Spotlight on EMF Research

Spotlight on “Long-term residential magnetic field exposure and neurodegenerative disease mortality: An 18-year nationwide cohort study in Switzerland” by Sandoval-Diez et al. in Environment International (2026)

Category [low frequency, epidemiology]

Spotlight - Apr/2026 no.2 (Eng)

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1 Context

Extremely low-frequency magnetic fields (ELF-MF) are ubiquitous but with typically low exposure levels in the general population. ELF-MF have been classified by the IARC (International Agency for Research on Cancer) as possibly carcinogenic to humans (Group 2B) [2] mainly based on epidemiological studies on childhood leukaemia. For non-cancer outcomes, in particular neurodegenerative diseases, the evidence has remained limited and inconsistent. Much of the existing epidemiological literature on neurodegenerative diseases and ELF-MF comes from occupational settings with comparatively high exposures and complex co-exposures. For residential ELF-MF, only a few population-based studies have examined outcomes such as Alzheimer's disease, other types of dementia, amyotrophic lateral sclerosis (ALS), Parkinson's disease, and multiple sclerosis, generally with small numbers of highly exposed subjects and heterogeneous exposure metrics.

Against this background, the nationwide Swiss cohort study by Sandoval-Diez et al. [1] extends the residential evidence base on ELF-MF and neurodegenerative disease mortality. It builds directly on an earlier analysis of the Swiss National Cohort (SNC) by Huss et al., which had suggested increased Alzheimer's disease mortality near high-voltage power lines. The new study extends follow-up to 18 years, refines exposure assessment by using validated proximity models, and, for the first time in a general-population setting, considers residential ELF-MF exposure from railway lines in addition to high-voltage power lines.

2 Results and conclusions from the perspective of Sandoval-Diez et al.

Sandoval-Diez et al. [1] used data from the Swiss National Cohort to establish a closed cohort of 3,555,064 adults aged 30 years or older at baseline and followed them from 2001 to 2018, contributing 55,377,543 person-years of observation. Mortality from neurodegenerative diseases was obtained from national death records, including Alzheimer's disease (ICD-10 G30), other types of dementia (F01, F03), ALS (G12.2), Parkinson's disease (G20), and multiple sclerosis (G35), considering these codes when listed as primary, concomitant, consecutive, or initial causes of death. Cox proportional hazards models with age as the underlying timescale were stratified by sex, language region, and follow-up interval; and adjusted for nationality, mother tongue, civil status, education, neighbourhood socioeconomic position, degree of urbanity, air pollution (NO_2), transportation noise, and residential greenness.

Residential ELF-MF exposure from 220 to 380 kV high-voltage power lines (50 Hz frequency) and from railway lines (16.7 Hz frequency) was estimated using proximity models. These models were derived from published measurement and modelling data. A nonlinear least squares approach was applied to model the inverse power law relationship between ELF-MF exposure from the literature and distance data. The proximity models were validated against indoor measurements in 59 homes. Correlations between modelled and measured ELF-MF were moderate for 220–380 kV high-voltage lines and high for railway lines. Based on census-linked residential histories, individual long-term exposure was calculated as a time-weighted average over four rolling 10-year windows preceding successive follow-up intervals, thereby explicitly accounting for residential mobility. In more detail, follow-up is divided into four periods (2001–2005, 2006–2010, 2011–2015, 2016–2018), and for each period a preceding 10-year exposure window is defined (1991–2001, 1996–2006, 2001–2011, 2006–2016) to characterise long-term ELF-MF exposure. Within each 10-year window, the authors reconstruct individual residential histories, determine the years spent at each address, and compute a duration-weighted average of modelled ELF-MF to better approximate long-term exposure for diseases with long induction and latency and to reduce misclassification from residential mobility.

In the study population, median long-term ELF-EMF exposure from high-voltage power lines was 0.01 µT (mean 0.02 µT), with 0.3% of individuals above 0.3 µT. Railway-related ELF-MF exposure was higher (median 0.03 µT, mean 0.06 µT), with 2.4% of individuals at levels above 0.3 µT.

In fully adjusted models for environmental co-exposures (e.g., NO2), long-term ELF-MF exposure from high-voltage power lines was positively associated with mortality from dementia. A 1 µT increase in ELF-MF exposure was associated with a hazard ratio (HR) of 1.54 (95% CI 1.23–1.92) for Alzheimer's disease and 1.31 (95% CI 1.13–1.52) for other types of dementia. For ELF-MF exposure from railway lines, the HR for Alzheimer's

disease was 1.08 (95% CI 0.99–1.18) and 0.99 (95% CI 0.94–1.04) for other types of dementia, indicating no increased risks.

When ELF-MF exposure from high-voltage lines was categorised, there was a positive trend in Alzheimer's disease and other types of dementia mortality risk across the intermediate exposure categories (0.05–<0.10 µT and 0.10–<0.30 µT), but not for the highest category (≥0.30 µT), where estimates were close to unity with wider confidence intervals. For ELF-MF exposure from railway lines there was no trend in the categorial analyses for any outcome.

In general, for ALS, Parkinson's disease, and multiple sclerosis, the authors observed consistent null results across continuous and categorical exposure metrics, and in multiple sensitivity and subgroup analyses.

The authors conclude that their results point to a possible association between long-term residential ELF-MF exposure from high-voltage power lines and increased mortality from Alzheimer's disease and other dementias. They find no evidence of an association for ALS, Parkinson's disease, or multiple sclerosis. For ELF-MF exposure from railway lines, the observed associations were weaker and disappeared after adjustment for environmental co-exposures. They note that since high ELF-MF exposure from power lines or railways is rare, the population-attributable fractions for Alzheimer's disease would be about 1.01% for ELF-MF exposure from high-voltage lines and 0.43% for ELF-MF exposure from railway lines, assuming the associations are causal. At the same time, they emphasise that causal inference remains constrained by the absence of established biological mechanisms, that residual confounding cannot be fully excluded, and that their findings should be interpreted as contributing to, but not resolving, the ongoing debate on ELF-MF and neurodegeneration.

3 Comments by the BfS

The study by Sandoval-Diez et al. [1] addresses a topic of high public health relevance. Dementia, particularly Alzheimer's disease, is a leading cause of disability and mortality in ageing populations [3, 4]. Robust evidence on potentially modifiable environmental determinants is scarce [5]. This work is, to our knowledge, the largest epidemiological study on residential exposure to ELF-MF and neurodegenerative disease mortality, with nationwide coverage for Switzerland, 18 years of follow-up, and detailed use of residential histories.

A key strength is the inclusion of long-term exposure metrics. Time-varying, time-weighted averages over the preceding 10 years, combined with reconstructed residential mobility, provide a more realistic representation of long-term exposure patterns. This approach is methodologically better aligned with the long induction and latency periods typical of neurodegenerative diseases. It goes beyond many ELF-MF cancer studies, that rely on a single address at diagnosis, and current case-control studies such as the recent work by Mancini et al. [6], where line-specific fields are modelled at one point in time only (address at diagnosis/inclusion) without residential histories. For slowly developing diseases such as dementia, the long-term, mobility-adjusted metric in Sandoval-Diez et al. appears particularly appropriate.

However, as in every observational study, there remain uncertainties in the exposure assessment. Sandoval-Diez et al. rely on simplified distance-based models that, by design, do not capture indoor sources (e.g., household wiring, appliances) or occupational ELF-MF exposure, even though these may contribute to individual long-term averages. In addition, they apply distance-based proximity models for 220–380 kV lines and railway lines, which were empirically validated against indoor measurements in 59 dwellings. For 220–380 kV lines, modelled and measured fields correlate only moderately (Spearman r ≈ 0.60–0.67), indicating substantial unexplained variability, while for ELF-MF exposure from railway lines correlations are high (r ≈ 0.83–0.88). Distance to 36–150 kV lines was essentially uncorrelated with measured fields and these sources were therefore not used for exposure modelling. Excluding 36–150 kV lines, for which distance is not an informative proxy, avoids adding random noise to the modelled exposure but leaves some infrastructure-related contribution to total ELF-MF unmodelled. This constellation is likely to lead mainly to non-differential exposure misclassification, with a tendency to attenuate rather than exaggerate any true associations.

Several other limitations are important for interpreting the dementia findings. First, despite the very large cohort, only 0.3% of participants have experienced long-term exposure ≥0.3 µT from high-voltage lines (2.4% for railway lines). Continuous exposure level estimates are therefore mainly driven by contrasts at low exposure levels, and categorical exposure level estimates at the upper tail are imprecise. Both analyses are therefore hampered. Second, power and railway grids are treated as static; only residential mobility was considered as source of time-variation in exposure. Third, individual data on occupational ELF-MF exposure, lifestyle factors, and medical history are unavailable, so residual confounding cannot be fully excluded, even though adjustment for multiple covariates, negative control outcomes, and additional analyses suggest that an unmeasured confounder would need moderate to strong associations with both exposure and outcome to fully explain the observed dementia risks.

Another important limitation concerns outcome assessment based on death certificates, which introduces potential misclassification, especially for dementia [7] and Parkinson's disease [8], which can be under-recorded. Because under-ascertainment may vary by socioeconomic status, and socioeconomic status correlates with both exposure and diagnosis, bias cannot be ruled out a priori. However, adjustment for education and Swiss-SEP (Swiss socioeconomic position index) did not materially affect risk estimates, and the pattern of null findings for ALS [9] and Parkinson's disease [10] is consistent with prior residential studies, suggesting that major distortions are unlikely.

When placed in the context of systematic reviews and meta-analyses, the Sandoval-Diez et al. results for dementia are compatible with modest risk elevations reported for occupational ELF-MF exposure [11, 12] and with advisory-body evaluations such as SCHEER [13], which describe the evidence as weak and potentially confounded. For ALS, meta-analyses show moderate associations in high-exposure workplaces [14] but not in residential settings [9]; the null findings in Sandoval-Diez et al. agree with this pattern for the residential exposure. For Parkinson's disease, a systematic review including both occupational and residential studies concludes that evidence for an ELF-MF effect is unconvincing [10], again in line with the null associations reported here.

In conclusion, the study by Sandoval-Diez et al. provides an important contribution to the evidence on ELF-MF and neurodegenerative diseases, particularly through its long-term, mobility-adjusted exposure assessment and the first inclusion of ELF-MF exposure from railway lines. The observed positive associations between long-term residential ELF-MF exposure from high-voltage lines and dementia mortality are noteworthy and justify further research. However, given the low prevalence of higher exposures, the reliance on proximity-based modelling without detailed load histories, the use of mortality data, and the absence of established biophysical mechanisms, the evidence to date remains insufficient to infer a causal relationship. Rather, the study underscores the need for large-scale and pooled analyses with harmonised, individual-level exposure assessment (residential, occupational, and indoor), alongside strengthened mechanistic and experimental work on ELF-MF and neurodegeneration.

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Impressum
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Please always use the following URN when citing this document:
urn:nbn:de:0221-2026041559872

Spotlight - Apr/2026 no.2 (Eng)