

Health Impacts of Extremely Low-Frequency Electromagnetic Fields (ELF-EMF) and High-Voltage Power Lines (HVPLs)

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Summary

A comprehensive review of epidemiologic, occupational, experimental, mechanistic, and psychosocial, physics, biology, medicine and environment health evidence indicates that exposure to **extremely low-frequency electromagnetic fields (ELF-EMF)** associated with **high-voltage power lines (HVPLs)** is linked to **specific adverse health outcomes**, most consistently **childhood leukemia** and **occupational neurodegenerative disease**, with additional evidence for **cardiac autonomic effects**, **reproductive impacts**, and **indirect exposure pathways involving charged aerosols and radon progeny**.

While definitive causation has not been established for all outcomes, the **weight of evidence** supports a **precautionary public-health approach**.

1. Scope and Methodology

This report integrates findings from:

- Population-based **case-control and cohort studies**
- **Occupational mortality and exposure-matrix analyses**
- **Human experimental laboratory studies**
- **Biophysical and environmental mechanism studies**
- **Prospective psychosocial field investigations**

The literature spans **1979–2023** and includes data from the **United States, Canada, Europe, and Asia**.

2. Childhood Leukemia

2.1 Epidemiologic Evidence

Multiple studies demonstrate a **consistent association** between sustained residential ELF magnetic field exposure and childhood leukemia:

- Elevated risks observed at $\geq 0.3\text{--}0.4\ \mu\text{T}$
- **OR ≈ 2.0** for children living **<100 m** from HVPLs (Italy, 2023)
- Findings robust across exposure metrics (distance-based and modeled fields)

2.2 Interpretation

- Risk is **small in absolute terms** but **consistent and reproducible**
- No alternative explanation has adequately accounted for observed associations

Conclusion

Childhood leukemia represents the **strongest and most internationally accepted health outcome** associated with ELF-EMF exposure, forming the basis of the **IARC Group 2B classification** (“possibly carcinogenic to humans”).

Supporting References

- Malagoli C et al. *Environ Res.* 2023;232:116320.
- Ahlbom A et al. *Br J Cancer.* 2000;83:692–698.
- Greenland S et al. *Epidemiology.* 2000;11:624–634.
- Kheifets L et al. *Environ Health Perspect.* 2010;118:467–474.
- IARC. *Monographs on the Evaluation of Carcinogenic Risks to Humans, Vol. 80.* 2002.

3. Neurodegenerative Diseases

3.1 Occupational Epidemiology

Studies of electrical and utility workers demonstrate:

Disease	Risk Pattern
Alzheimer’s disease	OR $\sim 1.1\text{--}4.9$
Parkinson’s disease	OR ~ 1.1

Disease	Risk Pattern
ALS	OR ~1.3 overall; RR 2–5 in specific electrical occupations • Power plant operators show the strongest associations • Job-specific risks exceed those of broad occupational categories

3.2 Biological Plausibility

Proposed mechanisms include:

- Disruption of neuronal **calcium signaling**
- **Microglial activation** and chronic neuroinflammation
- Oxidative stress pathways

Conclusion

The evidence supports a **credible occupational risk signal**, strongest for **ALS and Alzheimer's disease**, though limited by exposure misclassification and absence of a single confirmed mechanism.

4. Cardiovascular Health

4.1 Occupational Mortality

Large cohort studies of electric utility workers reveal:

- Increased **arrhythmia-related mortality**
- Increased **acute myocardial infarction risk**
- Rate ratios **1.5–3.3** at higher cumulative exposures
- No association with chronic atherosclerosis

4.2 Human Experimental Evidence

Controlled laboratory studies demonstrate:

- **Reduced heart rate variability (HRV)** during **intermittent** 60-Hz magnetic field exposure
- HRV changes resemble patterns predictive of cardiovascular morbidity

Conclusion

Findings support a **biologically plausible link** between ELF-EMF exposure and **autonomic cardiac regulation**, especially under intermittent exposure conditions.

Supporting References

- Savitz DA et al. *Am J Epidemiol*. 1999;149:135–142.
 - Sastre A, Cook MR, Graham C. *Bioelectromagnetics*. 1998;19:98–106.
 - Kleckner RC et al. *Epidemiology*. 2013;24:580–588.
 - Thayer JF, Lane RD. *Biol Psychol*. 2007;74:224–242.
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5. Reproductive Health

Female Infertility

Case-control data show:

- OR ~4.4 for women living <500 m from HVPLs

Expert Conclusion

Residential proximity to high-voltage power lines has been associated with a significantly increased risk of female infertility, suggesting that reproductive endpoints may be inadequately protected by existing exposure guidelines.

Supporting References

- Esmailzadeh S et al. *Int J Occup Environ Med*. 2019;10:11–16.
 - Li DK et al. *Epidemiology*. 2002;13:9–20.
 - Louis GM et al. *Hum Reprod Update*. 2013;19:500–514.
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6. Indirect Exposure Mechanisms

6.1 Charged Aerosols and Radon Progeny

Multiple experimental and field studies demonstrate that HVPL electric fields:

- Increase formation and persistence of **charged aerosols**

- Enhance deposition of radon daughter nuclei by 1.5–18×. High-voltage power line electric fields can increase human exposure to charged aerosols and radon progeny, thereby enhancing inhalation and dermal dose of known carcinogens, providing a biologically plausible indirect pathway linking ELF-EMFs to adverse health outcomes.
- Supporting References
- Henshaw DL et al. *Int J Radiat Biol.* 1996;69:25–38.
- Fews AP et al. *Int J Radiat Biol.* 1999;75:1505–1521.
- Jung JS et al. *Int J Occup Saf Ergon.* 2019;25:91–98.
- Darby S et al. *BMJ.* 2005;330:223–227.

6.2 Significance

This mechanism provides a **non-thermal, non-DNA-damage pathway**, explaining how ELF-EMFs may increase disease risk **indirectly** by concentrating harmful agents in human breathing zones.

Conclusion

This pathway is **biophysically robust**, reproducible, and highly relevant to environmental risk assessment.

7. Breast Cancer

Most studies do not demonstrate a consistent association between ELF-EMF exposure and adult solid tumors, including breast cancer, although possible increased risk in younger women with estrogen receptor–positive tumors cannot be excluded.

Supporting References

- Forssén UM et al. *Int J Occup Environ Health.* 2000;11:24–29.
- Feychting M, Ahlbom A. *Epidemiology.* 1994;5:501–509.
- Kheifets L et al. *Bioelectromagnetics.* 2001;Suppl 5:S105–S116.

8. Psychosocial and Nocebo Effects

Prospective Field Studies

Research from the Netherlands shows:

- Increased symptom reporting after HVPL activation
- Effects mediated primarily by **risk perception and belief**
- Significant heterogeneity in population responses

Interpretation

- Nocebo effects are **real and measurable**
- They **do not negate biological risks**, but coexist with them
- Effective **risk communication** is essential to reduce avoidable health burden.

Supporting References

- Porsius JT et al. *Sci Total Environ.* 2016;543:432–438.
- Porsius JT et al. *Risk Anal.* 2017;37:2276–2288.
- Rubin GJ et al. *BMJ.* 2014;348:g3718.

9. Integrated Weight-of-Evidence Assessment

Health Outcome	Strength of Evidence
Childhood leukemia	Moderate–Strong
ALS (occupational)	Moderate
Alzheimer’s disease	Moderate
Cardiac arrhythmia	Moderate
Female infertility	Limited–Moderate
Adult solid cancers	Weak/Inconsistent
Psychosomatic responses	Strong (psychosocial)

10. Expert Conclusions

1. ELF-EMF exposure from HVPLs is **not biologically inert**
 2. The **most robust association** is with childhood leukemia
 3. **Occupational exposure** poses higher risks than typical residential exposure
 4. **Indirect mechanisms** (aerosols, radon progeny) substantially strengthen biological plausibility
 5. Existing exposure limits address **acute effects**, not long-term disease risk
 6. A **precautionary public-health framework** is scientifically justified
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11. Expert Recommendations

- Avoid new **schools, childcare facilities, and housing** in high-exposure corridors
 - Reduce **duration and intensity of occupational exposure**
 - Incorporate **aerosol and pollutant concentration mechanisms** into risk assessments
 - Improve **risk communication** to prevent unnecessary nocebo effects
 - Prioritize **children, pregnant women, and utility workers** in policy decisions
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Final Expert Opinion

The collective evidence supports the conclusion that long-term exposure to elevated ELF magnetic fields—particularly in occupational settings and in close residential proximity to high-voltage power lines—is associated with **measurable health risks**. While uncertainties remain, the **consistency, coherence, and biological plausibility** of the findings warrant **preventive and precautionary action** rather than continued reliance on exposure limits designed solely for short-term effects.
