

Tutorial: 50/60 Hz magnetic field and health

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For power system expertise



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CIGRE Colloquim ATHENS 2018



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Ὄμνυμι...: The oath of Hippocrates

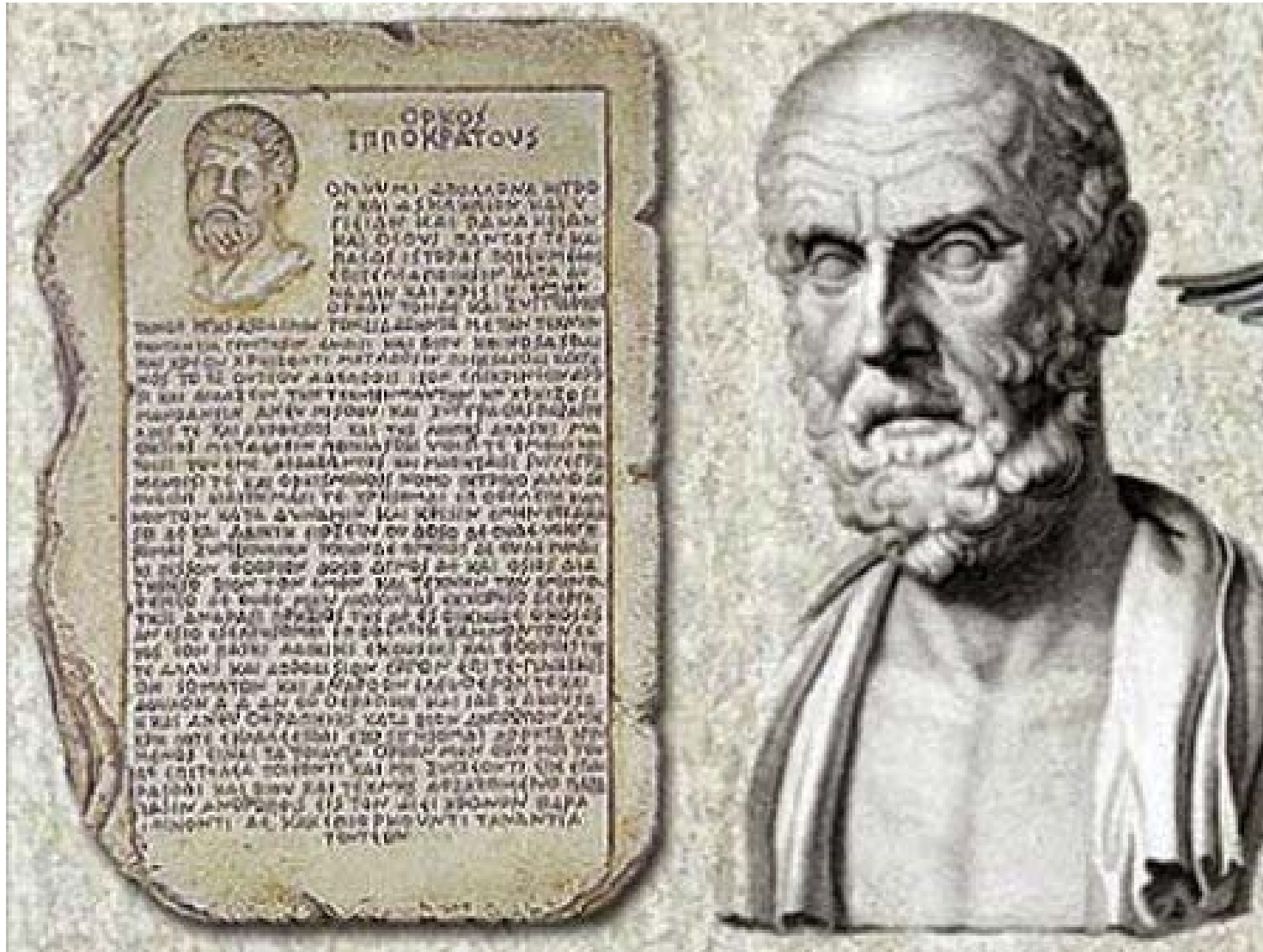


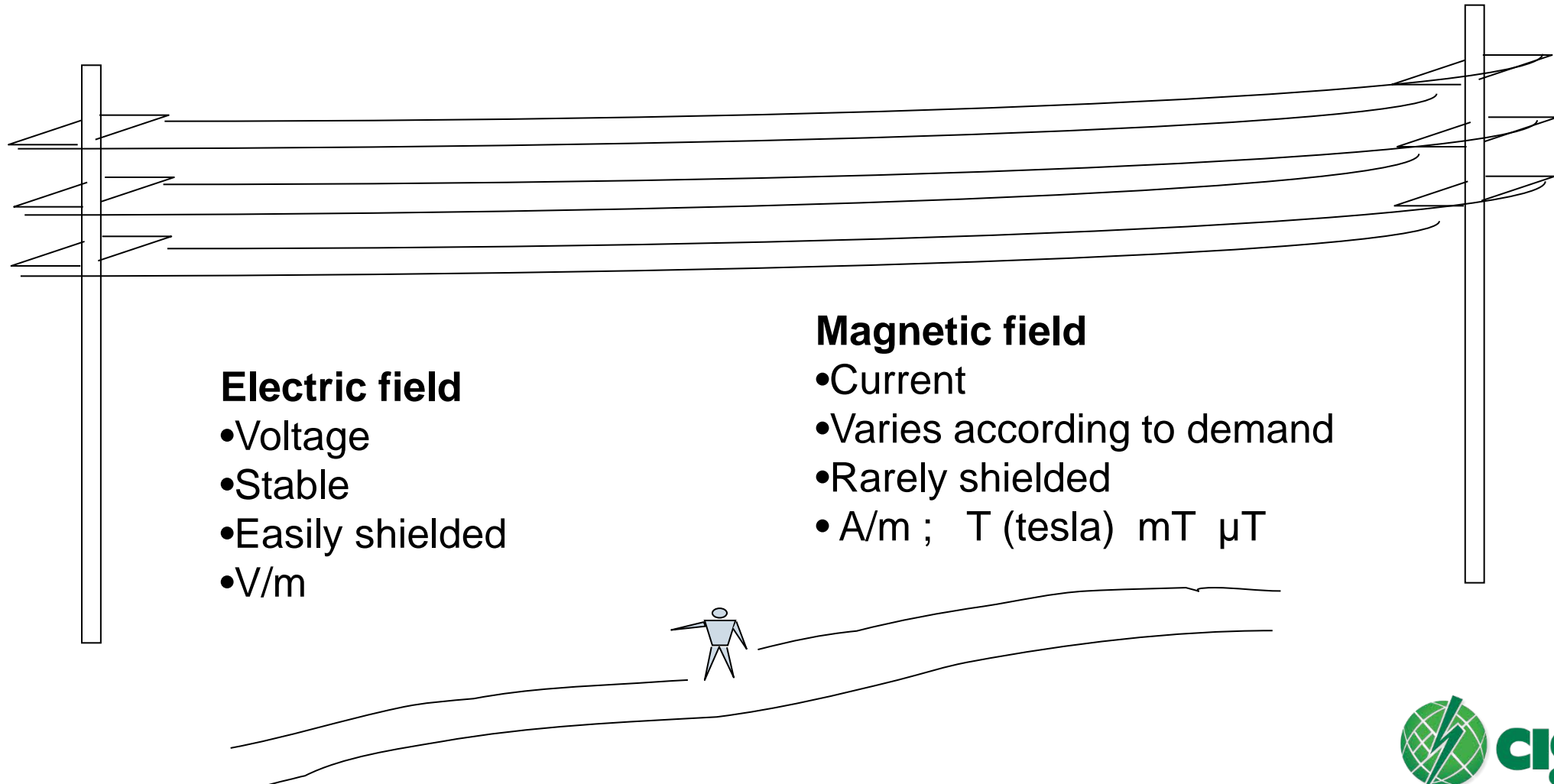
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 - Epidemiological studies
 - Experimental tests: long term animal studies
 - ✓ International Agency for Research on Cancer: 2B: «possibly carcinogenic »
 - ✓ All evidence points to a false alarm

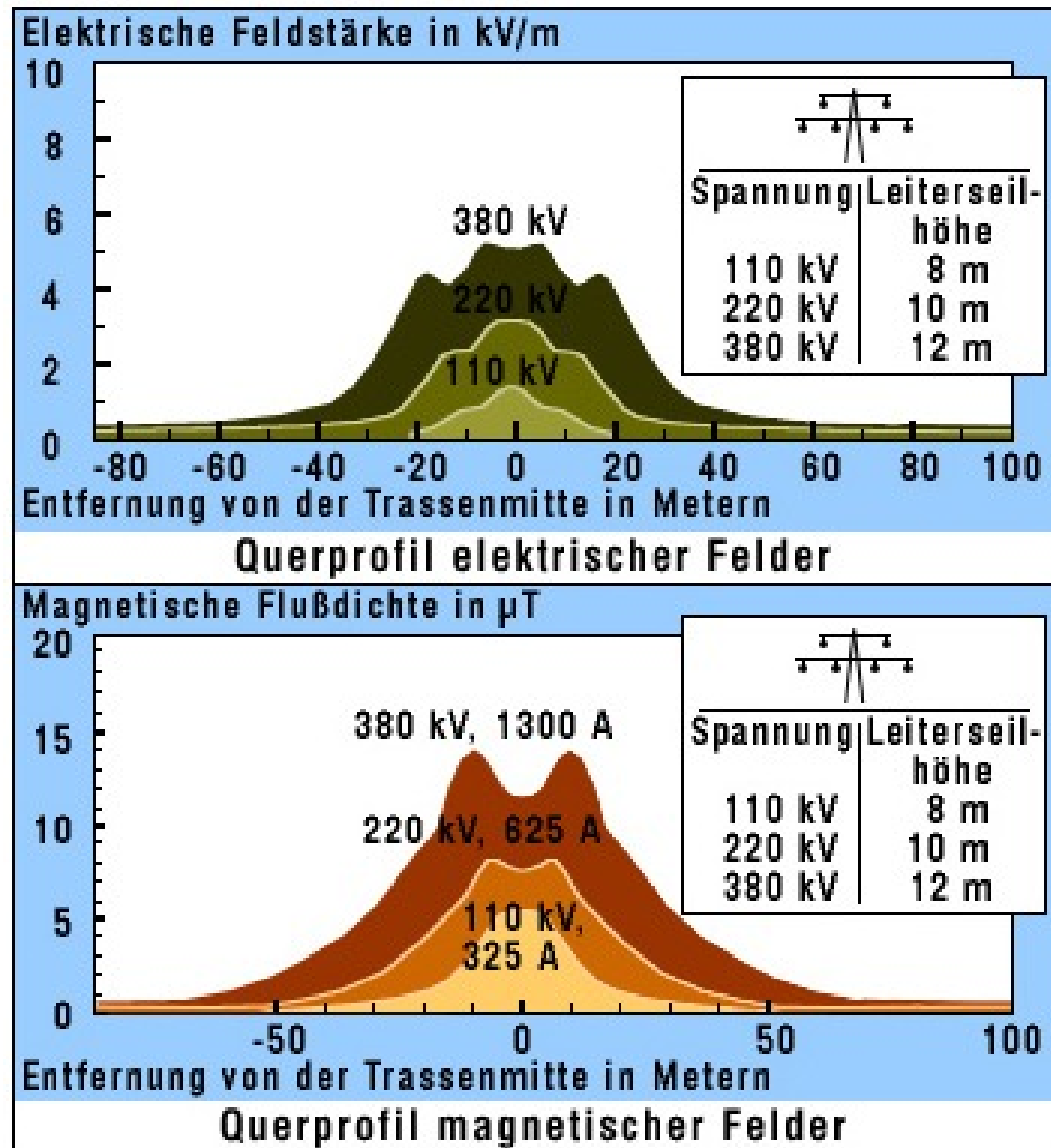
- **Section 2 : Neurophysiological effects**



Electric vs magnetic fields

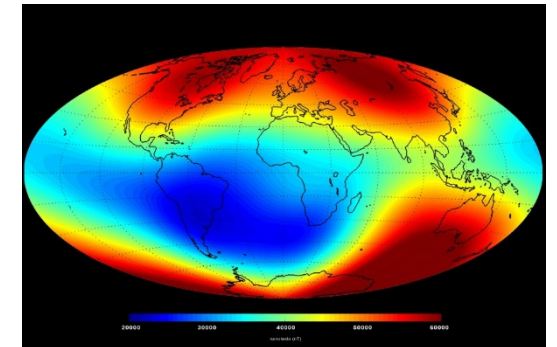
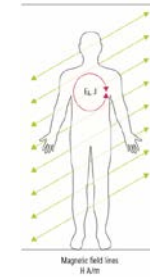


Typical EMFs for OHLs



Magnetic field and the human body

- The human body is almost transparent to the MF
 - No specific receptors to detect the MF
 - No detection of the earth natural MF (about 25 -75 μT)
 - MRI well tolerated (static field : 2 T = 2 000 000 μT)
 - Occasional symptoms: metallic taste; vertigo; at 2 T
 - Tested at higher field levels 9 T : minor physiological effects
-
- A movement in a static MF or an exposure to an alternating MF induces currents in the body.
 - Currents have to be maintained below a safe level.



Static MF fields

Some references

	MF: μT
▪ MRI	2 000 000
▪ Small magnets (fridge magnets; clips; belt; earpieces etc...)	1,000 – 10,000
▪ Earth magnetic field	25 - 75
▪ Under a DC Transmission line	10 – 20
▪ Recommended limit for workers	2,000,000
▪ Recommended limit for the general public	400,000
▪ Recommended limit for cardiac pacemakers	500

50/60 Hz MF fields

some references

- Human tolerance
- Lowest level for an effect (magnetophosphene)
- Surface of small electrical appliances
- Under a AC Transmission line
- Average residential level

- Recommended limit for workers (ICNIRP)
- Recommended limit for the general public (ICNIRP)
- Recommended limit for cardiac implants

MF: μT

300,000 (?)

20,000

500

10 - 20

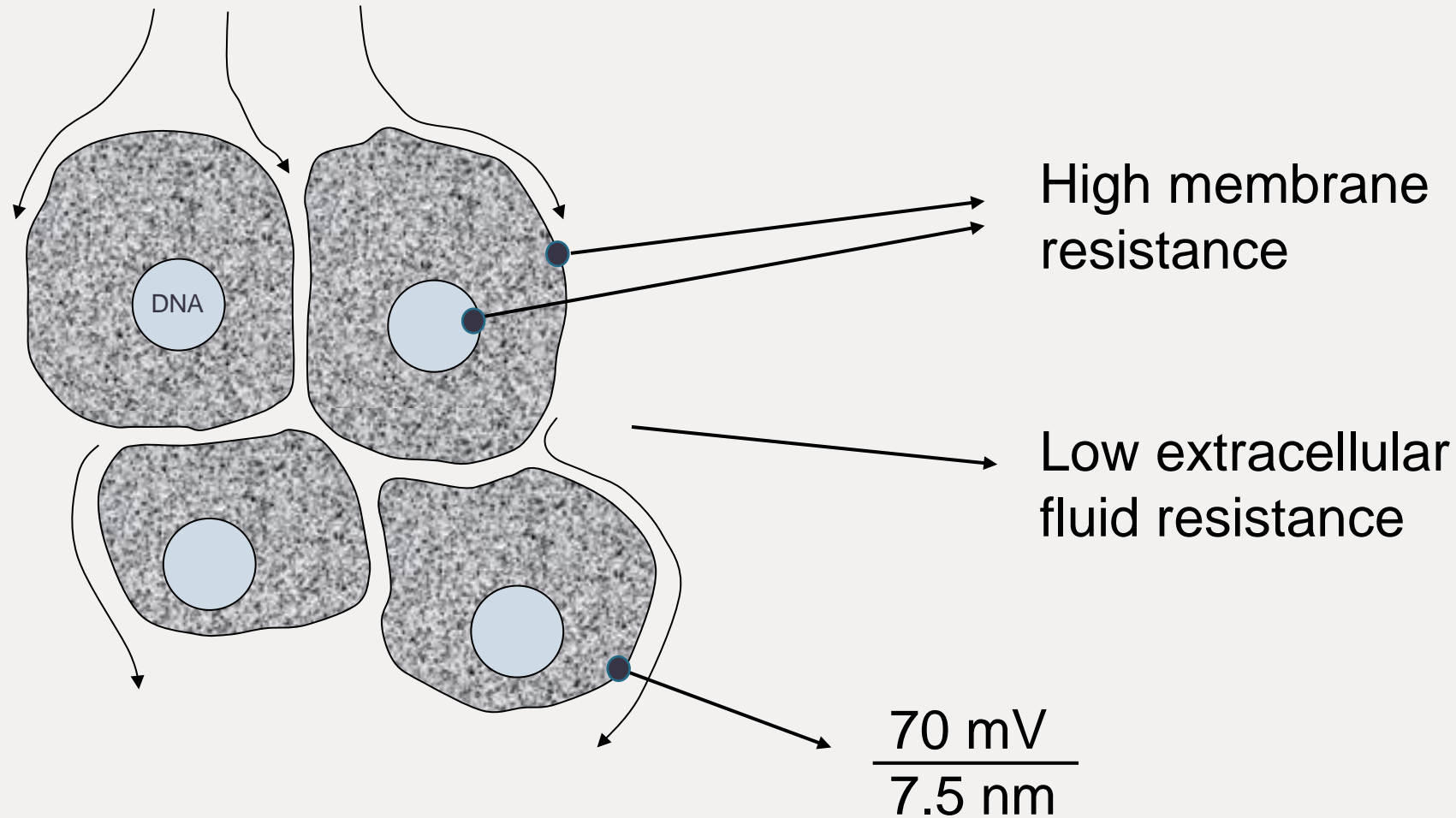
0.1

1,000

200

100

Distribution of the induced current



The origin of the controversy

« Electrical wiring configurations and childhood cancer »

Nancy Wertheimer and Ed Leeper. A. J. of Epidemiology 1979

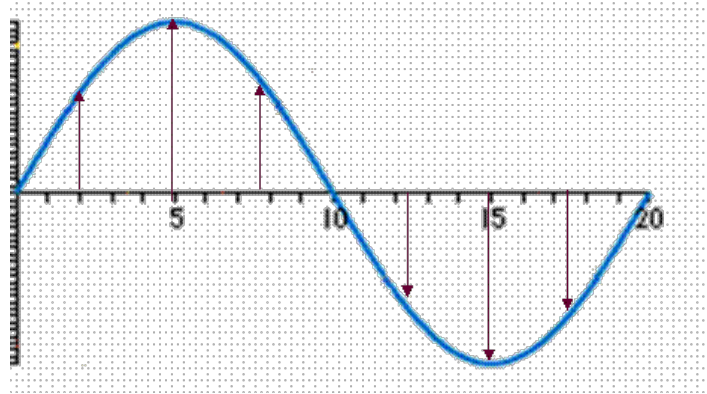
Location:	Denver, Colorado
Objective:	Identify possible environmental factors for childhood cancer.
Exposure :	High current configuration (HCC) vs Low current configuration (LCC)
Results:	Positive correlation between high-current electrical wiring and a higher than expected rate of cancer, in particular leukemia.
Relative risk:	2 to 3 associated with a MF above 0.2 μ T

Why the surprise and scepticism?

- **0.2 μ T !!!**
- No past anecdotal evidence for carcinogenicity over the last 100 years...
- No indication from workers' medical surveillance programs
- Childhood cancer has a strong genetic component (and virus infection)
- Human carcinogens : long latency period 10 – 25 y
- Limitations of the study design
- Correlation very unlikely to be a causal relationship.

E field Induction of a 50 Hz MF *

50 Hz MF



E field induced in the
bone marrow

$0.2 \mu\text{T} \Rightarrow 0.003 \text{ mV/m}$

*Threshold for excitation of the most sensitive cells of the body: 500 mV/m

* 1 Hz in a $50 \mu\text{T}$ field $\Rightarrow 0.015 \text{ mV/m}$

* From tables 23 and 27, WHO 2007

The voltage induced in the body a typical residential 50/60 Hz magnetic field is about 5 orders of magnitude lower than the threshold of the most sensitive cells of the body.

50/60 Hz MF: Exceptional volume of research

From 1979 to 2018:

~ 475 epidemiological studies

less than 1 μ T

Cancer: 261 studies

Childhood leukemia: 73 studies; 16 meta-analysis

~ 2,000 experimental studies

up to 50 000 μ T

- In vitro
- Animal studies
- Human experimental studies

Carcinogenicity assessment (1)

1- EPIDEMIOLOGICAL STUDIES

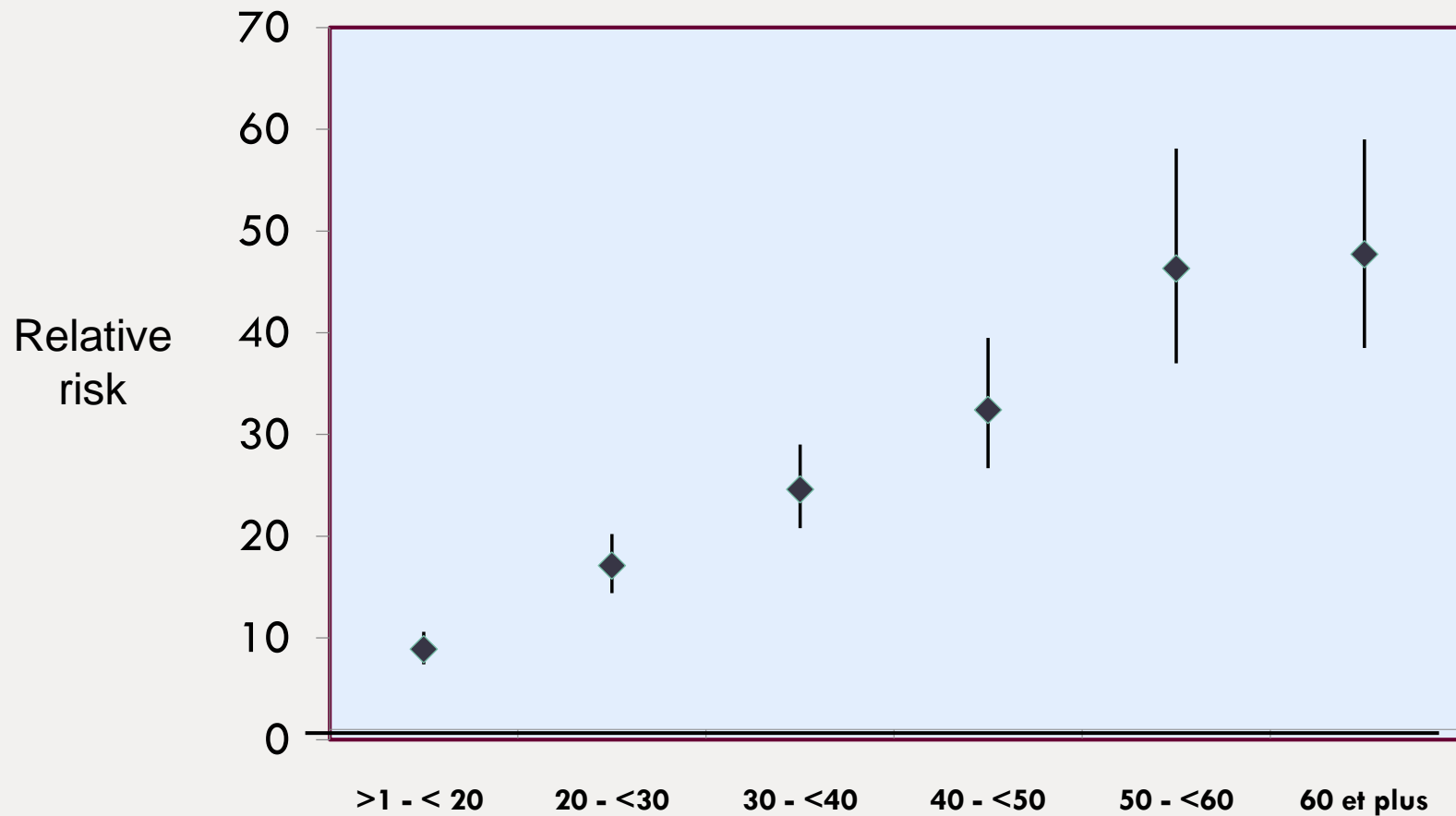
- Only approach that can provide definitive evidence;
- Direct observation on humans
- Possibility of biases and confounding factors
- Correlation or Causation: the real challenge
- Limitations: « false positive » and « false negative »



A relative risk of 2 or less is difficult to confirm or reject



Smoking and lung cancer



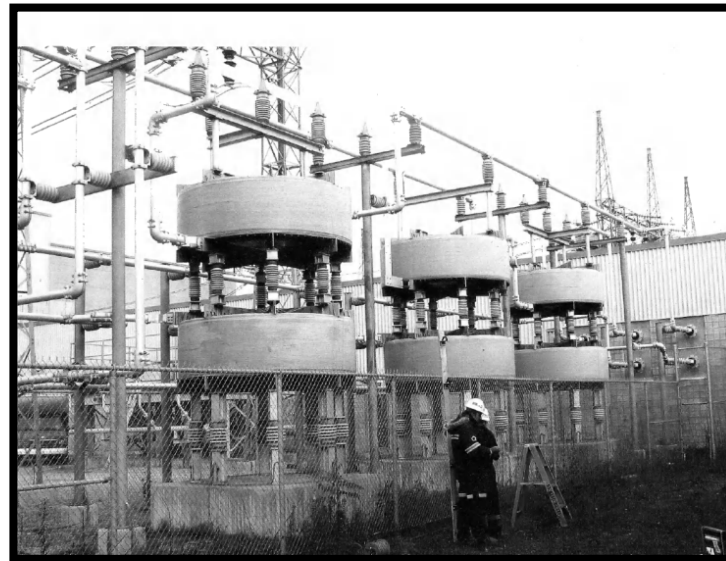
Number of pack-years
(packs smoked per day) × (years as a smoker)

High MF occupational exposure

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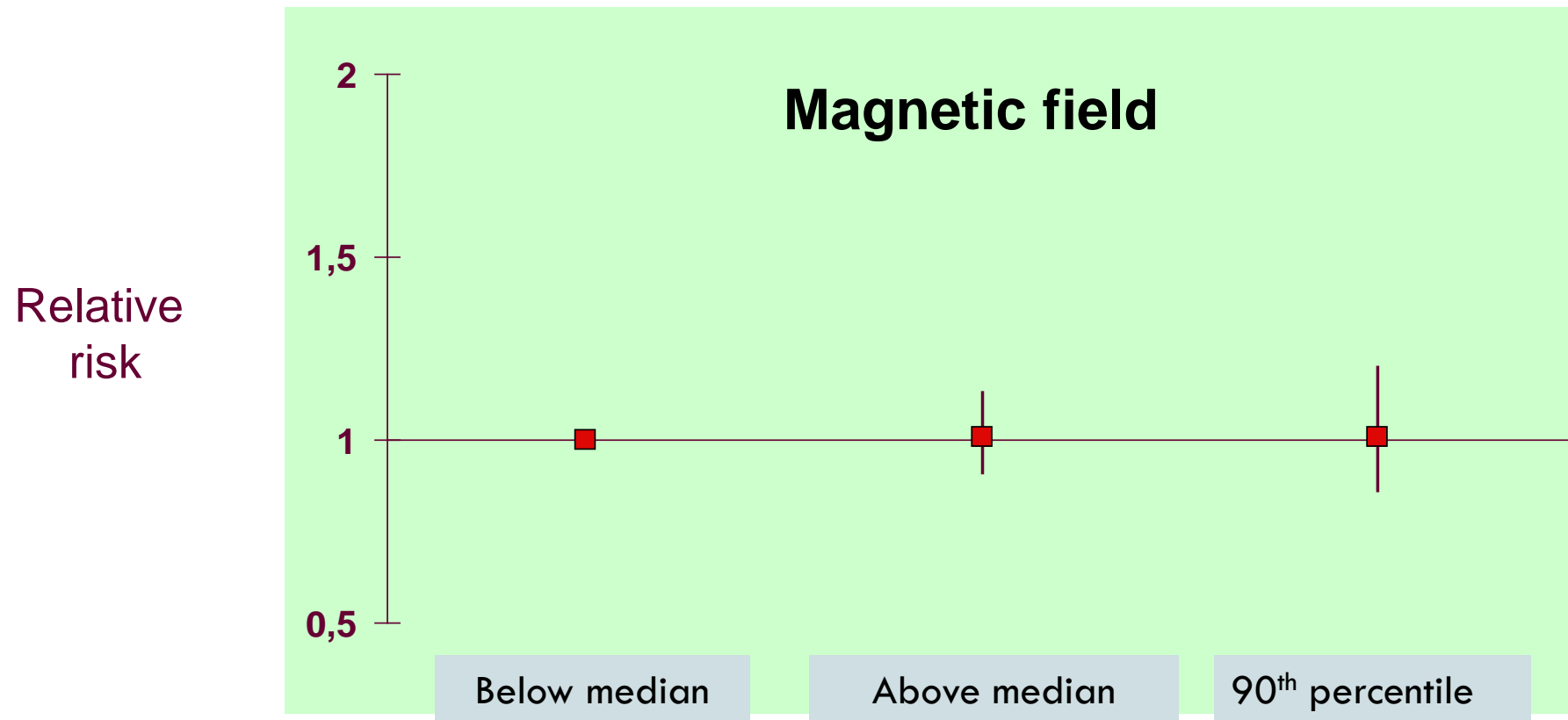
- Average exposure 1 μT
- Occasional exposure above 100 μT
- Maximum exposure : 1 000 μT

Joint Study HQ-EDF-OH

- Request from the Quebec Government
- Duration: 1988 -1994 (Mc Gill University; University of Toronto; INSERM)
- Cohort: 225 000 utility workers
- Exposure assessment:
 - Development of a portable dosimeter (E and B field)
 - 1 week dosimetry in each job title (2,000)
 - Professional job history for all study subjects
 - Endpoints: cancer incidence (all types)
- 4,151 incident cases of cancer; 1 to 4 controls per case
 - Total: 10,257 subjects (cases and controls)

Cancer among utilities' workers*

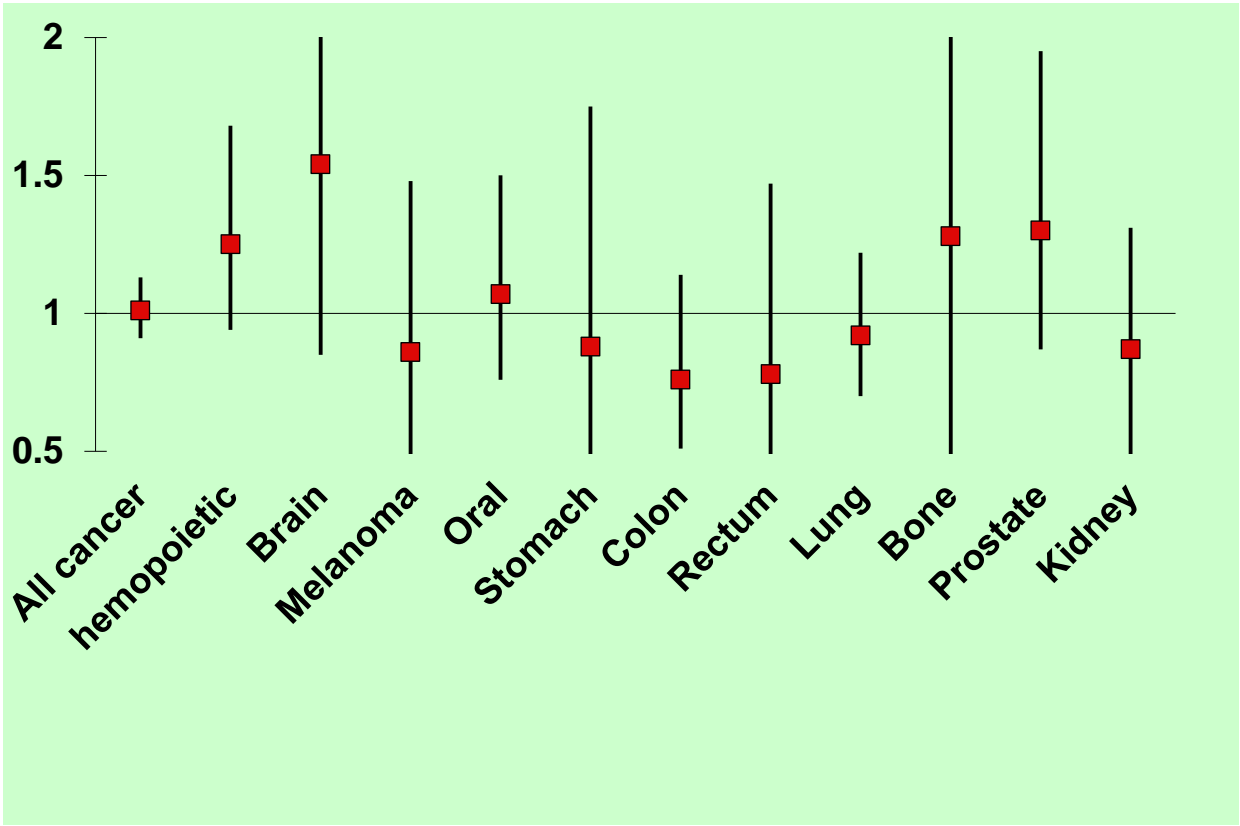
- Électricité de France; Ontario Hydro; Hydro-Québec workers (n = 225 000)
- Based on the analysis of 4,151 cases vs 6,106 controls



Cancer among utilities' workers*

Above median exposure vs below median exposure to magnetic field

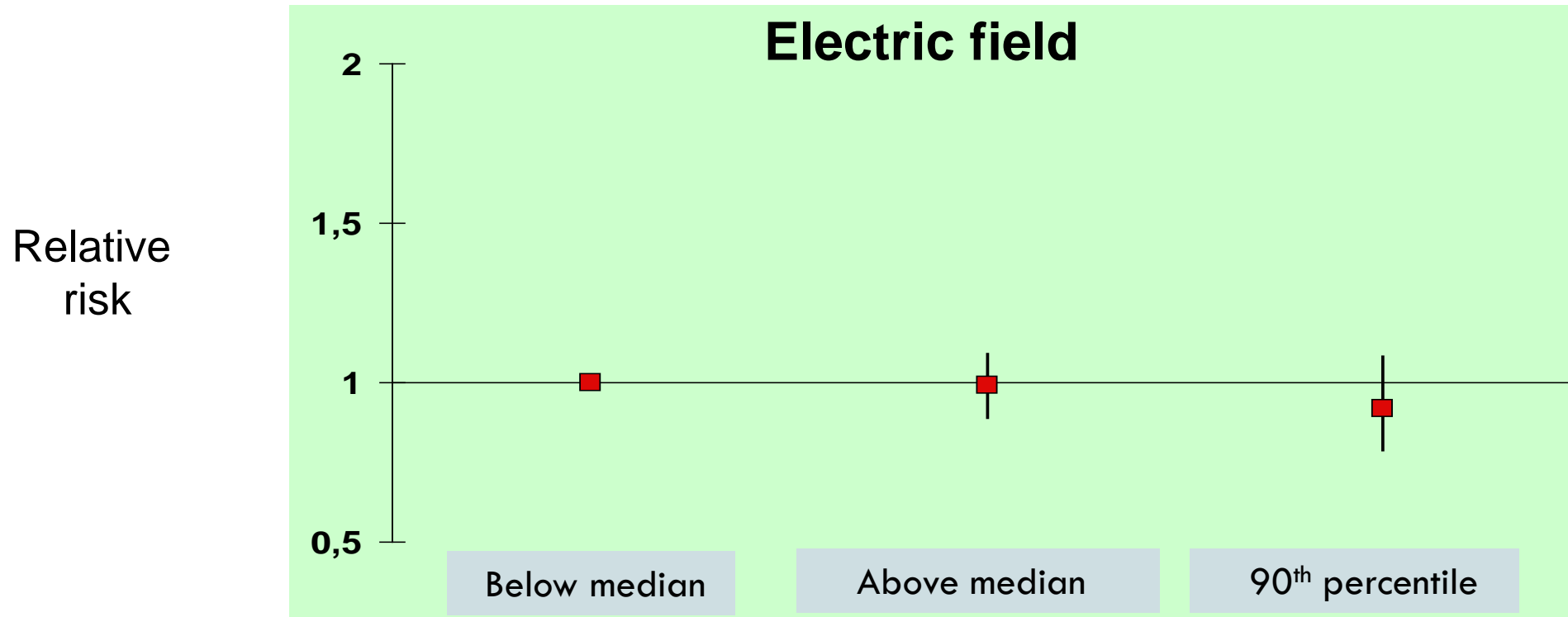
Relative risk



*Thériault et al. Cancer Risks Associated with Occupational Exposure to Magnetic Fields among Electric Utility Workers in Ontario and Quebec, Canada, and France: 1970-1989. Am. J. Epi. 1994

Cancer among utilities' workers*

- Électricité de France; Ontario Hydro; Hydro-Québec workers (n = 225 000)
- Based on the analysis of 4,151 cases vs 6,106 controls



No evidence of an increased risk among workers

Carcinogenicity assessement (2)

2- LONG-TERM ANIMAL STUDIES

- 2 species; 2 sexes (rats and mice)
- Life-long exposure (2 years)
- 3 or 4 exposure level groups
- Limitations due to metabolic differences
- Limitations due to toxicity of high doses (MTD)
- All human carcinogens have tested positive; no false negative



Extremely sensitive test for human carcinogenicity



Long term animal studies

■ Mandeville 97	Rats F	2y	2,000 μ T	No effect
■ Yasui 97	Rats F	2y	5,000 μ T	No effect
	Rats M	2y	5,000 μ T	No effect
■ Mc Cormick 99	Mice F	2y	1,000 μ T	No effect
	Mice M	2y	1,000 μ T	No effect
■ Boorman 99	Rats F	2y	1,000 μ T	No effect
	Rats M	2y	1,000 μ T	No effect

*No evidence of carcinogenicity in long term animal studies
(5000 μ T)*

International Agency for Research on Cancer

IARC's 2002 MF classification 2B

Group 1: Carcinogenic to humans

Group 2A: Probably carcinogenic to humans

Group 2B: Possibly carcinogenic to humans

Group 3: Unclassifiable

Group 4: Probably not carcinogenic to humans

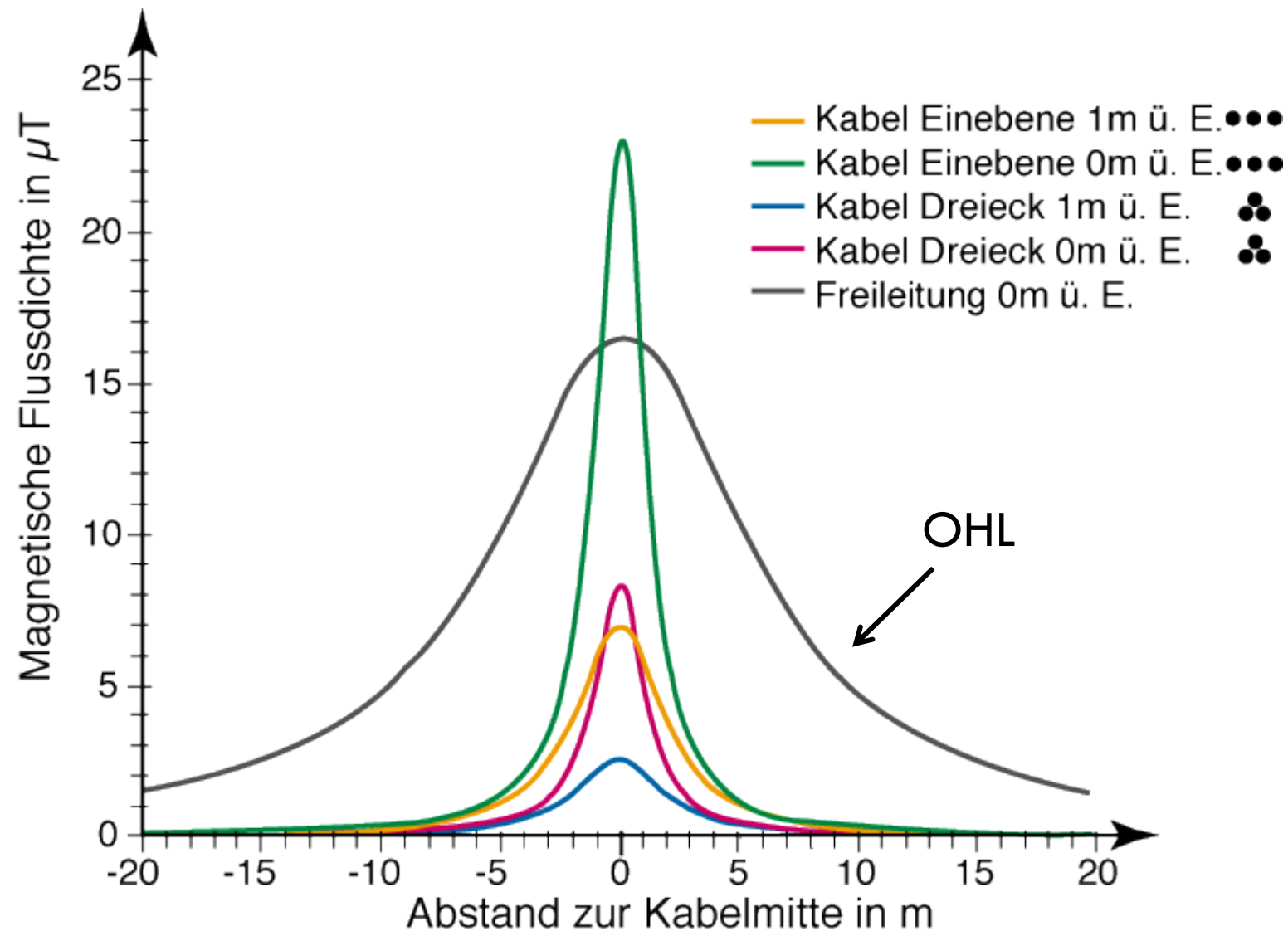
2014: Association **HVTL** distance vs leukemia risk*

- Exceptionally large study
- Britain; 16,457 leukemia cases ; 1962 - 2008
- Suggests an explanation for past associations

- **Conclusion:**

« ...past observations of associations between the presence of powerlines and childhood leukemia almost certainly cannot be attributed to powerline-generated magnetic fields but most likely to the evolving population characteristics of people living near powerlines. »

Magnetic fields of Overhead Lines and Underground Cables



Magnetic field and cancer: epidemiological evidence

David Savitz published large epidemiological studies on magnetic fields and cancer in 1980s and 1990s



New York Times interview (2014)

Asked to qualify the evidence about cancer and magnetic fields:

« If I had to pick a single number that would be the most likely, it would be zero. »

The initial association between MF and childhood cancer was not confirmed. The evidence has weakened considerably over time

50/60 Hz MF and cancer: facts to remember

By the year 2001...

1. No evidence of an increased risk among workers
2. No evidence of carcinogenicity in long term animal studies (5,000 μ T)
3. Absence of any physiological or toxic effects at high field levels (5,000 μ T)
4. Absence of a plausible mechanism of interaction
5. Initial correlation with childhood cancer was not confirmed. With better and larger studies the evidence weakened considerably over time.

New England Journal of Medicine 1997

EDITORIAL FREE PREVIEW

Power Lines, Cancer, and Fear

Edward W. Campion, M.D.

« It is sad that hundreds of millions of dollars have gone into studies that never had much promise of finding a way to prevent the tragedy of cancer in children. The many inconclusive and inconsistent studies have generated worry and fear and have given peace of mind to no one. The 18 years of research have produced considerable paranoia. But little insight and no prevention. It is time to stop wasting our research resources. »

Conclusions (WG C3.01) 2016

“The amount of data generated by this international research effort is exceptional. Independent experimental lines of evidence from the physics, the biology and the toxicology, failed to support the hypothesis raised by the 1979 epidemiological study. Large and sophisticated epidemiological studies failed to confirm the original finding.”

“We can safely assume that the hypothesis raised by the Denver study in 1979 is very likely to be a false alarm.”

“The exceptional amount of data accumulated over the last 35 years confirms what common sense would have suggested: power-frequency residential magnetic field levels are much too weak to influence human biology. Recommending preventive or precautionary measures is not justified. It would do more harm than good. It is time to be reasonable and reassure the public.”

WG C3.01 EMF and Health

❖ CIGRE WEB SITE

- ✓ Reference paper: *Living with electric and magnetic fields*

❖ ELECTRA WG C3.01 report

- ✓ « *50-60 Hz magnetic fields and cancer, forty years of research: it is time to reassure* »

✓

Plante M. Lambrozo J. Souques M. Brown D.C. Arnera P. Bulcao J.A. Nakasono S. ; Electra no 287 August 2016

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(Efcharistó)