaluated by cytochrome C reduction assay and flow cytometry, respectively. The simultaneous action of applied MF and PMC influenced cell viability in a MF-dependent manner. The changes in cell viability were correlated with protein expression and ROS levels. It was verified experimentally that applied stress stimuli influence cell susceptibility to undergo cell death. Moreover, the evoked bioeffects might be recognized as specific to both types of leukocyte populations.
https://doi.org/10.1016/j.etap.2023.104320

The endocannabinoid system is involved in the anxiety-like behavior induced by dual-frequency 2.65/0.8 GHz electromagnetic radiation in mice,
XUE T., R. H. MA, C. XU, B. SUN, D. F. YAN, X. M. LIU, D. W. GAO, Z. H. LI, Y. GAO and C. Z. WANG, *Frontiers in Molecular Neuroscience* 17 (Apr 2024),
As wireless communication devices gain popularity, concerns about the potential risks of environmental exposure to complex frequency electromagnetic radiation (EMR) on mental health have become a public health issue. Historically, EMR research has predominantly focused on single-frequency electromagnetic waves, neglecting the study of multi-frequency electromagnetic waves, which more accurately represent everyday life. To address these concerns, our study compared the emotional effects of single-frequency and dual-frequency EMR while exploring potential molecular mechanisms and intervention targets. Our results revealed that single-frequency EMR at 2.65 or 0.8 GHz did not induce anxiety-like behavior in mice. However, exposure to dual-frequency EMR at 2.65/0.8 GHz significantly led to anxiety-like behavior in mice. Further analysis of mouse sera revealed substantial increases in corticosterone and corticotrophin releasing hormone levels following exposure to 2.65/0.8 GHz EMR. Transcriptome sequencing indicated a significant decrease in the expression of Cnr1, encoding cannabinoid receptor 1 Type (CB1R), in the cerebral. This finding was consistently verified through western blot analysis, revealing a substantial reduction in CB1R content. Additionally, a significant decrease in the endocannabinoid 2-arachidonoylglycerol was observed in the cerebral cortex. Remarkably, administering the cannabinoid receptor agonist Win55-212-2 significantly alleviated the anxiety-like behavior, and the cannabinoid receptor antagonist AM251 effectively counteracted the anti-anxiety effects of Win55-212-2. In summary, our research confirmed that dual-frequency EMR is more likely to induce anxiety-like behavior in mice than single-frequency EMR, with implications for the hypothalamic-pituitary-adrenal axis and the endocannabinoid system. Furthermore, our findings suggest that Win55-212-2 may represent a novel avenue for researching and developing anti-EMR drugs. https://doi.org/10.3389/fnmol.2024.1366855

Shortwave radiation-induced reproductive organ damage in male rats by enhanced expression of molecules associated with the calpain/Cdk5 pathway and oxidative stress,
YAO B. W., J. Q. MEN, S. C. LIU, Y. X. BAI, C. YU, Y. B. GAO, X. P. XU, L. ZHAO, J. ZHANG, H. WANG, Y. Y. LI and R. Y. PENG, *Electromagnetic Biology and Medicine* 42, no. 4 (Oct 2023): 150-162,
Shortwave radiation has been reported to have harmful effects on several organs in humans and animals. However, the biological effects of 27 MHz shortwave on the reproductive system are not clear. In this study, we investigated the effects of shortwave whole-body exposure at a frequency of 27 MHz on structural and functional changes in the testis. Male Wistar rats were exposed to 27 MHz continuous shortwaves at average power densities of 0, 5, 10, or 30 mW/cm2 for 6 min. The levels of insulin-like factor 3 (INSL3) and anti-sperm antibodies (AsAb) in the peripheral serum, sperm motility, sperm malformation rate, and testicular tissue structure of rats were analyzed. Furthermore, the activity of superoxide dismutase (SOD), catalase (CAT), malondialdehyde (MDA) content, calpain, and Cdk5 expression were analyzed at 1, 7, 14, and 28 days after exposure. We observed that the rats after radiation had decreased serum INSL3 levels ($p < 0.01$), increased AsAb levels ($p < 0.05$), decreased percentage of class A+B sperm ($p < 0.01$ or $p < 0.05$), increased sperm malformation ($p < 0.01$ or $p < 0.05$), injured testicular tissue structure, decreased SOD and CAT activities ($p < 0.01$ or $p < 0.05$), increased MDA content ($p < 0.01$), and testicular tissue expressions of calpain1, calpain2, and Cdk5 were increased ($p < 0.01$ or $p < 0.05$). In conclusion, Shortwave radiation caused functional and structural damage to the reproductive organs of male rats. Furthermore, oxidative stress and key molecules in the calpain/Cdk5 pathway are likely involved in this process. https://doi.org/10.1080/15368378.2023.2296896

Comparison of pulsed and continuous electromagnetic field generated by WPT system on human dermal and neural cells,
ZAHUMENSKA R., B. BADUROVA, M. PAVELEK, P. SOJKA, T. PAVLISOVA, P. SPANIK, M. K. SIVONOVA, S. NOVAKOVA, J. STRNADEL, E. HALASOVA, M. FRIVALDSKY and H. SKOVIEROVA, *Scientific Reports* 14, no. 1 (Mar 2024),
In recent decades, we have seen significant technical progress in the modern world, leading to the widespread use of telecommunications systems, electrical appliances, and wireless technologies. These devices generate electromagnetic radiation (EMR) and electromagnetic fields (EMF) most often in the extremely low frequency or radio-frequency range. Therefore, they were included in the group of environmental risk factors that affect the human body and health on a daily basis. In this study, we tested the effect of exposure EMF generated by a new prototype wireless charging system on four human cell lines (normal cell lines-HDFa, NHA; tumor cell lines-SH-SY5Y, T98G). We tested different operating parameters of the wireless power transfer (WPT) device (87-207 kHz, 1.01-1.05 kW, 1.3-1.7 mT) at different exposure times (pulsed 6 x 10 min; continuous 1 x 60 min). We observed the effect of EMF on cell morphology and cytoskeletal changes, cell viability and mitotic activity, cytotoxicity, genotoxicity, and oxidative stress. The results of our study did not show any negative effect of the generated EMF on either normal cells or tumor cell lines. However, in order to be able to estimate the risk, further population and epidemiological studies are needed, which would reveal the clinical consequences of EMF impact. https://doi.org/10.1038/s41598-024-56051-z

Méthodes

In Silico Numerical Model of Aluminum and Iron Dissolution During Electric Pulse Application for Electroporation,
BALANTIC K., P. KRAMAR and D. MIKLAVCIC, *Bioelectricity* 6, no. 1 (Mar 2024): 42-53,
Introduction: Electroporation is a technique that increases the cell membrane permeability by application of electric pulses and has a widespread use in different fields such as medicine, biotechnology as well as in the food industry. Electric pulses unavoidable cause electrochemical reactions at the electrode-electrolyte interface among others, metal release from the electrodes. Consequently, a challenge in developing electroporation treatments is in predicting and optimizing the factors affecting electrochemical reactions. Efficient tool for optimization of electroporation protocols is by modeling the reactions that take place close to the electrodes. Objectives: The aim of this work was to develop and validate a numerical model to describe electrochemical reactions, mainly metal dissolution taking place at the electrode-electrolyte interface during the application of electric pulses. Methods: The analysis was focused on modeling aluminum cuvette and stainless steel plate electrodes, as they are commonly used in electroporation research. A two-dimensional model was used with Nernst-Planck equations for ion transport and Butler-Volmer equations to describe electrode kinetics thus for the first time giving the possibility to implement different electroporation protocols, that is, pulse waveforms as an input function to the numerical model. The developed model was validated using experimental study by Kotnik et al. Results: Numerical model shows that the pulse amplitude and polarity (monophasic vs. biphasic) greatly affects the dissolution of aluminum and iron ions from the electrodes. Conclusions: The presented model requires further improvements but can with its limitations be used to optimize electroporation pulse waveforms in medicine and biology. https://doi.org/10.1089/bioe.2023.0026

Tensor-conductance model for reducing the computational artifact in target tissue for low-frequency dosimetry,
DIAO Y. L., L. LIU, N. DENG, S. LYU and A. HIRATA, *Physics in Medicine and Biology* 68, no. 20 (Oct 2023),
Objective. In protecting human from low-frequency (<100 kHz) exposure, an induced electric field strength is used as a physical quantity for assessment. However, the computational assessment suffers from a staircasing error because of the approximation of curved boundary discretized with cubic voxels. The international guidelines consider an additional reduction factor of 3 when setting the limit of external field strength computed from the permissible induced electric field. Here, a new method was proposed to reduce the staircasing error considering the tensor conductance in human modeling for low-frequency dosimetry. Approach. We proposed a tensor-based conductance model, which was developed on the basis of the filling ratio and the direction of the tissue interface to satisfy the electric field boundary condition and reduce staircasing errors in the target tissue of a voxel human model. Main results. The proposed model was validated using two-layer nonconcentric cylindrical and spherical models with different conductivity contrasts. A comparison of induced electric field strengths with solutions obtained using an analytical formula and finite element method simulation indicated that for a wide range of conductivity ratios, staircasing errors were reduced compared with a conventional scalar-potential finite-difference method. The induced electric field in a simple anatomical head model using our approach was in good agreement with finite element method for exposure to uniform magnetic field exposure and that from coil, simulating transcranial magnetic stimulation. Significance. The proposed tensor-conductance model demonstrated that the staircasing error in an inner target tissue of a voxel human body can be reduced. This finding can be used for the electromagnetic compliance assessment and dose evaluation in electric or magnetic stimulation at low frequencies.
https://doi.org/10.1088/1361-6560/acfae0

Skin electroporation for transdermal drug delivery: Electrical measurements, numerical model and molecule delivery,
KOUGKOLOS G., L. LAUDEBAT, S. DINCULESCU, J. SIMON, M. GOLZIO, Z. VALDEZ-NAVA and E. FLAHAUT, *Journal of Controlled Release* 367 (Mar 2024): 235-247,
Skin electroporation for drug delivery involves the application of Pulsed Electric Fields (PEFs) on the skin to disrupt its barrier function in a temporary and non-invasive manner, increasing the uptake of drugs. It represents a potential alternative to delivery methods that are invasive (e.g. injections) or limited. We have developed a drug delivery system comprising nanocomposite hydrogels which act as a reservoir for the drug and an electrode for applying electric pulses on the skin. In this study, we employed a multi-scale approach to investigate the drug delivery system on a mouse skin model, through electrical measurements, numerical modeling and fluorescence microscopy. The Electrical properties indicated a highly non-linear skin conductivity behavior and were used to fine-tune the simulations and study skin recovery after electroporation. Simulation of electric field distribution in the skin showed amplitudes in the range of reversible tissue electroporation (400-1200 V/cm), for 300 V PEF. Fluorescence microscopy revealed increased uptake of fluorescent molecules compared to the non-pulsed control. We reported two reversible electroporation domains for our configuration: (1) at 100 V PEF the first local transport regions appear in the extracellular lipids of the stratum corneum, demonstrated by a rapid increase in the skin's conductivity and an increased uptake of lucifer yellow, a small hydrophilic fluorophore and (2) at 300 V PEF, the first permeabilization of nucleated cells occurred, evidenced by the increased fluorescence of propidium iodide, a membrane-impermeable, DNA intercalating agent.
https://doi.org/10.1016/j.jconrel.2024.01.036

Antenna Model for Safe Human Exposure in Future 6G Smartphones: A Network Perspective,

KOUR H., R. K. JHA and S. JAIN, *Ieee Transactions on Green Communications and Networking* 7, no. 4 (Dec 2023): 2010-2024,
In this article we present the biological effect of antenna topology on a user's body. At different values of exposed frequency, the absorbent nature varies in human body. One of the major factors to be taken into consideration for designing 5G/6G mobile antenna is the biological effect and Electromagnetic Field Exposure (EMF). This is because the radio waves absorbed in human tissue leads to temperature elevation and has associated health hazards. We present an 8 port Multiple Input Multiple Output antenna system for use in 6G and beyond smartphone application devices. The proposed antenna is PIFA (Planar Inverted F Antenna) with dimensions $17.85\times 5\mathbf {\mathrm {mm}}<^>{\mathbf {2}}$ and has dual band function at Sub 6GHz and 28/54 GHz band. The mean effective gain variation is < 3dB and the efficiency ranges from 65-75% for the proposed antenna. There are three case scenarios present for the proposed antenna system to reduce the EM radiation exposure. The execution of the proposed antenna system is studied in terms of EM metrics. The performance is validated with low peak SAR values obtained, low power density, exposure ratio and temperature elevation. There is EM radiation reduction while maintaining a desired Quality of service (QoS) and QoE. Battery life enhancement is also seen in a smartphone device with the proposed configuration. https://doi.org/10.1109/tgcn.2023.3303471

Fast and Reliable Human Exposure Assessment Around High Power Systems Using Surrogate Modeling,
LAGOUANELLE P., F. FRESCHI, L. PICHON and L. GIACCONE, *Ieee Access* 12 (2024): 34835-34845,
Due to the high level of magnetic stray field around high power electromagnetic systems, the human exposure needs to be properly assessed in order to check the compliance with international standards and guidelines. Such analyses are usually made in two steps: first a proper map of the magnetic field in the vicinity area is computed, where, in a second time a human model is used to compute induced dosimetric quantities. Unfortunately, such high power systems have a high computational cost in addition to the complexity of 3D human models. Thus, this paper shows the useful combination of stochastic tools with numerical solvers in order to build accurate predictors at a low computation cost in the case of human exposure for various high power systems. These surrogate models can be used to accurately analyze the sensitivity of the exposure problem regarding various input parameters at a low computation cost. A dosimetric methodology for assessing the safety of a human body around an inductive power transfer system for automotive applications, using an adaptive metamodelling algorithm coupled with a voxelized 3D human model, has been developed. Such analysis has been successfully extended to a system where human exposure assessment are crucially needed: medium-frequency direct-current welding guns, treating the case of human exposure to a pulsed magnetic field. This methodology manages to reduce the computation time by more than 99.9% compared to a classical analysis for both exposure problems. https://doi.org/10.1109/access.2024.3366654

Compliance Assessment of the Spatial Averaging Method for Magnetic Field Leakage from a Wireless Power Transfer System in Electric Vehicles,
OKADA M., K. MIWA, S. KODERA and A. HIRATA, *Applied Sciences-Basel* 14, no. 7 (Apr 2024),
Wireless power transfer (WPT) via magnetic resonance offers efficient electrical power transfer, making it an increasingly attractive option for charging electric vehicles (EVs) without conventional plugs. However, EV charging requires a transfer power in order of kW or higher, resulting in a higher-leaked magnetic field than conventional wireless systems. The leaked magnetic field is nonuniform, and the assessment in terms of the limit prescribed in the guideline is highly conservative because it assumes that a person standing in free space is exposed to a uniform field. In such cases, an assessment should be performed using the limits of the internal electric field, as it is more relevant to the adverse health effects, whereas its evaluation is time-consuming. To mitigate this over-conservativeness, international product standards introduce a spatial averaging

method for nonuniform exposure assessment. In this study, we investigate assessment methods, especially for measurement points of nonuniform magnetic field strength leaked from the WPT system. Various spatial averaging methods are correlated with the internal electric field derived from electromagnetic field analysis using an anatomically based human body model. Our computational results confirm a good correlation between the spatially averaged magnetic and internal electric fields. Additionally, these methods provide an appropriate compliance assessment with the exposure guidelines. This study advances our understanding of the suitability of spatial averaging methods for nonuniform exposure and contributes to the smooth assessment in WPT systems. https://doi.org/10.3390/app14072672

On the Quasistationarity of the Ambient Electromagnetic Field Generated by Wi-Fi Sources, TUTA L., G. ROSU, A. ANDONE, S. SPANDOLE-DINU and L. O. FICHTE, *Electronics* 13, no. 2 (Jan 2024), In recent decades, the widespread use of mobile phones and wireless technologies has led to a significant increase in radiofrequency electromagnetic fields (RF-EMFs), raising concerns about continuous RF-EMF exposure among the general population. Recent research indicates that real-life RF signals are more biologically active than controlled laboratory signals with a low variability, suggesting that living organisms can adapt to EMF exposure when the pattern has a low variability. However, using real-life sources with unpredictable variation signals in biological experiments contradicts the principle of experiment controllability. This paper aims to investigate the nature of signals generated by current sources of ambient EMFs in terms of stationarity, with the goal of replicating them in biological experiments to study the effects of EMF exposure. Employing a range of statistical methodologies, starting with descriptive statistical analysis and progressing to the advanced APDP and APTF methods, an examination is conducted on a collection of Wi-Fi signal recordings across various operating modes, with particular attention given to video streaming. The chosen datasets are scrutinized with respect to their adherence to a Gaussian distribution and the concept of stationarity. The results indicate that the observed Wi-Fi signals lack stationarity in both the time and frequency domains. However, based on the analytical findings, it is possible to generate signals in frequency that authentically replicate Wi-Fi signals, accounting for nonstationarity considerations. https://doi.org/10.3390/electronics13020301

Measurement and Calibration of EMF: A Study Using Phone and GBDT for Mobile Communication Signals,
ZENG S., W. W. CHEN, Y. H. JI, L. P. YAN and X. ZHAO, *Radio Science* 59, no. 2 (Feb 2024), Electromagnetic exposure caused by mobile communication signals has always been a cause of concern. Due to the cost and inconvenience of professional measurement equipment, researchers have turned to smartphone APPs to study and assess the electric field strength caused by mobile communication signals. However, existing cell phone-based measurements have two weaknesses. First, no system architecture suitable for large-scale crowdsourced testing has been proposed. Second, since smartphone sensors cannot measure electric field strength directly, existing methods for converting the received signal power of the phone and electric field strength have errors of more than 5 dB. This paper proposes a measurement and calibration method for electric field strength of mobile communication signals based on a smartphone app and gradient boosting decision tree (GBDT). This method consists of a downlink signal acquisition system based on an APP and a calibration model based on GBDT to convert received signal power into electric field strength. The experimental results show that the proposed model achieves a R2 score of 0.93 and a MAE of 0.97 dB. Compared with the existing methods, our method improves the calibration accuracy by 4 dB, enabling large-scale, low-cost, and high-precision direct measurement of the electric field strength of mobile communication signals. Using smartphones and machine learning to measure the electric field strength of mobile communication signals A system converting the power of mobile communication signals to electric field strength with high accuracy Suitable for large-scale

and low-cost measurement of the electric field strength of mobile communication signals https://doi.org/10.1029/2023rs007890

Mesures de prévention

Nanocomposite polymers and their applications for electromagnetic interference shielding, ABD ELAZIZ N. A., F. S. HAFEZ, A. HAMID, M. E. E. MOSTAFA, T. E. AHMED, I. OMAR, L. ZEID, A. YOUNES, R. HAMED, D. N. ZAGHLOUL, H. MOHAMED and M. DARWISH, *Polymer-Plastics Technology and Materials* (2024 Apr 2024),
Electromagnetic pollution has increased because of technological advances and the use of telecommunication equipment and electronics. Developing a smart shielder based on nanocomposite polymer with excellent electromagnetic radiation shielding (EMS) is highly desired for protection. This review will cover the challenge of reducing electromagnetic radiation by developing smart nanocomposite polymers with a broad absorption frequency. The study will focus on the impact of electromagnetic radiation on our natural surroundings. The reflection, absorption, and multiple reflection EMS strategies will also be covered. The fabrication methods of nanocomposite polymer will be investigated. Finally, future perspectives and research routes will be considered. [GRAPHICS] . https://doi.org/10.1080/25740881.2024.2341095

An All-Stretchable, Ultraviolet Protective, and Electromagnetic-Interference-Free E-Textile, DONG J. C., Y. D. PENG, J. Y. LONG, Y. X. ZHANG, Z. C. WANG, T. E. PARK, Y. P. HUANG and T. X. LIU, *Advanced Functional Materials* 33, no. 45 (Nov 2023),
Flexible and skin-mountable electronics have drawn tremendous research attention with the booming of smart medical systems and wearing technologies, however, their environmental adaptability to electromagnetic and solar radiation has long been neglected. Herein, a novel health monitoring e-textile with robust ultraviolet (UV) protecting and strong electromagnetic interference (EMI) shielding performance is rationally developed on an ultraelastic and bilayered nonwoven textile. Via the respective incorporation of silver flake-modified liquid metal (AgLM) and silver nanoparticles (AgNPs) on each side of a permeable substrate, a Janus sensing layer with electrophysiological monitoring function, Joule heating ability, and excellent EMI shielding capability (up to 38.5 dB in X band) is first fabricated. Elastic microfibers embedded with sensitive photochromic microcapsules are then in situ assembled on the bioelectric-sensing layer, achieving a bilayered e-textile with a reversible UV-chromic property and an extraordinary UV protection factor (UPF) of 335.56. The developed all-stretchable and UV-EMI proof e-textile is utilized as a safe and comfortable on-skin electronic to provide point-of-care health regulation under complex UV/EMI radiative environments. Specifically, stable Joule heating performance and accurate monitoring of electrocardiogram (ECG) and surface electromyography (sEMG) are simultaneously obtained, demonstrating promising applications in multifunctional and robust wearing electronics. https://doi.org/10.1002/adfm.202308426

Mitigation of the Electric Field Under EHVTL in Limited Space Crowded With Human Activities, ELMASHTOLY M. H., O. E. GOUDA, M. LEHTONEN and M. M. F. DARWISH, *Ieee Access* 12 (2024): 41009-41018,
Workers in the activities under high-voltage lines are exposed to the influence of the electric field of these lines, which may cause, in some cases, death as a result of some serious accidents such as the collapse of the towers and the occurrence of line to ground faults. In some densely populated countries, people may live near the right-of-way (ROW) of extra high-voltage transmission lines (EHVTLs), which may cause, as a result of the high electric field, health problems, for this reason,

some researchers have pointed out the possible relationship between exposure to electric and magnetic fields on the one hand and the appearance of some diseases, especially in children, on the other hand. The aim of this article is to suggest a way to reduce the electric field in the place where people are found by using metal grids at safe distances from the EHVTLs. In this article, the electric field is calculated in the event that these grids are isolated or grounded. A comparison between the electric field without the use of shielding grids and with using these grids when they are isolated and earthed is carried out. The effect of changing the location of the shielding grids on the electric field values is examined. It is illustrated from this study that the peak value of the electric field intensity is mitigated to be 16.66% of its value before shielding, which proved the method's effectiveness in lowering the intensity of the electric field. The effect of an isolated shielding grid is to shift the electric field curve to be more flat. The installation of the earthed grids beside and parallel to the lines has a significant influence on the mitigation of the electric field under the EHVTL. https://doi.org/10.1109/access.2024.3376417

Washable and stable coaxial electrospinning fabric with superior electromagnetic interference shielding performance for multifunctional electronics,
FAN S. T., D. L. GUO, Y. T. ZHANG, T. CHEN, B. J. LI and S. ZHANG, *Chemical Engineering Journal* 488 (May 2024),
There is an urgent need for multifunctional and wearable smart devices to address the growing environmental impact on the human body, especially for pregnant women. However, it is big challenge to explore fabric combined multi-functions, such as EMI shielding, electrical therapy and biomotion detection while maintaining their intrinsic durability and washability. Here, we have employed an efficient coaxial electrospinning technique, followed by Ag precursor reduction and polydimethylsiloxane spraying to fabricate a multifunctional film which contains core-shell fibers with polyurethane/carbon nanotube (CNT) as core and polyurethane/Fe3O4 as shell. The CNT and the Ag nanoparticles (AgNPs) form double conductive network for EMI shielding, electrical heating and biological motion detection. The Fe3O4 provides magnetic loss and helps the fibers to provide rich attachment sites for AgNPs. The obtained film has an excellent combination of high EMI SE (110.0 dB in X-band), large Joule heating (up to 230 degrees C at 3 V), good sensing performance and large sensing range of 230 % strain. In addition, it showed an extremely superior durability and stability in complex conditions, good breathability and wash stability, ensuring the comfort wearing. This study offers an outstanding paradigm to construct next generation intelligent fabric combined versatility, stability and wearing comfort for protection of pregnant women and military solider. https://doi.org/10.1016/j.cej.2024.151051

A Review of the Effectiveness of Shielding Curtains for Improving Radiation Safety Management of Electromagnetic Radiation in Diagnostic X-ray Rooms,
KIM J. H., G. J. KIM, S. J. YOO and M. S. JU, *Journal of Magnetics* 28, no. 4 (Dec 2023): 438-442,
During diagnostic radiography examinations, due to problems such as patient falls, the door between the examination room and the control room is often opened for quick action. Therefore, the purpose of this study is to evaluate the effectiveness of curtain-type shielding for worker radiation protection. Shielding efficiency, weight, cost, and user opinions were analyzed for leaded, leaded rubber, lead-free shielding sheet, and chainmail. The results showed that the shielding efficiency was 97.7 % for the steel door, 97.5 % for the lead sheet, 97.0 % for the lead rubber, 96.0 % for the lead-free sheet, and 91.3 % for the chain mail, and the weight was 7,399 g for the lead sheet, 8,482 g for the lead rubber, 1,148 g for the lead-free sheet, and 8,127 g for the chain mail. The cost was $46.9 for the lead sheet, $126 for the lead rubber, $270.5 for the lead-free sheet, and $147.8 for the chain mail. Based on this, it is believed that shielding curtains can be used to provide both worker and patient safety by considering the conditions of diagnostic radiography rooms in each medical institution. https://doi.org/10.4283/jmag.2023.28.4.438

Thermally Conductive and UV-EMI Shielding Electronic Textiles for Unrestricted and Multifaceted Health Monitoring,
PENG Y. D., J. C. DONG, J. Y. LONG, Y. X. ZHANG, X. W. TANG, X. LIN, H. R. LIU, T. Q. LIU, W. FAN, T. X. LIU and Y. P. HUANG, *Nano-Micro Letters* 16, no. 1 (Dec 2024),
Skin-attachable electronics have garnered considerable research attention in health monitoring and artificial intelligence domains, whereas susceptibility to electromagnetic interference (EMI), heat accumulation issues, and ultraviolet (UV)-induced aging problems pose significant constraints on their potential applications. Here, an ultra-elastic, highly breathable, and thermal-comfortable epidermal sensor with exceptional UV-EMI shielding performance and remarkable thermal conductivity is developed for high-fidelity monitoring of multiple human electrophysiological signals. Via filling the elastomeric microfibers with thermally conductive boron nitride nanoparticles and bridging the insulating fiber interfaces by plating Ag nanoparticles (NPs), an interwoven thermal conducting fiber network (0.72 W m(-1) K-1) is constructed benefiting from the seamless thermal interfaces, facilitating unimpeded heat dissipation for comfort skin wearing. More excitingly, the elastomeric fiber substrates simultaneously achieve outstanding UV protection (UPF = 143.1) and EMI shielding (SET > 65, X-band) capabilities owing to the high electrical conductivity and surface plasmon resonance of Ag NPs. Furthermore, an electronic textile prepared by printing liquid metal on the UV-EMI shielding and thermally conductive nonwoven textile is finally utilized as an advanced epidermal sensor, which succeeds in monitoring different electrophysiological signals under vigorous electromagnetic interference. This research paves the way for developing protective and environmentally adaptive epidermal electronics for next-generation health regulation. https://doi.org/10.1007/s40820-024-01429-x

Repères pour la prise en charge des personnes électrohypersensibles,
POUGNET R., J.-D. DEWITTE, S. FANTONI, L. BENSEFA-COLAS, F. GRECO, M. LEDENT, X. GOCKO, N. KERGARAVAT, M.-B. ENIAFE-EVEILLARD, V. PITRON and M. GROHENS, *Archives des Maladies Professionnelles et de l'Environnement* 85, no. 2 (2024/05/01/ 2024): 102130,
Introduction Les sources d'ondes électromagnétiques sont diverses et leur utilisation est en augmentation depuis une vingtaine d'années. Certaines personnes se plaignent des ondes électromagnétiques générées et les lient à des complications médicales et des signes fonctionnels. On parle couramment d'électrohypersensibilité (EHS) ou, dans la CIM-11, d'intolérance environnementale idiopathique aux champs électromagnétiques (IEI-CEM). La prévalence des personnes se déclarant électrohypersensibles n'est pourtant pas connue car elle différait selon les études les estimations allant de moins de 0,7 % à 13,4 %. En 2018, l'ANSES a émis un rapport sur l'EHS. La Direction général de la santé, suite à ce rapport, a demandé à la Société française de santé au travail, de coordonner un groupe de travail (GT) en vue de remettre des repères pour la prise en charge de ces personnes. L'objet de cette communication est de résumé le travail réalisé par la SFST et d'en exposer les principaux apports. Matériel et méthode En amont de la composition d'un groupe et d'une méthodologie, la première étape, lors de la saisine de la SFST par la DGS, a été de déterminer les questions pratiques auxquelles étaient confrontés les praticiens face à une personne se déclarant EHS, parmi lesquelles certaines concernent particulièrement les médecins du travail : quelle démarche mettre en œuvre pour établir un diagnostic ? Quelles sont les indications et modalités de recours aux consultations spécialisées en CRPPE ? Quelle prise en charge médicosociale envisager pour les patients se déclarant EHS ? Quelles sont les circonstances pour lesquelles une évaluation voire une mesure de l'exposition aux CEM serait pertinente (à domicile et/ou sur le lieu de travail du patient) ? Le GT était pluridisciplinaire. L'approche était à la fois de faire la synthèse bibliographique, et d'interroger des personnalités à interroger en fonction de leur expérience clinique, ou de leur expérience de patient, ou encore de leur activité de recherche. Résultats Le GT a interrogé de personnalités de plusieurs pays européens (France, Belgique, Espagne, Autriche). Les 10 questions de la DGS ont été analysées. Le GT propose un déroulé des évènements du temps de la rencontre, à la démarche de diagnostic différentiel, en abordant la

question de la place des CRPPE, ainsi que la place des mesures. Conclusion Ce travail de la SFST a pour but d'aider les professionnels de santé dans la prise en charge des personnes EHS. Certaines personnes EHS ont des difficultés dans leur insertion professionnelle et une partie des éléments de ce rapport pourra peut-être aider à prévenir une éventuelle désinsertion.
https://doi.org/https://doi.org/10.1016/j.admp.2024.102130

Flexible and breathable textile-based multi-functional strain sensor for compressive sensing, electromagnetic shielding, and electrical heating,
SUN Z. F., J. J. YANG, Y. H. LI, Z. Y. CHEN, F. REN, Y. L. JIN, G. J. ZHU and P. G. REN, *Journal of Alloys and Compounds* 983 (May 2024),
The textile-based sensors have drawn increasing attention in wearable smart electronics, owing to the comfort, breathability, and elasticity. However, the low compressive strain response range, poor thermal comfort and electromagnetic shielding performance hinder severely the application of textile-based sensors in the complex environments. To address these issues, we chose a weft-flat knitted textile with a large gap as a flexible substance, graphene nanosheets (GNS), and Ag nanowires (Ag NWs) as conductive fillers, and treated the textile with a simple dip coating strategy to obtain TPU/GNS/Ag NWs@textile (TAG@textile). The prepared TAG@textile sensor not only exhibits 90% compressive strain response range and high sensitivity (GF=9.25), but also exhibits an efficient electromagnetic shielding performance of 61.68 dB. In addition, the TAG@textile sensor has excellent Joule thermal performance (it can reach 104 C-degrees at a low voltage of 4 V). In brief, this work integrates human motion detection, electromagnetic shielding, and electrical heating, showing a great potential in future multifunctional wearable electronic devices.
https://doi.org/10.1016/j.jallcom.2024.173867

Electromagnetic pollution as a factor of vulnerability of the right to a healthy environment in cities: an approach based on uncertainty and the precautionary principle,
VARGAS-CHAVES I. and A. M. BETANCUR-QUICENO, *Revista De Direito Da Cidade-City Law* 15, no. 3 (2023): 1345-1367,
This article proposes to analyze the phenomenon of electromagnetic pollution as a vulnerability factor of the right to a healthy environment. The authors study this phenomenon based on scientific uncertainty and propose that it is a problem that the legislator and the judges must resolve, as a consequence of the evidence that shows that there is a potential risk of affecting human health. The article proposes a solution to the precautionary principle, a legal mechanism designed to anticipate potential risks in the context of uncertainty. The methodology chosen was the documentary analysis of scientific texts, norms, and jurisprudence, following from an indicative method a systematic interpretation to contrast the results with the realities of environmental law. The authors concluded that the precautionary principle is a useful guide criterion to regulate exposure to sources of electromagnetic pollution in densely populated urban centers, protecting the right to a healthy environment for its inhabitants.
https://doi.org/10.12957/rdc.2023.78054ISSN2317-7721

A Scalable and Robust Personal Health Management Textile with Multiple Desired Thermal Functions and Electromagnetic Shielding,
TANG L. T., B. LYU, D. G. GAO, Y. Y. ZHOU, Y. C. WANG, F. X. WANG, Z. T. JIA, Y. T. FU, K. CHEN and J. Z. MA, *Advanced Science* (2024 Apr 2024),
The development of functional textiles combining conventional apparel with advanced technologies for personal health management (PHM) has garnered widespread attention. However, the current PHM textiles often achieve multifunctionality by stacking functional modules, leading to poor durability and scalability. Herein, a scalable and robust PHM textile is designed by integrating electrical, radiative, and solar heating, electromagnetic interference (EMI) shielding, and piezoresistive sensing performance onto cotton fabric. This is achieved through an uncomplicated

screen-printing process using silver paste. The conductivity of the PHM textile is approximate to 1.6 x 104 S m-1, ensuring an electric heating temperature of approximate to 134 degrees C with a low voltage of 1.7 V, as well as an EMI shielding effectiveness of approximate to 56 dB, and human motion monitoring performance. Surprisingly, the radiative/solar heating capability of the PHM textile surpasses that of traditional warm leather. Even after undergoing rigorous physical and chemical treatments, the PHM textile maintains terrific durability. Additionally, the PHM textile possesses maneuverable scalability and comfortable wearability. This innovative work opens up new avenues for the strategic design of PHM textiles and provides an advantageous guarantee of mass production. A novel Personal Health Management textile is proposed by integrating electrical heating, radiative heating, EMI shielding, and piezoresistive sensing performance onto a cotton fabric, which is achieved through an uncomplicated screen-printing process using silver paste. image https://doi.org/10.1002/advs.202400687

Bionic-leaf vein inspired breathable anti-impact wearable electronics with health monitoring, electromagnetic interference shielding and thermal management,
WANG X. Y., Y. TAO, C. Y. ZHAO, M. SANG, J. P. WU, K. C. F. LEUNG, Z. Y. FAN, X. L. GONG and S. H. XUAN, *Journal of Materials Science & Technology* 188 (Jul 2024): 216-227,
Breathable and stretchable conductive materials are ideal for healthcare wearable electronic devices. However, the tradeoff between the sensitivity and detection range of electronic sensors and the challenge posed by simple-functional electronics limits their development. Here, inspired by the bionic-leaf vein conductive path, silver nanowires (AgNWs)-Ti3 C2 Tx (MXene) hybrid structure assembled on the nonwoven fabrics (NWF) is well sandwiched between porous polyborosiloxane elastomer (PBSE) to construct the multifunctional breathable wearable electronics with both high anti-impact performance and good sensing behavior. Benefiting from the high conductive AgNWs-MXene hybrid structure, the NWF/AgNWsMXene/PBSE nanocomposite exhibits high sensitivity (GF = 1158.1), wide monitoring range (57 %), controllable thermal management properties, and excellent electromagnetic interference shielding effect (SET = 41.46 dB). Moreover, owing to the wonderful shear stiffening effect of PBSE, the NWF/AgNWsMXene/PBSE possesses a high energy absorption performance. Combining with deep learning, this breathable electronic device can be further applied to wireless sensing gloves and multifunctional medical belts, which will drive the development of electronic skin, human-machine interaction, and personalized healthcare monitoring applications. (c) 2024 Published by Elsevier Ltd on behalf of The editorial office of Journal of Materials Science & Technology.
https://doi.org/10.1016/j.jmst.2023.11.038

Actualité, société

L'électro-hypersensibilité (EHS),
Ministère du travail de la santé et des solidarités (février 2024),
Il est constaté que des personnes se plaignent de symptômes affectant leur état de santé, symptômes qu'elles attribuent à l'exposition aux champs électromagnétiques. Si des personnes rapportent des symptômes bénins, d'autres se sentent gravement affectées. Cette sensibilité présumée aux champs électromagnétiques est généralement appelée hypersensibilité électromagnétique, électro-hypersensibilité (EHS) ou intolérance environnementale idiopathique aux champs électromagnétiques. https://sante.gouv.fr/sante-et-environnement/activites-humaines/exposition-aux-ondes/article/l-electro-hypersensibilite-ehs

Problems in evaluating the health impacts of radio frequency radiation,
BEN ISHAI P., D. DAVIS, H. TAYLOR and L. BIRNBAUM, *Environmental Research* 243 (Feb 2024),

In an effort to clarify the nature of causal evidence regarding the potential impacts of RFR on biological systems, this paper relies on a well-established framework for considering causation expanded from that of Bradford Hill, that combines experimental and epidemiological evidence on carcinogenesis of RFR. The Precautionary Principle, while not perfect, has been the effective lodestone for establishing public policy to guard the safety of the general public from potentially harmful materials, practices or technologies. Yet, when considering the exposure of the public to anthropogenic electromagnetic fields, especially those arising from mobile communications and their infrastructure, it seems to be ignored. The current exposure standards recommended by the Federal Communications Commission (FCC) and International Commission on Non-Ionizing Radiation Protection (ICNIRP) consider only thermal effects (tissue heating) as potentially harmful. However, there is mounting evidence of non-thermal effects of exposure to electromagnetic radiation in biological systems and human populations. We review the latest literature on in vitro and in vivo studies, on clinical studies on electromagnetic hypersensitivity, as well as the epidemiological evidence for cancer due to the action of mobile based radiation exposure. We question whether the current regulatory atmosphere truly serves the public good when considered in terms of the Precautionary Principle and the principles for deducing causation established by Bradford Hill. We conclude that there is substantial scientific evidence that RFR causes cancer, endocrinological, neurological and other adverse health effects. In light of this evidence the primary mission of public bodies, such as the FCC to protect public health has not been fulfilled. Rather, we find that industry convenience is being prioritized and thereby subjecting the public to avoidable risks. https://doi.org/10.1016/j.envres.2022.115038

Software Program for the Evaluation of Human Exposure to Electric and Magnetic Fields,
GIURGIUMAN A., M. GLIGA, A. BOJITA, S. ANDREICA, C. MUNTEANU, V. TOPA, C. CONSTANTINESCU and C. PACURAR, *Technologies* 11, no. 6 (Dec 2023),
The evaluation of human exposure to electric and magnetic fields represents a subject of great scientific and public interest due to the biological effects of electromagnetic fields (EMFs) on the human body and the risks caused by them to living organisms. In this context, this article proposes a software program designed by the authors for the evaluation of human exposure to electric and magnetic fields at low frequencies (EMF software program), an application that can also be accessed from a mobile phone. The analytical model on which the EMF program is based is synthetically presented, and the application is then described. The first example implemented in the EMF program is taken from the existing literature on this subject, thus confirming the correctness and calculation precision of the program. Next, a case study is proposed for an overhead transmission line of 400 KV from the Cluj-Napoca area, Romania, for which the electric and magnetic fields are first measured experimentally and then using the EMF program. The validation of the EMF software program is performed by comparing the obtained results with those measured experimentally and with those obtained with a commercial software program. https://doi.org/10.3390/technologies11060159

Hypersensibilité électromagnétique, qu'a-t-on fait depuis cinq ans ?,
J.M M., *Revue francophone des laboratoires* (janvier 2024),
Plan Le "oui, mais..." de l'Anses Adapter le quotidien quand on est EHS Réponse du ministre Les ressources : centres d'expertise, loi de 2005, MDPH Radiofréquences et santé https://www.em-consulte.com/article/1644399/article/hypersensibilite-electromagnetique-qu-a-t-on-fait-

The European Union assessments of radiofrequency radiation health risks - another hard nut to crack,
NYBERG R., J. MCCREDDEN and L. HARDELL, *Reviews on Environmental Health* (2023 Aug 2023),

In 2017 an article was published on the unwillingness of the WHO to acknowledge the health effects associated with the use of wireless phones. It was thus stated that the WHO is 'A Hard Nut to Crack'. Since then, there has been no progress, and history seems to be repeating in that the European Union (EU) is following in the blind man's footsteps created by the WHO. Despite increasing evidence of serious negative effects from radiofrequency radiation on human health and the environment, the EU has not acknowledged that there are any risks. Since September 2017, seven appeals by scientists and medical doctors have been sent to the EU requesting a halt to the roll-out of the fifth generation of wireless communication (5G). The millimeter waves (MMW) and complex waveforms of 5G contribute massively harmful additions to existing planetary electromagnetic pollution. Fundamental rights and EU primary law make it mandatory for the EU to protect the population, especially children, from all kinds of harmful health effects of wireless technology. However, several experts associated with the WHO and the EU have conflicts of interest due to their ties to industry. The subsequent prioritizing of economic interests is resulting in human and planetary health being compromised. Experts must make an unbiased evaluation with no conflicts of interest. The seven appeals to the EU have included requests for immediate protective action, which have been ignored. On the issue of wireless radiation and the health of citizens, the EU seems to be another hard nut to crack. https://doi.org/10.1515/reveh-2023-0046

Metasurface-Based Phone Case for the SAR Reduction of the 5G Mobile Phones,
SUFIAN M. A. and N. HUSSAIN, *Ieee Transactions on Electromagnetic Compatibility* 66, no. 2 (Apr 2024): 417-426,
The prolonged radiation exposure from mobile phone antennas may cause several health problems. In this article, an innovative method derived from a metasurface-based phone case is introduced to reduce the electromagnetic (EM) exposure from mobile phones. A metasurface consisting of 2 x 3 unit cells, is directly printed on a commercially available phone case. The effective utilization of the slotted square metallic metasurface with the phone cover, the EM exposure, expressed as specific absorption rate (SAR) is significantly reduced by more than 26%. Moreover, the overall performance of the mobile antenna including operating bandwidth and gain is also improved using the proposed metasurface phone case. To validate the design concept, SAR is analyzed for the mobile antenna with and without the proposed phone case with the mannequin model that closely resembles a human head. The measurement data shows that the SAR value is reduced in the human head from 1.387 W/kg to 0.985 W/kg using the metasurface-integrated phone case. The proposed method not only provides an effective way to suppress mobile phone radiation exposure but also invites other researchers to explore metasurface-based phone cases to minimize the health risks from radiation exposure to cell phones and other handheld devices.
https://doi.org/10.1109/temc.2023.3348110

The determinants of legislation for radiofrequency electromagnetic fields (RF-EMFs) with the onset of 5G: An empirical analysis with a worldwide cross-sectional dataset,
VIRTO L. R., M. CZERWINSKI and J. FROIDEVAUX, *Risk Analysis* (2024 Mar 2024),
The unprecedented exposure of radiofrequency electromagnetic field (RF-EMF) to humans from mobile communications raises serious public concern about the possibility of unexpected adverse health effects and has stimulated authorities to adopt precautionary exposure limits. These limits are distinctly different across countries, and the causes of these differences are unclear from the literature. This article is the first empirical analysis on the determinants of RF-EMF exposure legislation, using a novel cross-sectional database of 164 countries worldwide. The analysis shows that decentralization and mobile competition in countries with low mobile network deployment tend to promote more stringent RF-EMF exposure limits across the dataset with 164 countries. In more decentralized countries, the regions had a greater influence on national legislation and could accommodate local demands with the advent of mobile technology in the 2000s. In contrast,

decentralization and mobile competition in countries with high levels of mobile network deployment tend to relax RF-EMF exposure limits in the sample of 61 countries with fifth-generation (5G) technology. Indeed, restrictive RF-EMF exposure limits are constraining 5G deployment in a context of the widespread adoption of mobile-broadband technologies. These results should be useful for policymakers and mobile operators alike to anticipate the outcome of legislation in countries that have yet to introduce 5G technology. The results should also be useful when reviewing policies and strategies for the implementation of the upcoming 6G technology in frequency bands that will be increasingly higher (above 6 GHz up to THz for very local usage), and hence where the health effects on humans are less well studied.
https://doi.org/10.1111/risa.14298

Understanding the public voices and researchers speaking into the 5G narrative,
WELLER S. and J. E. MCCREDDEN, *Frontiers in Public Health* 11 (Jan 2024),
The many different voices speaking into the current narrative surrounding the health effects of 5G technologies necessitate an exploration of the background of the various published author-spokespersons and their potential motives. This has been attempted recently by de Vocht and Albers. However, that opinion piece used a narrow investigative lens, resulting in an undermining of both the rationality of the concerned general public and the motives of specific researchers. At the same time, biases, conflicts of interest, and flaws found in "independent" reviews were not considered. To address these oversights, an evidence-based appraisal of public opinion and the scientific caliber of authors involved in the 5G health discussion is warranted. Subsequently, this review article presents an analysis of the available Australian data representing public voices, while also conducting a broader investigation of the level of expertise of recent author-spokespersons based on their experience as scientists, particularly in the area of health effects of radiofrequency electromagnetic fields. This review thus attempts to more clearly illustrate for the reader the caliber and motives of the voices speaking into the 5G narrative. The article concludes with a set of questions that need to be answered to enable scientists to advise policy makers more effectively on matters of 5G and public health. https://doi.org/10.3389/fpubh.2023.1339513