Bundesamt
für Strahlenschutz

Spotlight on EMF Research

Spotlight on "Residential exposure to magnetic field due to high-voltage power lines and childhood leukemia risk in mainland France – GEOCAP case-control study, 2002-2010" by Mancini et al. in Environmental Research (2025)

Category [low frequency, epidemiology]

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Competence Centre for Electromagnetic Fields (KEMF)

1 Context

Exposure to extremely low-frequency magnetic fields (ELF-MF) from high-voltage overhead power lines (HVOL) has long been discussed as a possible risk factor for acute leukaemia (AL) in children. Earlier pooled analyses of epidemiological studies suggested an approximately twofold increased risk for children exposed to higher ELF-MF levels (≥ 0.3–0.4 µT) [1, 2], which contributed to the classification of ELF-MF as possibly carcinogenic to humans (Group 2B) by the International Agency for Research on Cancer (IARC). More recent pooled analyses of primary studies, however, have reported risk estimates closer to unity and did not confirm a clear association at higher exposure levels [1, 3]. At the same time, several registry-based studies reported increased AL risks for children living very close to HVOL, using residential distance as a proxy for ELF-MF exposure [4, 5].

The nationwide French case-control study by Mancini et al. [6], embedded in the GEOCAP project, is a detailed investigation of residential ELF-MF exposure from HVOL. It extends earlier French analyses of distance to HVOL [7] by adding a line-specific modelling of ELF-MF exposure at children's residences. GEOCAP has been running since 2002 and is based on the French National Registry of Childhood Cancer (RNCE), set up to investigate environmental risk factors of childhood cancer.

2 Results and conclusions from the perspective of Mancini et al.

Mancini et al. [6] conducted a large, registry-based case-control study in mainland France (excluding Corsica) covering the years 2002–2010. The study included 4,117 AL cases (3,403 acute lymphoblastic leukaemia and 622 acute myeloid leukaemia) diagnosed under age 15 and 44,838 controls sampled from national tax and income databases, shown to be representative of the French paediatric population. All addresses at the time of diagnosis (cases) or inclusion (controls) were geocoded by an external partner blinded to case-control status, with information on geocoding precision.

Two exposure metrics were assessed. First, the distance between each geocoded address and the closest HVOL (63–400 kV) and, separately, the closest very high voltage line (VHVOL, 225–400 kV) was calculated using a Geographic Information System (GIS). Distance categories were > 600 m (including municipalities located ≥ 600 m from any HVOL as reference), 200–599 m, 100–199 m, 50–99 m and < 50 m. Second, ELF-MF exposure at the residence was modelled by the French transmission system operator (RTE) for all addresses within < 1000 m around HVOL. The calculations considered characteristics of all HVOL nearby that likely contributed to the ELF-MF exposure, including parameters such as type of pylon, the shape of the span, and annual average electric current. Average ELF-MF exposure was categorised as < 0.1 µT (reference), 0.1–< 0.3 µT and ≥ 0.3 µT. For the majority of addresses located sufficiently far from HVOL, exposure was a priori classified as < 0.1 µT without detailed calculation.

Logistic regression adjusted for age was used to estimate odds ratios (OR) for AL. An OR measures how much more likely an outcome is to occur in an exposed group compared to a non-exposed group by comparing their odds. Nearly a quarter of children lived in municipalities ≥ 600 m from any HVOL, while less than 1 % lived within 50 m of a HVOL.

Overall, distance to the nearest HVOL or VHVOL was not associated with AL risk in the full age range. For children under 5 years, living within 50 m compared to living more than 600 m away (reference) from a HVOL was associated with an OR of 1.6 (95 % confidence interval (CI) 1.0–2.7), and this association strengthened when analyses were restricted to addresses with high geocoding precision (< 25 m error; OR 3.2, 95 % CI 1.3–7.9). Elevated ORs in young children were also observed up to 100 m for HVOL and up to 200 m for VHVOL in these high-quality subsets.

In contrast, analysis based on ELF-MF exposure categories showed no association with AL. Only 0.3 % of children had estimated ELF-MF ≥ 0.3 µT. In the main analysis, the OR for ≥ 0.3 µT compared to < 0.1 µT was 0.6 (95 % CI 0.3–1.3), and remained close to unity in analyses restricted to children under 5 or to addresses with higher geocoding quality. Dose-response models using ELF-MF as a continuous variable likewise did not indicate an increased risk per 0.1 µT increment. A simulation study incorporating individual geocoding uncertainty via exposure grids also failed to show consistent positive associations for higher ELF-MF exposure categories or in younger children.

Based on these findings, the authors conclude that residential ELF-MF exposure due to HVOL is probably not associated with childhood AL and cannot explain the observed association between AL risk and living very close to HVOL. They consider confounding by other, yet unidentified factors specific to residences near HVOL as a possible explanation.

3 Comments by the BfS

The study by Mancini et al. [6] addresses a topic of high relevance. Childhood cancer represents a small fraction of all malignancies [8] but remains a leading cause of disease-related death in children in high-income countries [9], with AL being by far the most common subtype. Identifying modifiable environmental risk factors is therefore of central importance. ELF-MF exposure from HVOL has been discussed for decades as a potential risk factor for childhood leukaemia [10], but findings across studies have remained inconsistent [1]. The Mancini study is an important contribution because it combines a large, nationwide, registry-based design with advanced exposure assessment.

Key strengths include the large sample size, registry-based case ascertainment and control selection, blinding of the geocoding process, and the ELF-MF modelling. Unlike many earlier studies that used only proximity to HVOL or simplified field calculations, Mancini et al. considered in one part of their investigation multiple line-specific parameters and all relevant nearby lines. Sensitivity analyses restricted to higher-quality geocoded addresses, as well as simulation analyses to account for positional uncertainty, are further methodologic strengths.

However, several important limitations need to be considered when interpreting the results. First, despite the large overall population, the number of highly exposed children remains very small. Only about 0.3 % of participants had modelled ELF-MF exposure ≥ 0.3 µT, leading to wide confidence intervals and limited statistical power to detect moderate risk increases. As the authors note, the study had sufficient power to detect an OR of about 1.7 in the highest exposure category. Smaller risks cannot be reliably ruled out. Second, exposure assessment relies on the residential address at time of diagnosis or inclusion and does not take residential history into account. If children moved shortly before inclusion, misclassification of long-term exposure is possible. While this limitation is shared by many record-based studies and is likely to be largely non-differential (i.e., independent of case-control status), it could still dilute true associations. The authors also had to impute or approximate current values for some lines and could not assess ELF-MF for a subset of addresses with low geocoding precision. Third, as in previous studies, information on individual-level confounders is limited. The authors adjusted for several area-based or environmental indicators (urbanicity, deprivation, traffic, UV radiation, viticulture), and these adjustments did not materially change the results. Nevertheless, other factors that might correlate with living close to HVOL remain speculative. The study does not identify a plausible alternative risk factor that could explain the increased risk observed for short distances to HVOL, particularly among children under 5.

In comparison with more recent published pooled analyses, which reported childhood AL risk estimates near unity for high ELF-MF exposure (calculated or measured fields) [1], the Mancini results are broadly consistent with the view that residential ELF-MF from HVOL is unlikely to be a strong causal factor for childhood AL. In detail, the findings of Mancini et al. are consistent with the most recent pooled study by Amoon et al. [1], which did not observe an increased risk for children exposed to ≥ 0.4 µT compared to < 0.1 µT and reported an overall OR of 1.01 (95 % CI 0.61–1.66).

At the same time, the persistence of elevated ORs for very short distances to HVOL in high-quality geocoding subsets and in young children suggests that the “distance signal” observed in some earlier distance-based studies has not completely disappeared [11]. However, distance to the nearest HVOL alone appears to be not sufficient to reflect residential exposure to ELF-MF at levels of > 0.3 µT as a substantial proportion of children living close to HVOLs do not have high ELF-MF exposure in the data of Mancini et al.

The main message of this paper is threefold: First, the study provides further, relatively robust evidence against a substantial risk of AL in children at ELF-MF exposure levels of ≥ 0.3 µT. The observed increased risks for children living very close to HVOL, particularly under age 5, remain insufficiently explained and may point to residual confounding, selection or misclassification issues, or other environmental or infrastructural factors associated with HVOL corridors. Second, the study had sufficient statistical power to detect a relative risk of 1.7 or higher for ELF-MF exposure ≥ 0.3 µT. Therefore, if such an increased risk existed, similar to earlier pooled analyses around the year 2000 (OR 2.00; 95 % CI 1.27–3.13) [12], the study would likely have detected an association. Since no such association was found, this suggests that high ELF-MF exposures are unlikely to be linked with a substantial increase in childhood acute leukaemia. However, we consider it premature to draw definitive conclusions about small increases in risk at these ELF-MF levels. Thirdly, large pooled analyses with harmonised, individual-level exposure modelling and information on potential confounders, as well as studies exploring co-exposures specific to HVOL environments, would be desirable to clarify the relationship between HVOL, ELF-MF and childhood leukaemia. However, such studies remain challenging to implement.

Despite the mentioned limitations, the study contributes important new evidence to the ongoing debate whether increased AL risks in children near HVOL can be explained by ELF-MF exposure or by other factors correlated with proximity to HVOL.

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