

Overview of the epidemiologic studies on the health effects of ELF electric and magnetic fields (ELF-EMF) published in the second quarter of 2025.

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1. Reviews and meta-analyses

1.1 Recent Research on electromagnetic fields and Health Risk, nineteenth report from SSM's Scientific Council on Electromagnetic Fields

Swedish Radiation Safety Authority (SSM).(2025).

www.ssm.se

Introduction: The Swedish Radiation Safety Authority's (SSM) Scientific Council on Electromagnetic Fields monitors current research on potential health risks in relation to exposure to electromagnetic fields and provides the authority with advice on assessing possible health risks. The Council gives guidance when the authority must give an opinion on policy matters when scientific testing is necessary.

Methods: The council is required to submit a written report each year on the current research and knowledge situation. This is a consensus report, which means that all members of the Scientific Council agree with the complete report. This increases the strength of the given conclusions. The report has the primary objective of covering the previous year's research in the area of electromagnetic fields (EMF) and health but also to place this in the context of present knowledge. The report gives the authority an overview and provides an important basis for risk assessment. This report reviews studies on electromagnetic fields (EMF) and health risks, published from January 2023 up to and including December 2023. The report is the nineteenth in a series of annual scientific reviews, which consecutively discusses and assesses relevant new studies and put these in the context of available information. The report covers different areas of EMF (static, low frequency, intermediate and radio frequency fields) and different types of studies such as biological, human and epidemiological studies. The result will be a gradually developing health risk assessment of exposure to EMF.

Results: No new established causal relationships between EMF exposure and health risk have been identified. The studies presented in this report do not resolve whether the consistently observed association between ELF magnetic field (ELF-MF) exposure and childhood leukaemia in epidemiology is causal or not. New research on brain tumours and mobile phone use is in line with previous research suggesting mostly an absence of risk. The thyroid gland is potentially highly exposed during mobile phone calls but little research on thyroid cancer has been conducted so far. Concerning studies on animals, it is difficult to draw general conclusions other than that under certain circumstances some effects from RF-EMF exposure are observed in experimental animals. The observations of increased oxidative stress reported in previous SSM reports continue to be found, some even below current reference levels. Oxidative stress is a natural biological process that can sometimes be involved in pathogenesis, but under what circumstances oxidative stress due to weak radio wave exposure may affect human health remains to be investigated. It is notable that new studies again revealed that human perception thresholds are lower in hybrid exposure conditions than in DC or AC field exposure alone.

Conclusion: Despite the fact that no health risks associated with weak electromagnetic fields have been demonstrated up to date, the authority considers that further research is important, in particular regarding long-term effects as more or less the entire population is exposed. One key issue here is to further investigate the relationship between radio wave exposure and oxidative stress observed in animal studies and to establish whether a relationship in humans exists and, if so, to what extent it may affect human health. Another important issue is to clarify the association between weak low-frequency magnetic fields and childhood leukaemia as observed in epidemiological studies. Wireless information technology is constantly evolving and new frequency ranges will be used. Even though there is no established mechanism for affecting health from weak radio wave exposure, there is need for more research covering the novel frequency domains used for 5G. The authority

encourages researchers to start undertaking epidemiological studies in this area. For example, there are currently very few studies in the 26 GHz band.

1.2 Risk factors of neuroblastoma: a systematic review and meta-analysis.

Onyije, F. M., Dolatkhah, R., Olsson, A., Bouaoun, L., Schüz, J. (2025) *Frontiers in Public Health*, 13:1576101.

<https://doi.org/10.3389/fpubh.2025.1576101>

Introduction: Neuroblastoma (NB) is the most common extracranial tumor in children. Synthesizing and elucidating modifiable risk factors is fundamental to inform primary prevention of NB. The objective is to review literature and synthesize risk factors for NB.

Methods: PubMed, Web of Science, and Embase databases were searched using lists of key words and MeSH terms related to exposures and risk of NB. Studies were included if they were case-control or cohort studies of children under the age of 20 years at diagnosis and reported Relative Risks (RRs) with 95% confidence intervals (CIs). Pooled effect sizes (ES) and 95% CIs for risk factors associated with NB were estimated using random-effects models.

Results: The authors included 50 eligible studies from Asia, Europe, and North America, and Oceania on cases of NB diagnosed between 1964 and 2016. They observed associations for maternal occupational exposure to pesticides during preconception/pregnancy (ES 1.62, CI 1.04–2.54), high birthweight [($>4,000$ g) ES 1.21, CI 1.02–1.42], and Cesarean section (ES 1.14, CI 1.00–1.30) and the risk of NB. Parental smoking showed a weak association, while breastfeeding ≥ 6 months (ES 0.50, CI 0.30–0.84) was inversely associated with NB. Birth characteristics such as low birthweight ($<2,500$ g), small and large-for-gestational age, gestation age <37 weeks and gestation age >40 weeks, and assisted reproductive technology were not associated with NB. Similarly, no associations were suggested for parental age, gestational diabetes, and pre-eclampsia. Maternal alcohol consumption during preconception/pregnancy, maternal intake of vitamin and folic acid during pregnancy, paternal occupational exposure to extremely low-frequency magnetic fields (ELF-MF), and maternal X-ray exposure during pregnancy were also not associated with the risk of NB. Paternal occupational and child's postnatal exposure to pesticides were also not associated with NB.

Discussion: This systematic review and meta-analysis suggest that maternal occupational exposure to pesticides during preconception/pregnancy, high birthweight, Cesarean section, and breastfeeding (beneficial) were associated with the risk of NB, but all associations were rather modest in strength. Synthesizing of these risk factors are needed to inform whether there are avenues for primary prevention of NB.

Limitations: This systematic review and meta-analysis was limited by the number of eligible articles which was small for most risk factors, hence, results should be interpreted with caution. Others include potential information and selection biases inherent in the studies, crude exposure assessment methods and exposure misclassification, most likely non-differential, may also have influenced the results. Majority of the studies were conducted in Europe and North America.

2. Residential exposure

2.1 Sleep and Arousal Hubs and Ferromagnetic Ultrafine Particulate Matter and Nanoparticle Motion Under Electromagnetic Fields: Neurodegeneration, Sleep Disorders, Orexinergic Neurons, and Air Pollution in Young Urbanites.

Calderón-Garcidueñas, L., Cejudo-Ruiz, F.R., Stommel, E.W., González-Maciel, A. et al. (2025) *Toxics*, 13, 284. <https://doi.org/10.3390/toxics13040284>

Introduction: Air pollution plays a key role in sleep disorders and neurodegeneration. Alzheimer's disease (AD), Parkinson's disease (PD), and/or transactive response DNA-binding protein TDP-43 neuropathology have been documented in children and young adult forensic autopsies in the metropolitan area of Mexico City (MMC), along with sleep disorders, cognitive deficits, and MRI brain atrophy in seemingly healthy young populations. Ultrafine particulate matter (UFPM) and industrial nanoparticles (NPs) reach urbanites' brains through nasal/olfactory, lung, gastrointestinal tract, and placental barriers.

Methods: The authors documented Fe UFPM/NPs in neurovascular units, as well as lateral hypothalamic nucleus orexinergic neurons, thalamus, medullary, pontine, and mesencephalic reticular formation, and in pinealocytes. They quantified ferromagnetic materials in sleep and arousal brain hubs and examined their motion behavior to low magnetic fields in MMC brain autopsy samples from nine children and 25 adults with AD, PD, and TDP-43 neuropathology.

Results: Saturated isothermal remanent magnetization curves at 50–300 mT were associated with UFPM/NP accumulation in sleep/awake hubs and their motion associated with 30–50 μ T (DC magnetic fields) exposure. Brain samples exposed to anthropogenic PM pollution were found to be sensitive to low magnetic fields, with motion behaviors that were potentially linked to the early development and progression of fatal neurodegenerative diseases and sleep disorders. Single-domain magnetic UFPM/NPs in the orexin system, as well as arousal, sleep, and autonomic regions, are key to neurodegeneration, behavioral and cognitive impairment, and sleep disorders. It is necessary to identify children at higher risk and monitor environmental UFPM and NP emissions and exposures to magnetic fields.

Conclusion: Ubiquitous ferrimagnetic particles and low magnetic field exposures are a threat to global brain health.

Limitations: Three major limitations apply to this study. Autopsy forensic studies are focused on MMC residents exposed for decades to complex mixtures of air pollutants, plus potential neurotoxicants from water, soil, foods, and industrial and indoor pollution. Next to this, the cohort was almost entirely male. Finally, although the authors had access to the entire autopsy, they lacked clinical histories and occupational records.

3. Occupational exposure

3.1 Effect of Occupational Exposure to Low-frequency Electromagnetic Fields on Cataract Development.

Validad, M.H., Mahjoob, M., Pishjo, M. et al. (2025). *Journal of Ophthalmic and Vision Research*, 20, 1–6.

<https://doi.org/10.18502/jovr.v20.12281>

Introduction: Cataracts are the second leading cause of visual impairment worldwide. This study aimed to examine the impact of occupational exposure to low-frequency electromagnetic fields on cataract development.

Methods: One hundred employees of Zahedan Electricity Company participated in this study. They were assigned to four groups based on their level of exposure: regular, operational, operator personnel, and non-exposure. Based on LOCS III grading, the risk of developing different types of cataracts (i.e., nuclear, posterior subcapsular, and cortical) was evaluated for all participants.

Results: The frequency of cataracts was 62.2% in the exposure group (which includes three subgroups: the regular, operational, and operator personnel) and 53.8% in the non-exposure group. There was a significant difference between the study groups in terms of nuclear opacity grading ($P = 0.003$). The correlation between nuclear and posterior subcapsular cataract grading and work experience duration in the exposure group was statistically significant ($P < 0.018$).

Conclusion: This study's findings indicate that exposure to low-frequency electromagnetic fields such as power lines, power plants, and power distribution posts may be a risk factor for cataract development, particularly nuclear cataracts.

Limitations: The present study had several limitations. One of these limitations was the lack of imaging techniques to assess lens density. However, according to previous studies, these techniques correlate well with LOCS III, which confirms the results of this study. Another limitation of this study was the small sample size. Although the sample size of this study was larger than in previous studies, it is recommended to conduct further research with a larger sample size and with other lens opacity assessment tools.

4. Exposure Assessment

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5. Leukaemia Studies

5.1 Residential exposure to magnetic field due to high-voltage power lines and childhood leukemia risk in mainland France – GEOCAP case-control study, 2002–2010.

Mancini, M., Hémon, D., Faure, L., Clavel, J., Goujon, S. (2025). *Environmental Research*, 278:121638.

<https://doi.org/10.1016/j.envres.2025.121638>

Introduction: Environmental exposure to extremely low frequency magnetic fields (ELF-MF) is suspected of being a risk factor of childhood acute leukemia (AL) and classified as possible carcinogen. Results of recent epidemiological studies remain however heterogeneous. The present study aimed to evaluate AL risk in children exposed to ELF-MF by living close to high-voltage overhead power lines (HVOL) in France.

Methods: The authors included 4117 AL cases under the age of 15 diagnosed in 2002–2010 and 44,838 contemporary controls representative of the French pediatric population, drawn from the national registry-based GEOCAP study. The distance between the geocoded address of residence and the closest 63–400 kV HVOL, and the closest 225–400 kV HVOL, were evaluated. ELF-MF exposure was also calculated at the geocoded addresses considering the characteristics of the neighboring HVOLs. Logistic regression models adjusted for age were used to estimate odds-ratios (OR) and 95 % confidence intervals. Sensitivity analyses were carried out to account for geocoding error and potential confounders.

Results: 0.7 % of the controls lived within 50 m of HVOL and 0.3 % were exposed to more than 0.3 μ T. Living within 50 m of HVOL was associated with an increased risk of AL for children under 5 (OR = 1.6 (1.0–2.7)), an association more marked when restricting to the high-quality geocoded addresses (OR = 3.2 (1.3–7.9)). ELF-MF was not associated with AL risk (≥ 0.3 μ T, OR = 0.6 (0.3–1.3)). The results remained stable in all the sensitivity analyses.

Conclusions: This study brings new evidence that ELF-MF are probably not associated with AL risk, and cannot explain an association with distance to HVOL.

Limitations: The authors have assessed distance to HVOL and residential ELF-MF exposure at the time of diagnosis while prenatal and [neonatal periods](#) could also be relevant time windows. The authors do not know what best represents children's exposure and what would be biologically more relevant should ELF-MF be associated with AL risk. The more marked association with the distance to the nearest HVOL observed in children under 5 years could indeed suggest a role of earlier exposures. This could also suggest an age-related bias, however all the models we implemented were systematically adjusted for age categories, which limited this bias. However, ELF-MF exposure was not associated with AL in the [youngest children](#).

The limited number of individual variables is also a [weakness](#) of this study. In particular, sex, ethnicity, and socioeconomic category were not available. However, sex is unlikely to be associated with distance to HVOLs and is not strongly associated with the risk of LA (sex ratio: 1.2); ethnicity is an unclear

variable that is not collected in the French population census, and its relevance as a confounder for proximity to HVOLs is difficult to predict; individual socioeconomic category was approximated by the area-based deprivation index Fdep and adjustment for this index did not modify the results.

6. REFERENCES

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