BBEMG Webinar

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Agenda

From	To	Topic	Presenter
14:00	14:05	Welcome note	Catherine Bouland
14:05	14:15	Research on EMF & health in Belgium: a collaboration of 3 decades with the electricity sector	Vincent Du Four
14:15	14:40	ELF: regulations, modeling and measurements	Christophe Geuzaine, Véronique Beauvois & Maxime Spirlet
14:40	14:50	Analysis of the effects of long-term exposure to 50 Hz magnetic field (MF) on a TK6 cell line	Thi Thu Ha Nguyen
14:50	15:05	Analysis of cytogenetic damage in blood samples of electrical employees	Thi Thu Ha Nguyen
15:05	15:15	Study of individual's multiple exposures to environmental nuisances : ElectroMagnetic Fields (50Hz), Air, Noise and Endocrine Disrupting Chemicals (EXPO-HEALTH-1)	Agathe Salmon
15:15	15:20	Exposure to magnetic fields and childhood leukemia: a systematic review and meta-analysis of case-control and cohort studies	Christian Brabant & Olivier Bruyère
15:20	15:30	Application of the Precautionary Principle in the domain of Electromagnetic Fields	Els De Waegeneer
15:30	16:30	Q&A with questions by audience	All speakers

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Past before present

Luc Verschaeve

Annemie Maes

Jolien Van De Maele

Maurits De Ridder

Research on EMF & health in Belgium

a collaboration of 3 decades with the electricity sector

ELIA – VINCENT DU FOUR

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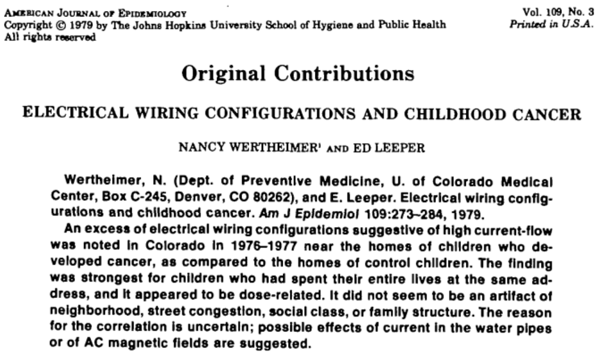
40 years of research

- **End 1960's**: first studies on health of electrical workers in the Soviet Union
- **1979**: first publication suggesting association between residential exposure and cancer in the US (Wertheimer & Leeper)


AMERICAN JOURNAL OF EPIDEMIOLOGY
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Vol. 109, No. 3
Printed in U.S.A.

Original Contributions

ELECTRICAL WIRING CONFIGURATIONS AND CHILDHOOD CANCER

NANCY WERTHEIMER[1] AND ED LEEPER

Wertheimer, N. (Dept. of Preventive Medicine, U. of Colorado Medical Center, Box C-245, Denver, CO 80262), and E. Leeper. Electrical wiring configurations and childhood cancer. *Am J Epidemiol* 109:273–284, 1979.

An excess of electrical wiring configurations suggestive of high current-flow was noted in Colorado in 1976–1977 near the homes of children who developed cancer, as compared to the homes of control children. The finding was strongest for children who had spent their entire lives at the same address, and it appeared to be dose-related. It did not seem to be an artifact of neighborhood, street congestion, social class, or family structure. The reason for the correlation is uncertain; possible effects of current in the water pipes or of AC magnetic fields are suggested.

Belgium

- **1988**: Interdisciplinary commission of experts investigated the complaints of negative effects with cattle near overhead lines
- **1990**: a 3-year research "Effects of EMF on Heath" was granted to the University of Liege (Ulg) by Federal administration

Funding was not continued, so the contract ended in 1994

Creation of the BBEMG

- **1995**, 8 teams from 5 institutes (ULB, RUG, KUL, ULG & Vito) joined to create the Belgian **BioElectroMagnetics Group** (BBEMG)

  Launched a multidisciplinary research program to:

  - get a better understanding of the interactions between electromagnetic fields and biological activity;
  - contribute to the development and diffusion of scientific knowledge on the potential health effects of electric and magnetic fields.

  So creating expertise and information centers accessible to the public, scientists, governing authorities and electricity companies.

- Support of the electricity sector
  - Public funding lacking
  - Financial support from CPPTE (Electrabel – SPE) in 1995
  - In 2001 Elia (unbundling) was created & the first research agreement of 4 years was signed

Research agreement with Elia

- **20 years of cooperation**
  - Contract renewal every 4 years: in 2021, for the 6th time (2021-’25)
  - Research topics and team are adjusted - scientific evolution & questions stakeholders
  - Need to continue research & develop expertise as electricity use will increase

- **Scientific independency & integrity**
  - Academic liberty guaranteed in the agreement
  - Publication of the results in scientific peer reviewed journals is required
  - Agreements signed with the universities/institutes, not with the individual researchers
  - Researchers need to comply with the ethical code for scientific research in Belgium

ELF: Regulations, Modeling and Measurements

V. BEAUVOIS, C. GEUZAINE, M. SPIRLET – ULIEGE ACE

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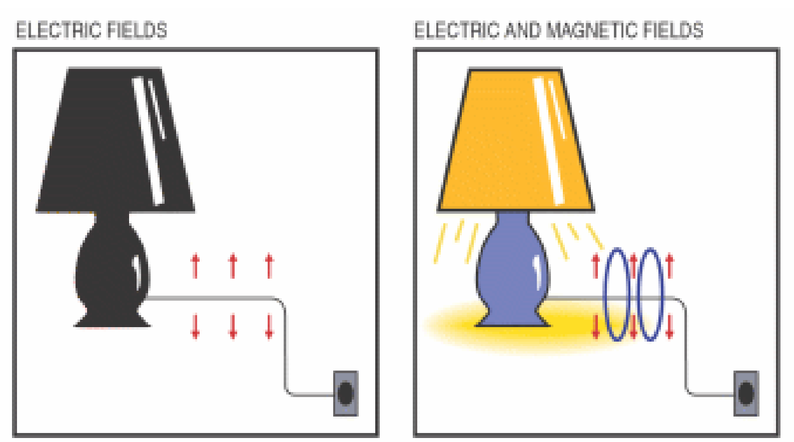
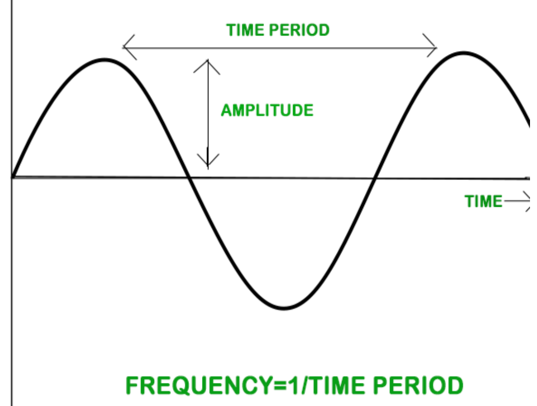
ELF?

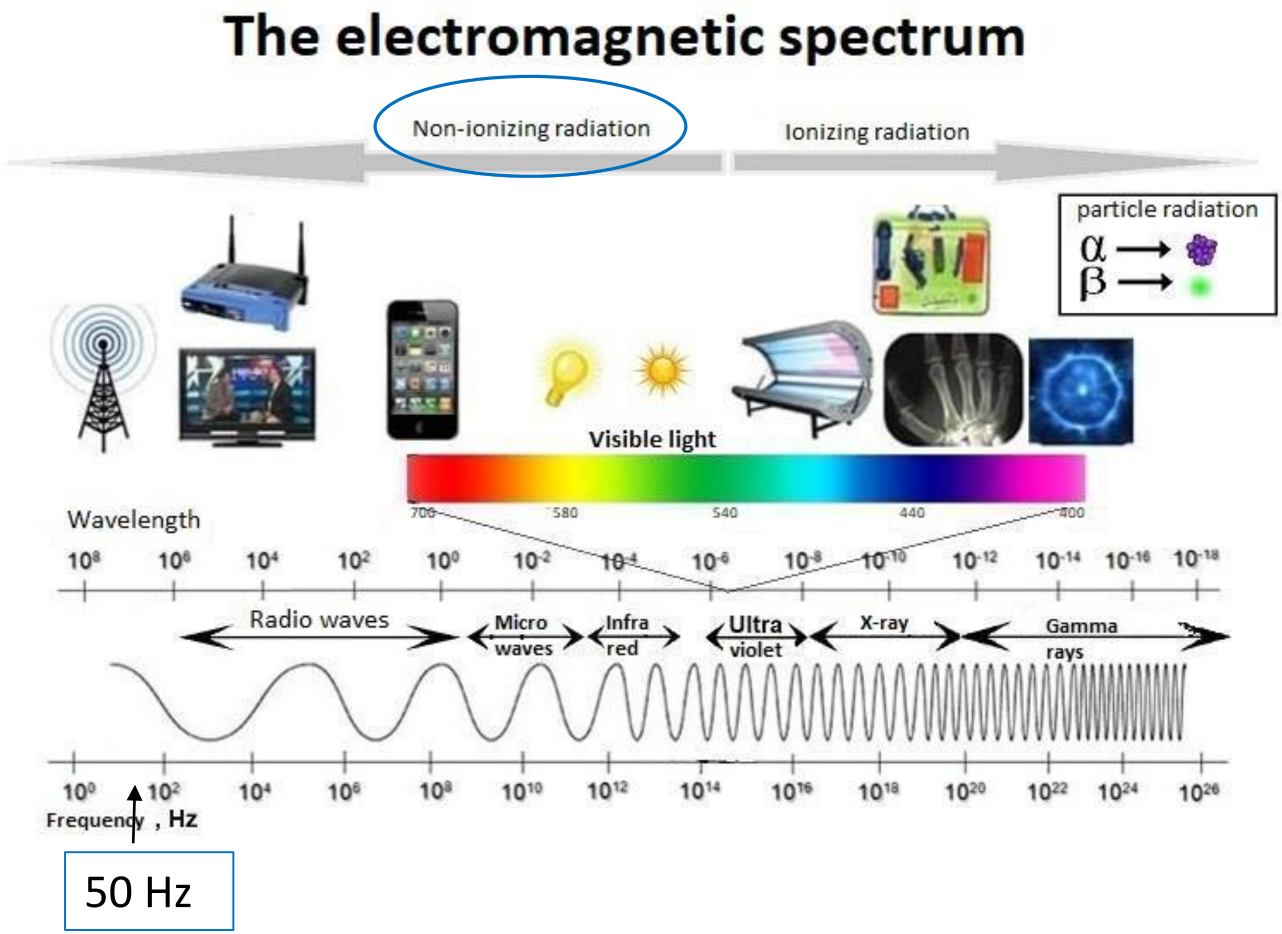
"ELF" electric and magnetic fields are **Extremely Low Frequency** electric and magnetic fields:

- The **electric field** is linked to the voltage (V), measured in Volt per meter (V/m).
- The **magnetic field** is linked to the current (A), measured in Ampere per meter (A/m); the Tesla (T or million of T, µT) can be used as well, with a direct relationship between both.

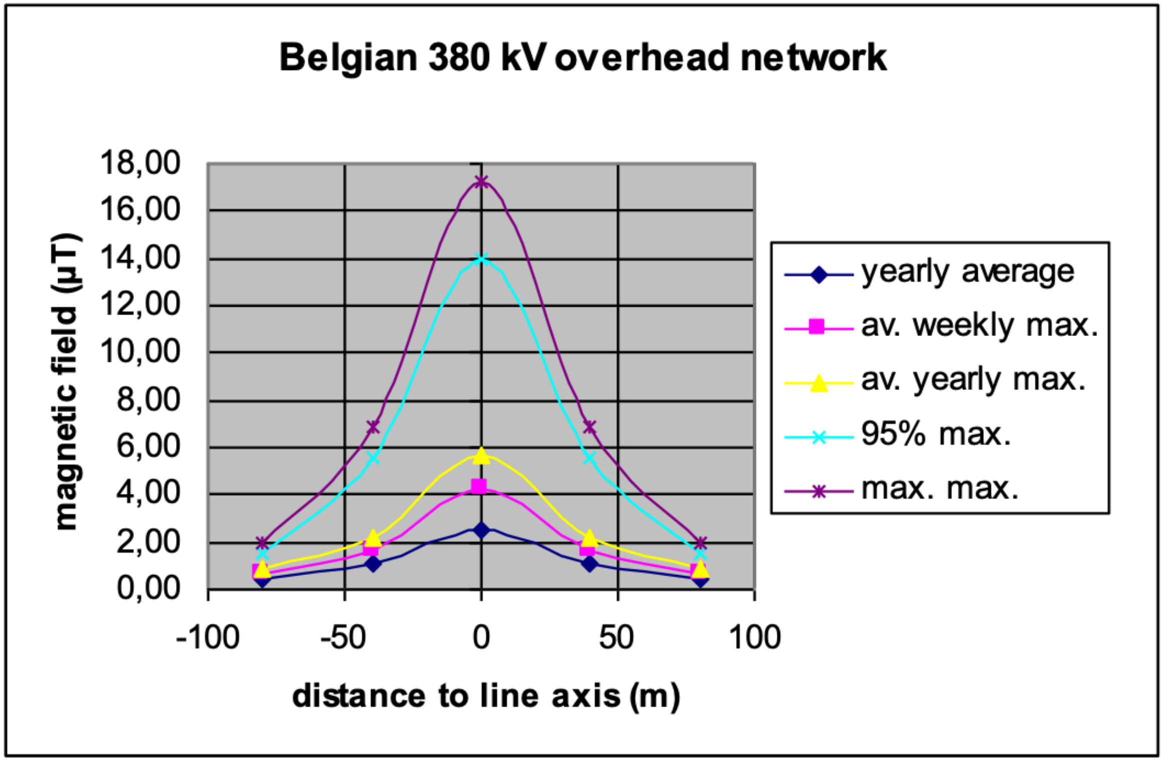




ELF?


The electromagnetic spectrum
Non-ionizing radiation
Ionizing radiation
particle radiation
α
β
Visible light
700
580
540
440
400
Wavelength
Radio waves
Micro waves
Infra red
Ultra violet
X-ray
Gamma rays
Frequency , Hz
50 Hz

ELF - Orders of magnitude



Regulations

Regulations exist for **general public** and **occupational** (workers) exposures and are different. Based mainly on **long term exposure**.

Different regulations levels exist:

1. **International level**

ICNIRP (International Commission on Non-Ionizing Radiation Protection)

Last edition of Low Frequency recommendations is 2010.

Recommendations first as basic restrictions: internal electric field. Impossible to measure > reference levels:

General public: 5 kV/m for E and 200 μT for B

Workers: 10 kV/m for E and 1000 μT for B

Regulations

2. **European level**

General public: EU recommendation (1999)

5 kV/m for E and 100 μT for B

Workers: 2004/40/EC Directive

Action values 10 kV/m for E and 1000 μT for B

Regulations

3. **Belgian level**

General public

E > Inhabited area, or area intended for habitation on sector plan 5 kV/m, overhangs of roads 7 kV/m and other places 10 kV/m

B > **regional level**

- Wallonia: only near static transformers, 5 kV/m and 100 μT
- Flanders: indoor pollution, intervention value 20 μT and guide value 0,4 μT
- Brussels: only near static transformers, 5 kV/m and 100 μT for permanent exposure

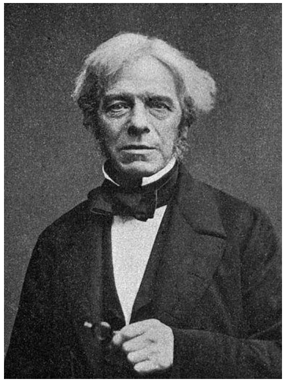
Workers > Belgian legislation similar to European Directive 10 kV/m for E and 1000 μT for B

Modeling

Like all electromagnetic phenomena, ELF electric and magnetic fields are described by **Maxwell's equations**.

James Clerk Maxwell
1831 – 1879

André-Marie Ampère
1775 – 1836



Michael Faraday
1791 – 1867

Carl Friedrich Gauss
1777 – 1855

Modeling

Like all electromagnetic phenomena, ELF electric and magnetic fields are described by **Maxwell's equations**.

$\mathbf{curl}\,\mathbf{H} = \mathbf{J} + \partial_t \mathbf{D}$	Maxwell-Ampère's equation
$\mathbf{curl}\,\mathbf{E} = -\partial_t \mathbf{B}$	Faraday's equation
$\mathrm{div}\,\mathbf{B} = 0$	Gauss's law for magnetism
$\mathrm{div}\,\mathbf{D} = \rho$	Gauss's law

$\mathbf{H}$	magnetic field (A/m)	$\mathbf{E}$	electric field (V/m)
$\mathbf{B}$	magnetic flux density (T)	$\mathbf{D}$	electric displacement (C/m^2)
$\mathbf{J}$	current density (A/m^2)	ρ	charge density (C/m^3)

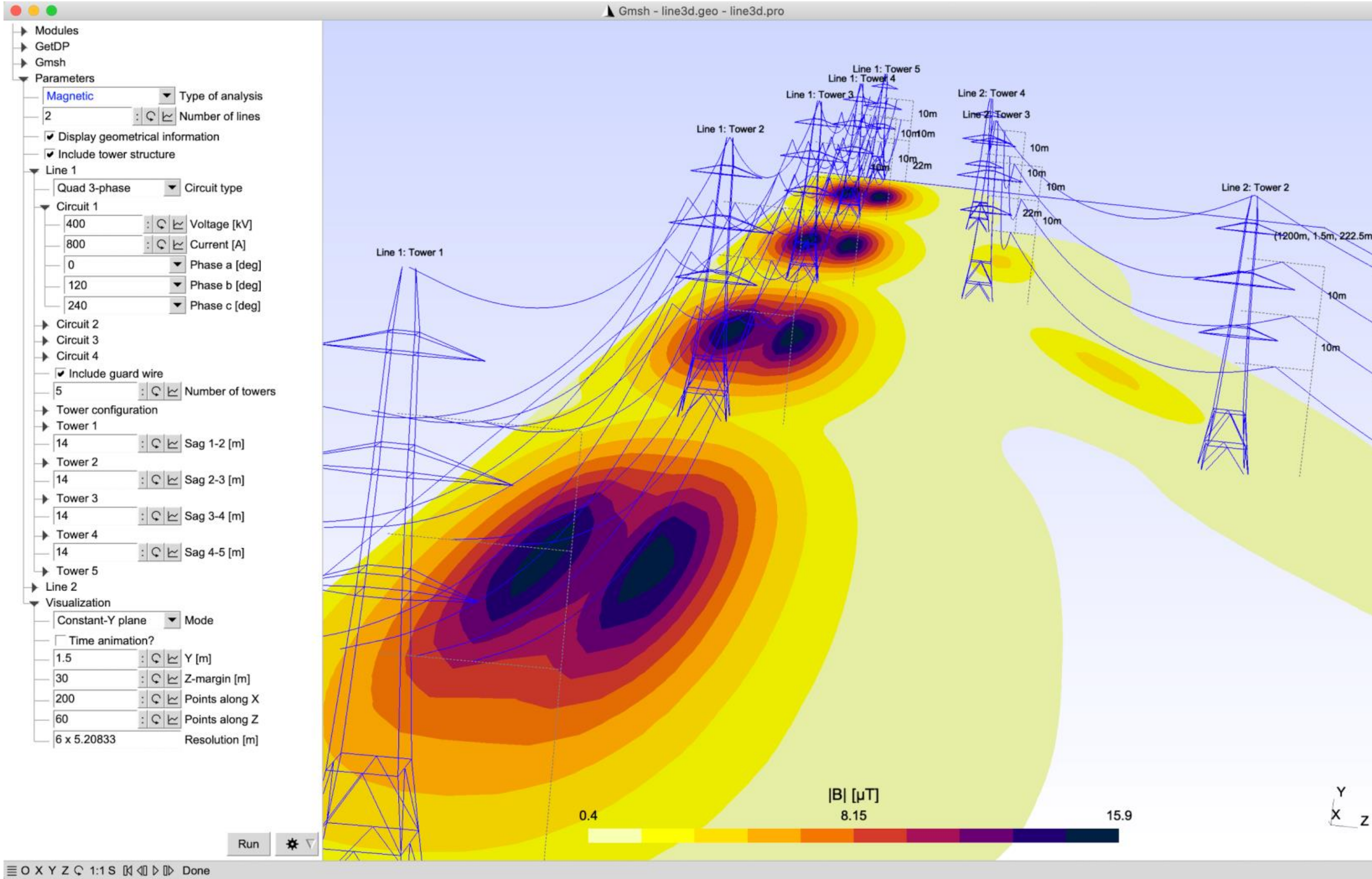
Modeling

These equations can be solved « by hand » in simple cases, but in more complicated situations they are **solved on computers**.

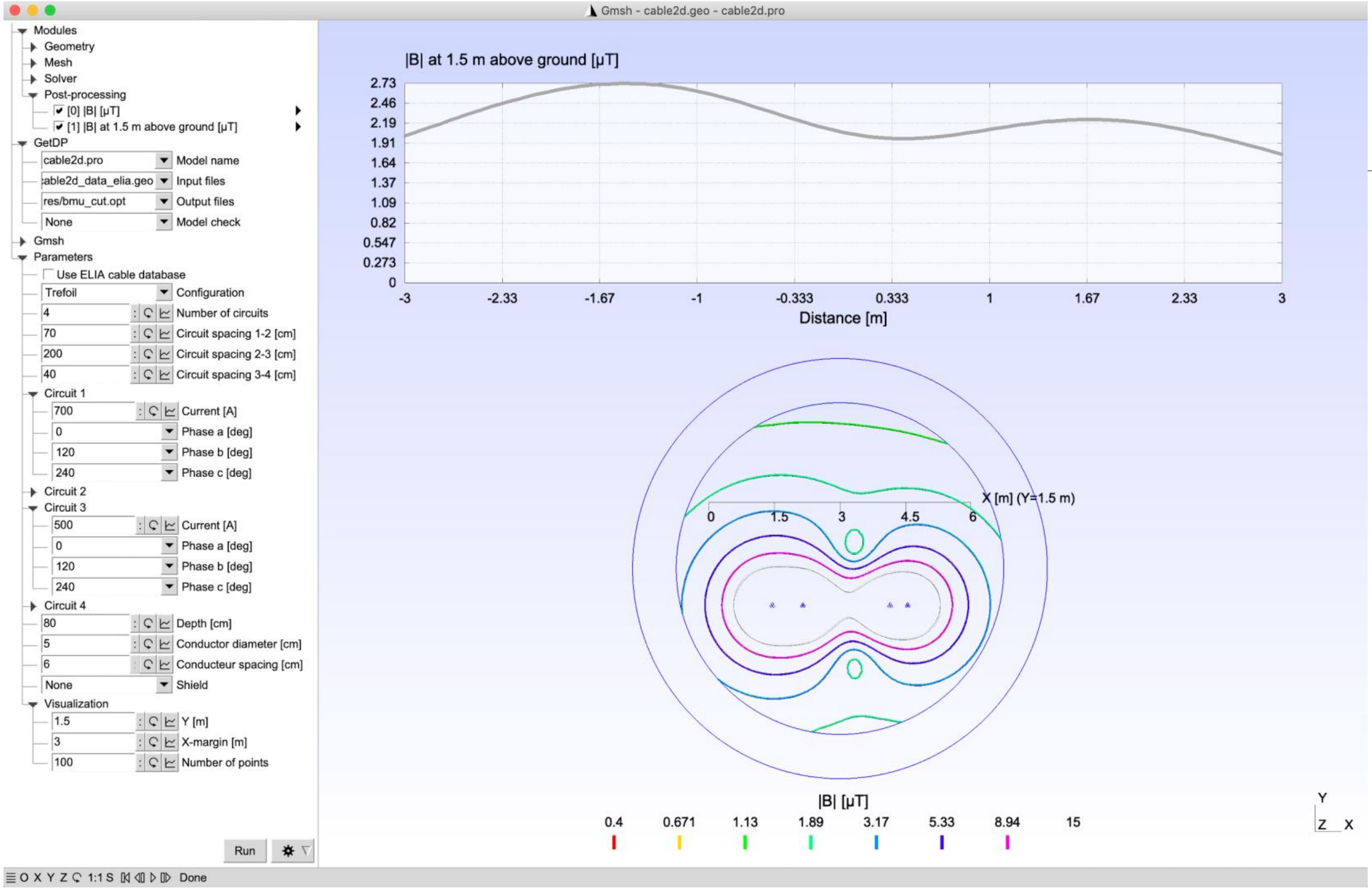
BBEMG team from the University of Liège is internationally recognized for its electromagnetic simulation tools:

- Free and open source
- 20+ PhDs, 100s of scientific articles
- Specific models for ELF: overhead lines and underground cables

https://onelab.info



Screenshot of a 3D configuration with two powerlines (four- and single-circuit).
Visualization of the magnetic flux density on a plane, with a custom range and colormap.



Screenshot of a 4-circuit underground cable configuration, with different currents and relative spacing. Visualization of the magnetic flux density on a graph at 1.5m above ground, and as iso-value curves.

Modeling

Pretty much anything can be simulated… however there is a fundamental limitation:

« Garbage in, Garbage out! »

Precise knowledge of

- geometries (high voltage towers, line sag, depth of cables, ...);
- materials; and
- sources (value of the currents in lines and cables, …)

is required to obtain **accurate results**.

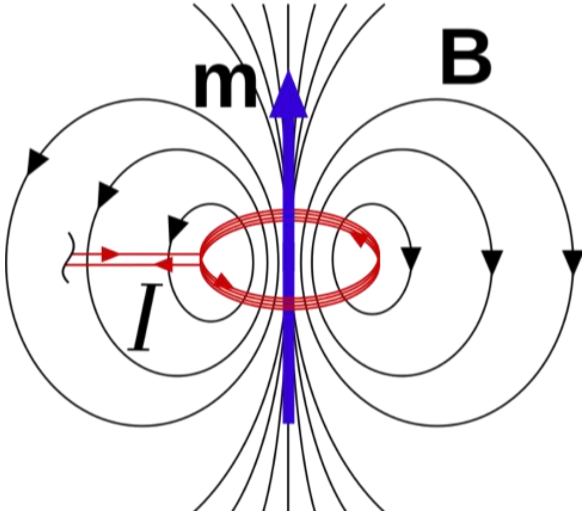
Measurements

- The electric and magnetic fields result from a complex combination of all the sources (known and unknown), which can lead to difficult quantification by simulation.
- In case of uncertainty, the definitive option is to **measure the resulting electric or magnetic field in-situ**.

In-situ measurements are very useful, especially for complex situations.

Measurements

However, except in the vicinity of electrical devices, the ELF magnetic field is generally small and thus difficult to measure (highly impacted by noise, lack of sensitivity due to the small size of the loop antenna, contributions from other sources, …).



Measurements - Orders of magnitude

Field intensity rapidly decreases with the distance to the source.

Magnetic field

Source	Order of magnitude ($1\mu T=10^{-6}$ T)
Human brain : field measured at the skull external surface	10^{-15} T
Earth: field measured at the external surface	50 µT
Wire flowd by 10 A current : field measured at 2 cm of the wire	100 µT
Permanent magnet : field measured at 10 mm of the surface	0.1 T – 1T

Measurements - Orders of magnitude

Field intensity rapidly decreases with the distance to the source.

Electric field

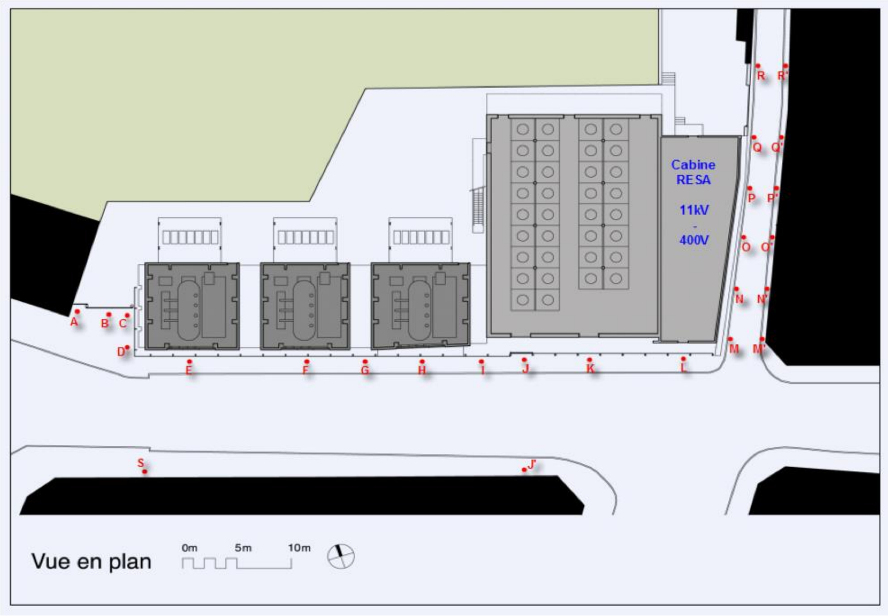
Source	Order of magnitude
High-voltage line (400 kV) ; field measured at 1.5 m under the cables	4000 V/m
Computer workstation; field measured at 10 cm of the power supply	100 V/m

Measurements

[µT]	30 cm from the fence	Back to houses
A	0,5	-
B	2,3	-
C	7,7	-
D	1,5	-
E	1,75	-
F	2,1	-
G	0,97	-
H	1	-
I	2,7	-
J	6,1	0,3
K	4,8	-
L	1,9	-
M	0,9	0,7
N	1	0,7
O	1,3	0,85
P	1,5	0,9
Q	1	0,8
R	0,75	0,6
S	-	0,18

Example:

Magnetic field around 11 kV – 400 V cab

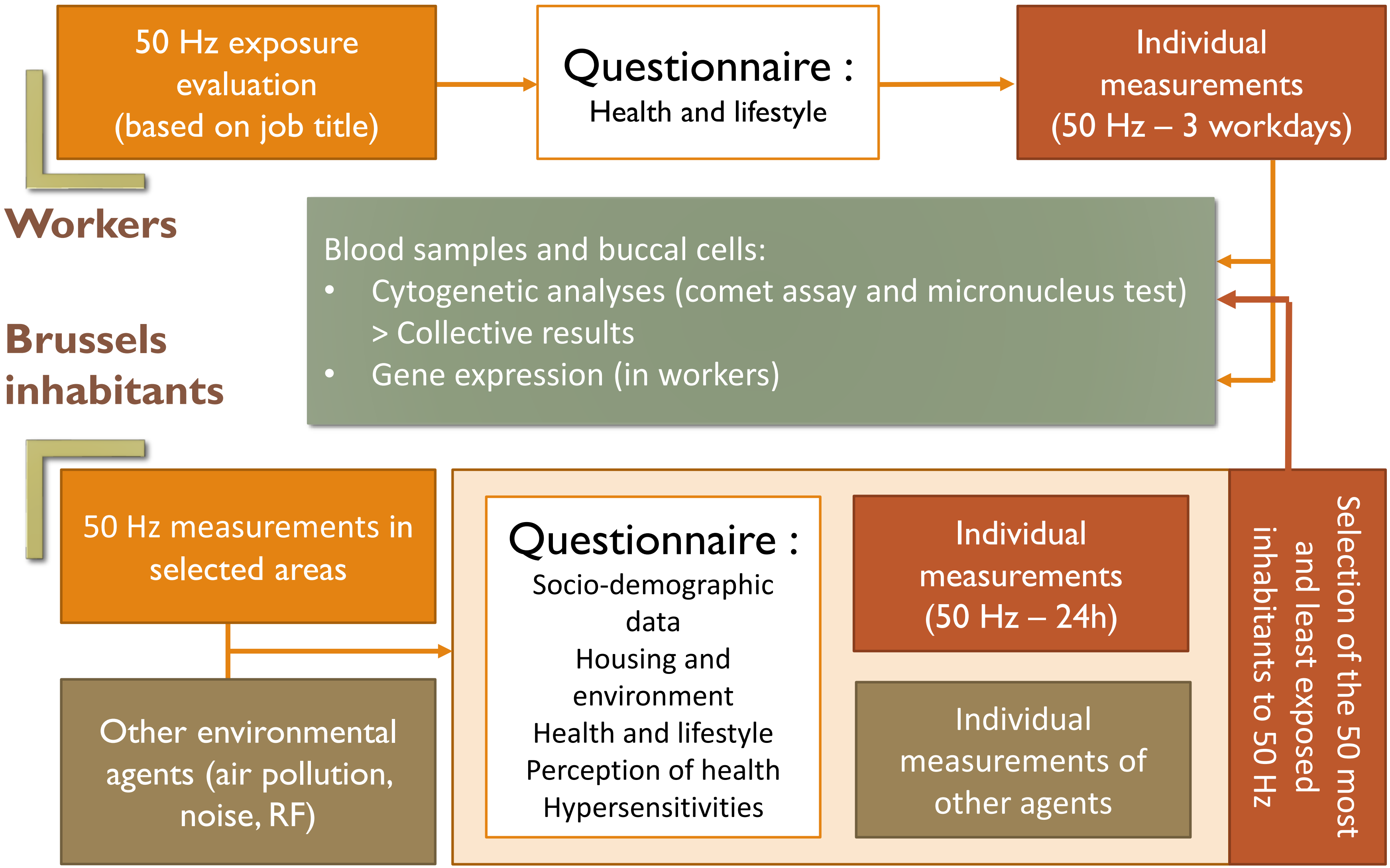


Conclusions

Extremely Low Frequency (ELF) electric and magnetic fields obey well-known equations and can be accurately modelled if the sources and the environment are precisely known.

In-situ measurements remain the definitive option to quantify ELF electric and magnetic fields in case of uncertainty.

Regulations exist for the general public and for workers, based mainly on long term exposure.


50 Hz exposure evaluation (based on job title)
Questionnaire : Health and lifestyle
Individual measurements (50 Hz – 3 workdays)
Workers
Blood samples and buccal cells:
• Cytogenetic analyses (comet assay and micronucleus test) > Collective results
• Gene expression (in workers)
Brussels inhabitants
50 Hz measurements in selected areas
Other environmental agents (air pollution, noise, RF)
Questionnaire : Socio-demographic data Housing and environment Health and lifestyle Perception of health Hypersensitivities
Individual measurements (50 Hz – 24h)
Individual measurements of other agents
Selection of the 50 most and least exposed inhabitants to 50 Hz

Analysis of the effects of long-term exposure to 50 Hz magnetic field (MF) on a TK6 cell line

H. NGUYEN, S. SEGERS, M. LEDENT, R. ANTHONISSEN, JF. COLLARD, M. HINSENKAMP, L. VERSCHAEVE, V. FEIPEL, E. DE CLERCQ, B. MERTENS

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1. Introduction

- Extremely low frequency magnetic field (ELF-MF) classified as possibly carcinogenic to humans (IARC, 2002)
    - Limited evidence of carcinogenicity in human
    - **No straightforward support from experimental studies**

- Current guideline on exposure limits relied on studies on **short-term exposure**

What about long-term exposure to lower magnitude of magnetic field?

Study objectives

Investigate the effects of long-term in vitro exposure to ELF-MF on cell line

- **Affect cell viability?** — Compare cell number: MF-exposed vs Unexposed culture
- **Increase genetic damage?** — Compare level of genetic damage: MF-exposed vs Unexposed culture
- **Adaptive response?** — Compare level of genetic damage: (MF+ Mutagen)-exposed vs Mutagen-exposed culture

Review

Adaptive response in mammalian cells exposed to non-ionizing radiofrequency fields: A review and gaps in knowledge

Vijayalaxmi [a], Yi Cao [b,**], Maria Rosaria Scarfi [c,*]

[a] Department of Radiology, University of Texas Health Science Center, San Antonio, TX 78229, USA
[b] School of Public Health, Medical College of Soochow University, Suzhou, People's Republic of China
[c] CNR – Institute for Electromagnetic Sensing of Environment, Napoli, Italy

2. Methodologies

Cell and Exposure system

- **Cell culture**: Human lymphoblastoid cell (TK6)

- **Magnetic field exposure system**
  - Solenoid coil
  - 380 coil, 20 cm diameter, 42cm length
  - Field range: 0- 2500 µT
  - Field applied: 10, 100, and 500 µT

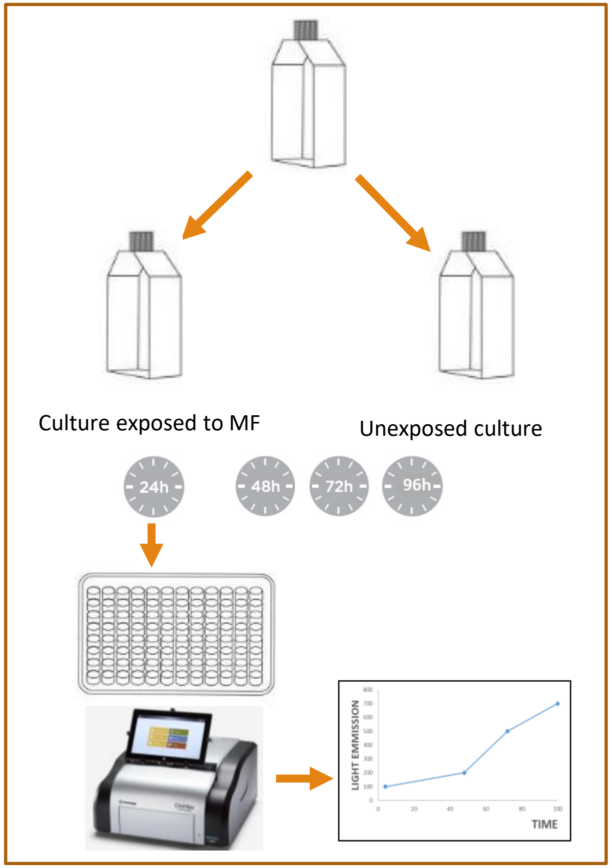
- **Magnetic field shielding system**: Mu-metal cylinder

Picture of exposure system (left) and shielding system(right) inside incubator

2. Methodologies

Cell viability test

- **ATP assay**
- **Estimate the relative amount of viable cells**
  - Viable cells → ATP → Light
  - Dead cells → ATP → No signal
- **Emitted luminescence is direct proportional to the number of viable cells**



2. Methodologies

Cytogenetic tests

Protocol 1: no exposure to chemical agents
Protocol 2: exposure to chemical agents (MMS/EMS) for 24h

Continuous exposure to 50Hz EMF

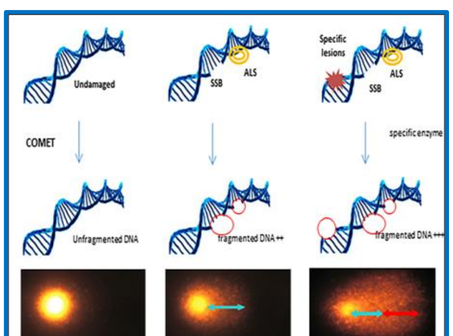
0h ========24h==--48h + 5w

Start MF exposure

48h (week 1) | **48h + 1w (week 2)** | **48h + 2w (week 3)** | **48h + 3w (week 4)** | **48h + 4w (week 5)** | **(week 6)**

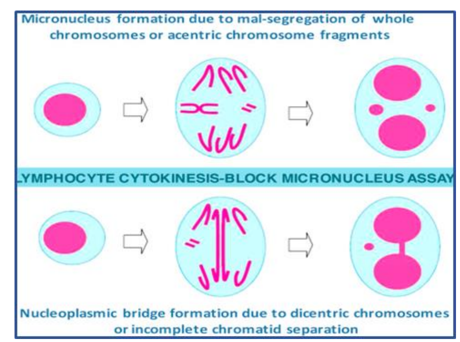
Collection of TK6 cells

***In vitro* comet assay**



Measure % damaged DNA in comet tail

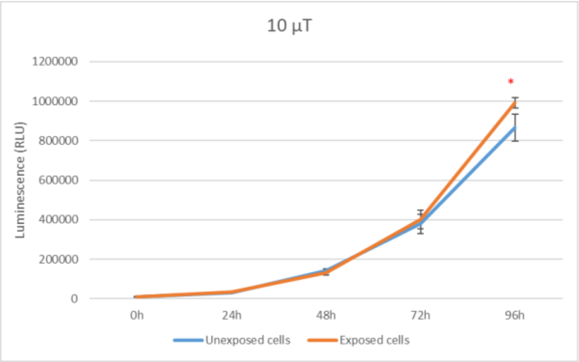
***In vitro* Micronucleus test**

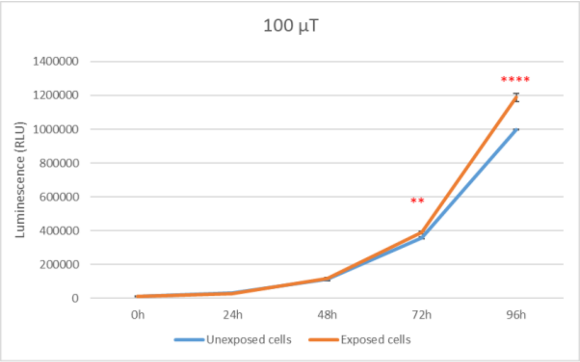


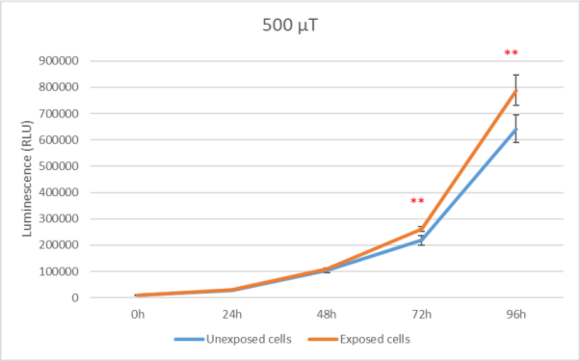
Score incidence of micronucleated cell/2000 bi-nucleated cells

3. Results

Cell viability test







-> Exposure to 50 Hz MF increased the cell viability
->Significant results were observed after 72h and 96h of exposure to 50 Hz MF 10, 100, and 500 µT.

-> Beneficial effect ???

3. Results

Examples of medical application:

- Tissue regeneration
- Wound healing
- .....

Review > Cell Prolif. 2014 Dec;47(6):485-93. doi: 10.1111/cpr.12142. Epub 2014 Oct 16.

Therapeutic potential of electromagnetic fields for tissue engineering and wound healing

T Saliev [1], Z Mustapova, G Kulsharova, D Bulanin, S Mikhalovsky

Affiliations + expand

PMID: 25319486 PMCID: PMC6496472 DOI: 10.1111/cpr.12142

Free PMC article

Abstract

Ability of electromagnetic fields (EMF) to stimulate cell proliferation and differentiation has attracted the attention of many laboratories specialized in regenerative medicine over the past number of decades. Recent studies have shed light on bio-effects induced by the EMF and how they might be harnessed to help control tissue regeneration and wound healing. Number of recent reports suggests that EMF has a positive impact at different stages of healing. Processes impacted by EMF include, but are not limited to, cell migration and proliferation, expression of growth factors, nitric oxide signalling, cytokine modulation, and more. These effects have been detected even during application of low frequencies (range: 30-300 kHz) and extremely low frequencies (range: 3-30 Hz). In this regard, special emphasis of this review is the applications of extremely low-frequency EMFs due to their bio-safety and therapeutic efficacy. The article also discusses combinatorial effect of EMF and mesenchymal stem cells for treatment of neurodegenerative diseases and bone tissue engineering. In addition, we discuss future perspectives of application of EMF for tissue engineering and use of metal nanoparticles activated by EMF for drug delivery and wound dressing.

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3. Results

Genetic damage and Adaptive response

Studies	Cytogenetic tests	Experiments with different flux density (µT)					
		10	10	100	100	500	500
Genetic effects of MF exposure	MN	-	-	-	-	-	-
	Comet assay	?	?	?	-	-	-
Adaptive response test	MN	-	-	-	-	-	-
	Comet assay	?	-	-	-	-	-

(- No significant result; ? Incoherent results)

- Micronucleus test always resulted in non-significant different results
- Some incoherent results when the cells were long-term exposed to 10 µT magnetic field
- Comet results showed no effects when cells were long-term exposed to 100 or 500 µT

4. Conclusion

- Long-term MF exposure affect TK6 cell viability
  - → Thus, studies investigating the mechanisms linked to cell viability should be carried out to explain this observation.
- Only some incoherent genetic effects were found when the TK6 cells were long-term continuously exposed to 10 µT
- No genetic effect or adaptive response was detected in the case of cells long-term exposed to 100 and 500 µT

Thank you for your attention!

Contact

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Analysis of cytogenetic damage in blood samples of electrical employees

H. NGUYEN, M. LEDENT, G. VANDEWALLE, J. VAN DE MAELE, JF. COLLARD, M. HINSENKAMP, L. VERSCHAEVE, V. FEIPEL, E. DE CLERCQ

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Introduction

Occupational ELF-EMF exposure→ Non-ionizing radiations → No direct DNA damages

- Controversial results showed in previous studies in occupational settings
- But**, studies often have shortcomings** → inconclusive (Verschaeve & Maes, 2016)

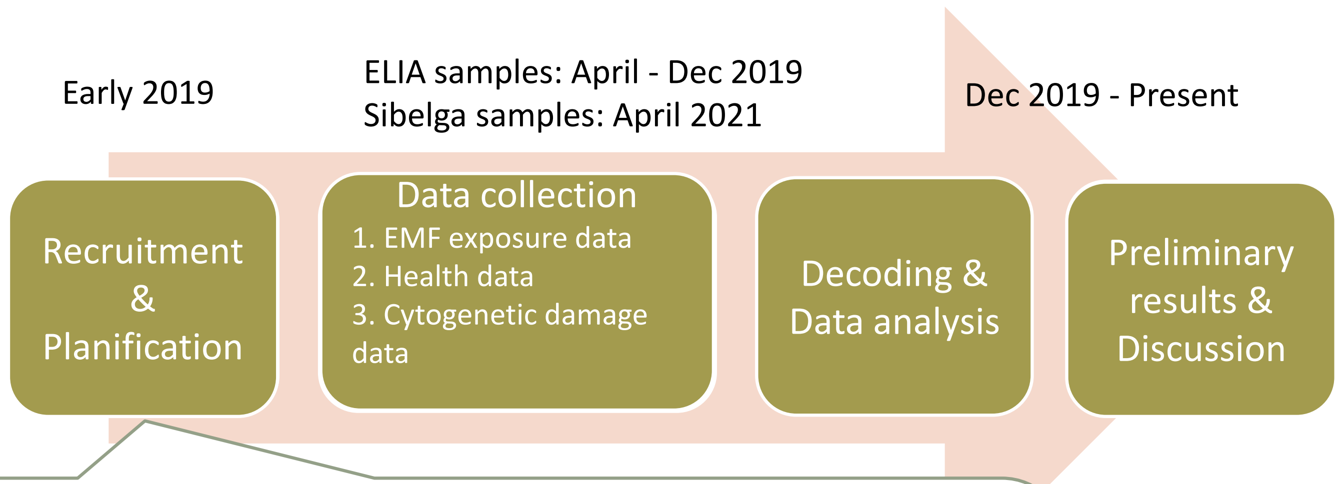
Objectives: Investigate the cytogenetic damage in blood samples of employees occupational exposure to ELF-EMF

- Sufficiently large number of employees
- Exposure assessment: Job titles + Actual exposure data
- Validated cytogenetic tests …

Null hypothesis: Employees who are professionally exposed to ELF-EMF, based on job titles, do not have increased genetic damage in their blood cells

→ Compare level of genetic damage in less exposed employees vs higher exposed employees

Biomonitoring study process



Inclusion criteria:
- Between 18 and 55 years of age;
- Preferentially be non-smoking males, but smokers / females could be accepted;
- Not subject to recent radiographic investigations;
- No significant medical antecedents or genetic diseases;
- Technicians: having at least 5 years of working experience in electricity-related jobs.

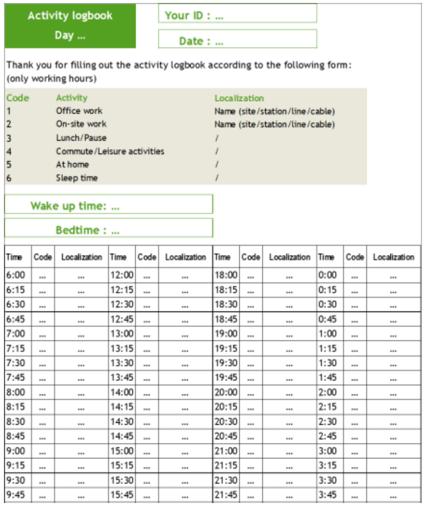
Exclusion criteria:
- Exposure at home
- Health problems

Detail on data collection

Magnetic field exposure data

- **Devices**: Emdex II
- **Measurement period: At least 3 consecutive days** during a typical work week
- **How to wear?**
    - At work: wear the device in a pouch around their hip or attached to their belt
    - At home: wear the device as much as possible.
    - Otherwise, leave it in its pouch and place it far from any electrical devices or transformers
- **Diary of activities**: delimit occupational exposure with other exposures

EMDEX II device



Activity logbook
Day ...

Your ID : ...
Date : ...

Thank you for filling out the activity logbook according to the following form:
(only working hours)

Code	Activity	Localization
1	Office work	Name (site/station/line/cable)
2	On-site work	Name (site/station/line/cable)
3	Lunch/Pause	/
4	Commute/Leisure activities	/
5	At home	/
6	Sleep time	/

Wake up time: ...

Bedtime : ...

Time	Code	Localization	Time	Code	Localization	Time	Code	Localization	Time	Code	Localization
6:00	...	...	12:00	...	...	18:00	...	...	0:00	...	...
6:15	...	...	12:15	...	...	18:15	...	...	0:15	...	...
6:30	...	...	12:30	...	...	18:30	...	...	0:30	...	...
6:45	...	...	12:45	...	...	18:45	...	...	0:45	...	...
7:00	...	...	13:00	...	...	19:00	...	...	1:00	...	...
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9:30	...	...	15:30	...	...	21:30	...	...	3:30	...	...
9:45	...	...	15:45	...	...	21:45	...	...	3:45	...	...

Diary of activities

Detail on data collection

Consent and Health data

- Questionnaires
  - Smoking habits
  - Alcohol consumption
  - Recent illness
  - Radiograph
  - ….

Titel onderzoek: Humane cytogenetische biomonitoringstudie bij Elia werknemers
Opdrachtgever: Belgian BioElectroMagnetics Group, Elia System Operator
Verantwoordelijke onderzoekers: Prof.Dr. L. Verschaeve, Dr. G. Vandewalle
Contactpersoon Elia: Vincent Du Four

VRAGENLIJST

Dit blad moet van het informatieformulier en de toestemmingsverklaring worden losgemaakt. Alleen het codenummer zal worden gebruikt als identificatie op de volgende pagina's.

Lees de volgende vragen zorgvuldig door en beantwoord ze zo volledig en nauwkeurig mogelijk. Indien nodig kan de achterkant van een pagina gebruikt worden om een antwoord te vervolledigen. Vermeld hierbij dan ook het nummer van de vraag. De antwoorden die u geeft, kunnen een directe invloed hebben op de interpretatie van onze resultaten. Bij twijfel kunt u dit vermelden op de vragenlijst en dan nemen we met u contact op. Bedankt voor uw interesse en deelname aan deze studie.

1. Beroepsinformatie

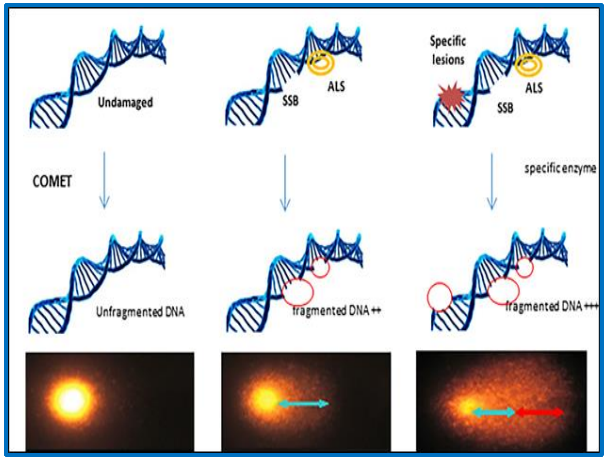
In dit deel van de vragenlijst wordt geïnformeerd naar de mate en de frequentie van beroepsmatige blootstelling aan 50HZ-elektromagnetische velden. Werknemers die niet werkzaam zijn in de nabijheid van 50-HZ velden beantwoorden alleen deel B.

A. Werknemers werkzaam in de nabijheid van elektrische installaties.

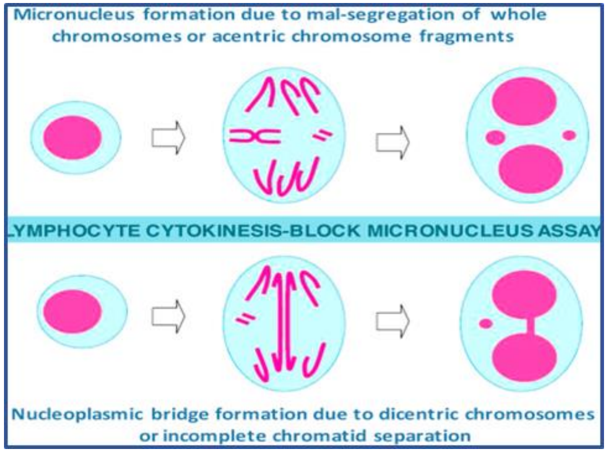
Detail on data collection

Cytogenetic damage data

- Blood samples were collected by venipuncture
- Immediately used for Comet assay and Micronucleus tests



Measure % damaged DNA in comet tail (tail intensity)



Score number of cell with micronuclei per 2000 bi-nucleated cells (frequency of MN)

RESULTS

Study population

- **126 ELIA's employees** (67 Office staffs and 59 Technicians) **+ 6 Sibelga's employees** (3 Office staffs and 3 Technicians) interested in participating in the study

- Based on the various exclusion criteria set before the study and after exposure data analyses, **the whole dataset is composed of 67 employees** (30 Office staffs and 37 Technicians)

Note: as some data of Sibelga's samples are still missing, analyses are based on data of Elia's employees only

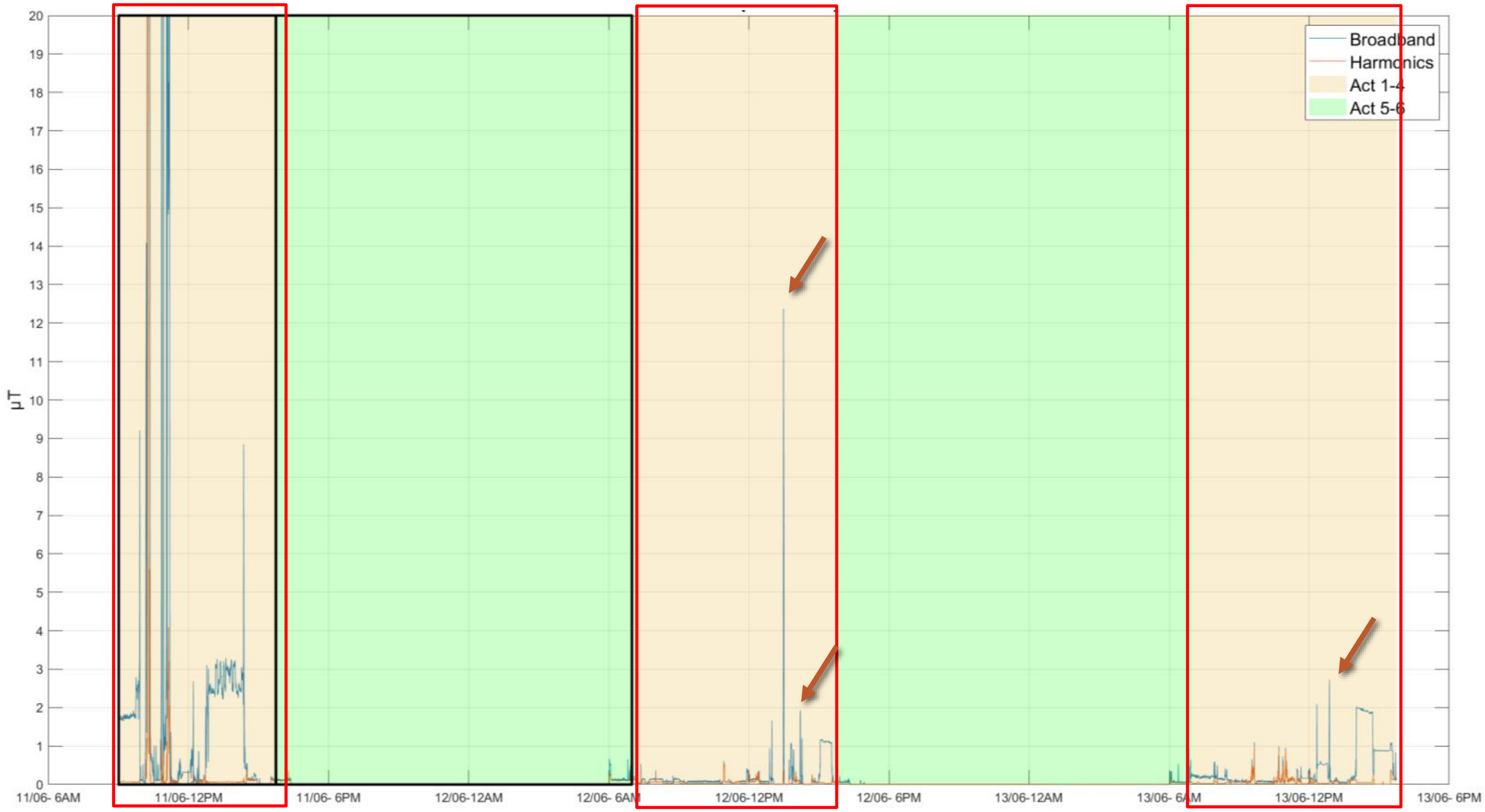
Characteristics of study population

- In the Office group, we have **6 women** and 24 men
- Average ages are quite similar between the Office group (36.9) and Technician group (37.1)
- Numbers of X-ray examination in the last 5 years are also similar between the Office group (1.3) and Technician group (1.2)

- In the Technician group:
  - Number of months working on-site (e.g. close to the power line or transformer): 60 - 360 months
  - Percentages of time working on-site range from 30 to 100%

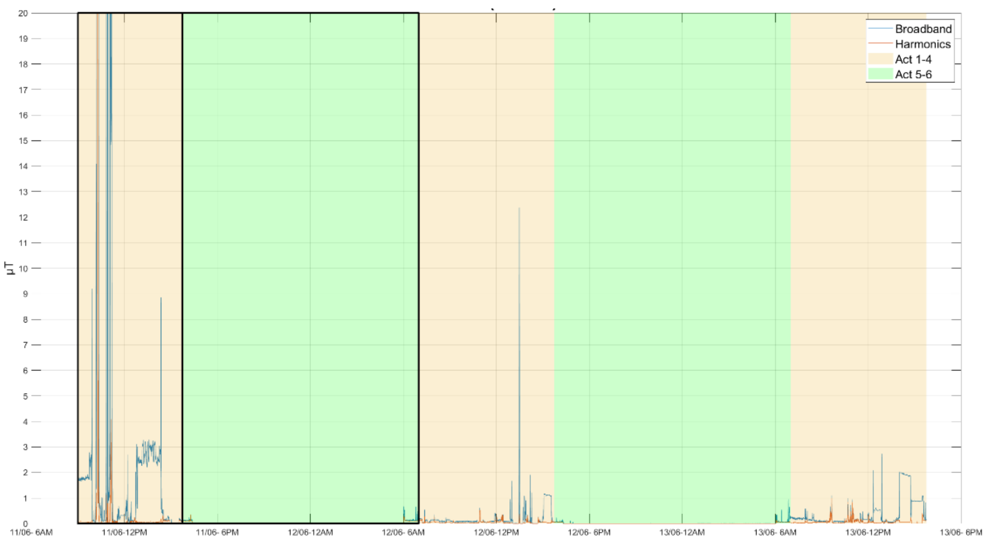
Exposure characterization

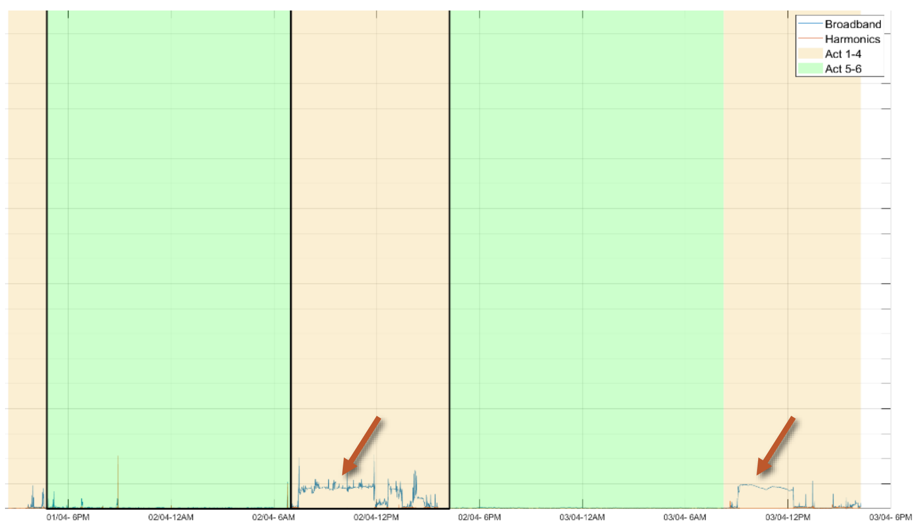
Up to 400 µT



Example of magnetic field exposure curve in a Technician over 3 days of measurement

Exposure characterization



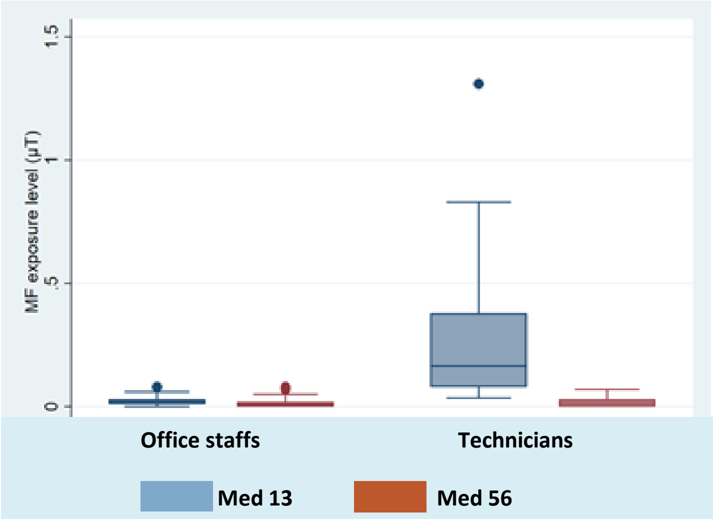


Example of magnetic field exposure curve in another Technician

- Magnetic field exposure varies between employees
- Magnetic field exposure varies between days
- High peak of magnetic field exposure level, but in a short period of time

Level of Magnetic field exposure in studied population

Summary statistic: Median occupational MF exposure (Med13)



Distribution of occupational and residential exposure levels in Office group (n= 30) and Technician group (n= 37) using Med13 and Med56

Table: Summary of occupational exposure levels (µT) in the Office and Technician groups

Workgroup	n	Mean	Median	Min	Max
Office staffs	30	0.02	0.02	0.00	0.08
Technicians	37	0.27	0.17	0.04	1.31

Exposure levels in both groups are low!

Strategies for data analysis

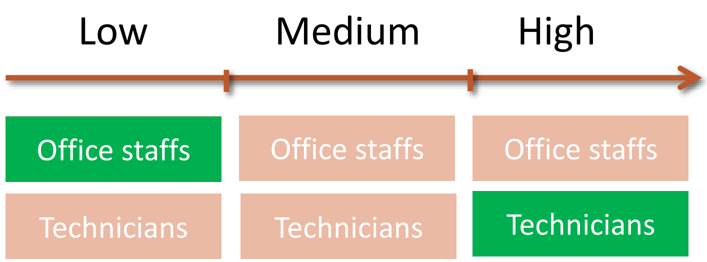
- Compare groups with different Magnetic field exposure levels
- How to define groups?
  - Based on Job titles?
  - Based on exposure data?

⇒ **Based on both parameters**

⇒ **Firstly divide the study population into 3 groups based on exposure levels (low, medium, high)**
- Based on cut-offs (0.1 and 1 µT) ;
- Percentile (p50, p75);
- ***Clustering***.

⇒ **Partition of job titles in each group**

⇒ **Choose only Office staffs at the low exposed group and Technicians in the high exposed groups for analysis**



Distribution of cytogenetic test results by employees

Comet assay

Average level of DNA damage in general public

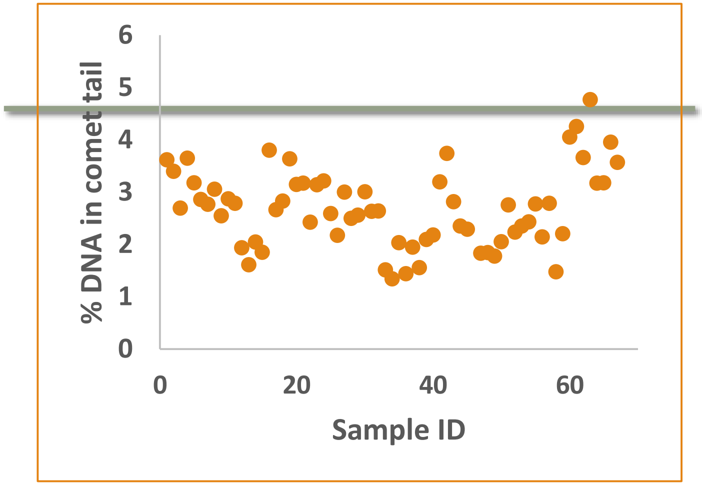


Figure 1: Percentage of damaged DNA observed in samples from 67 employees

Micronucleus test

Average frequency of MN in general public

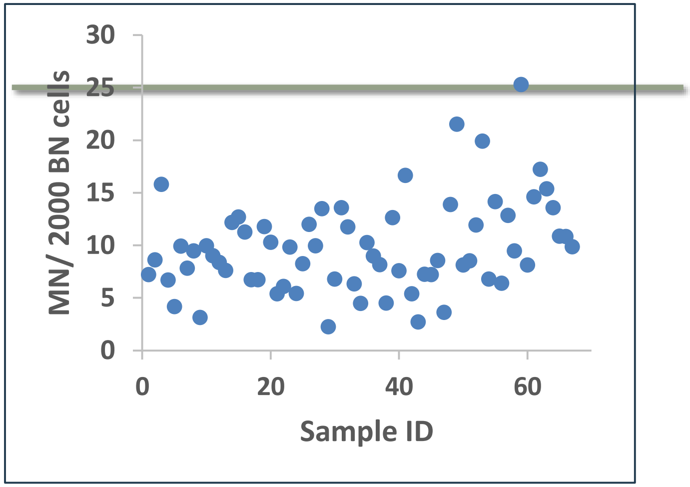
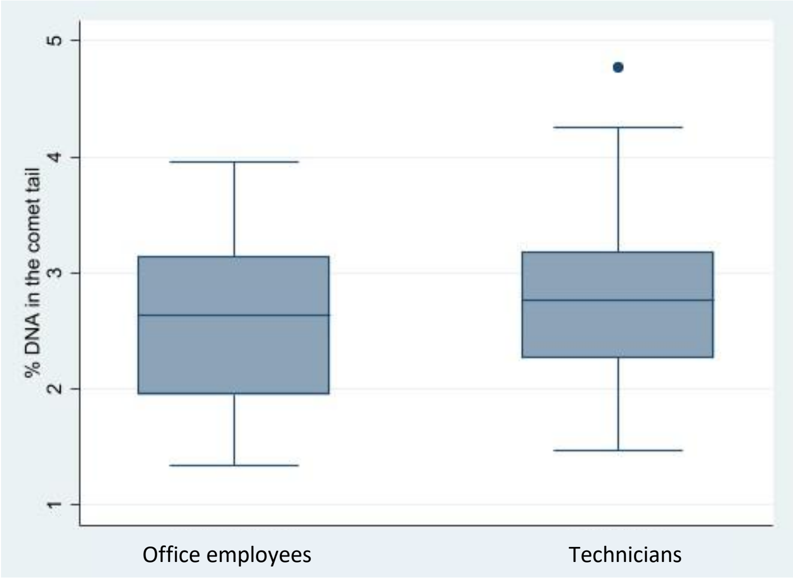


Figure 2: Frequencies of micronuclei observed in samples from 67 employees

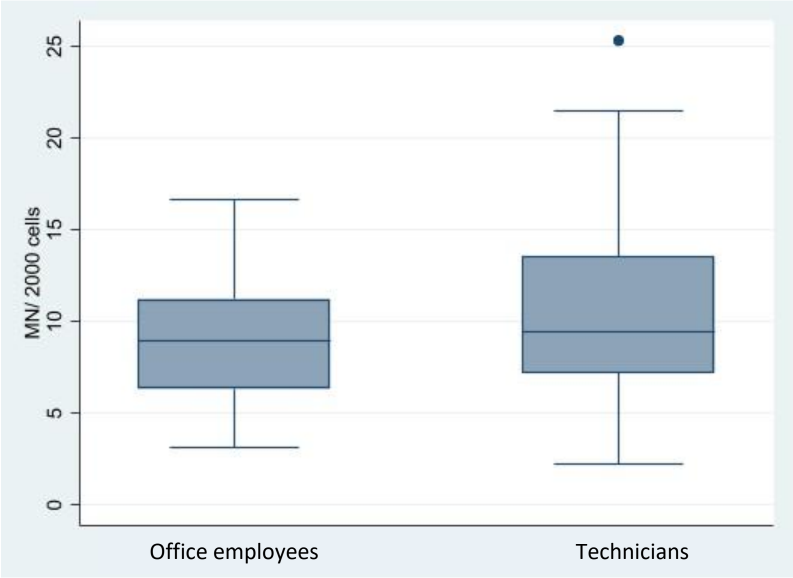
→ Cytogenetic results are all within the normal range

Comparison of cytogenetic test results in different job title groups – First hypothesis



Compare results of comet assay

Wilcoxon Rank Sum tests ($p = 0.6582$)

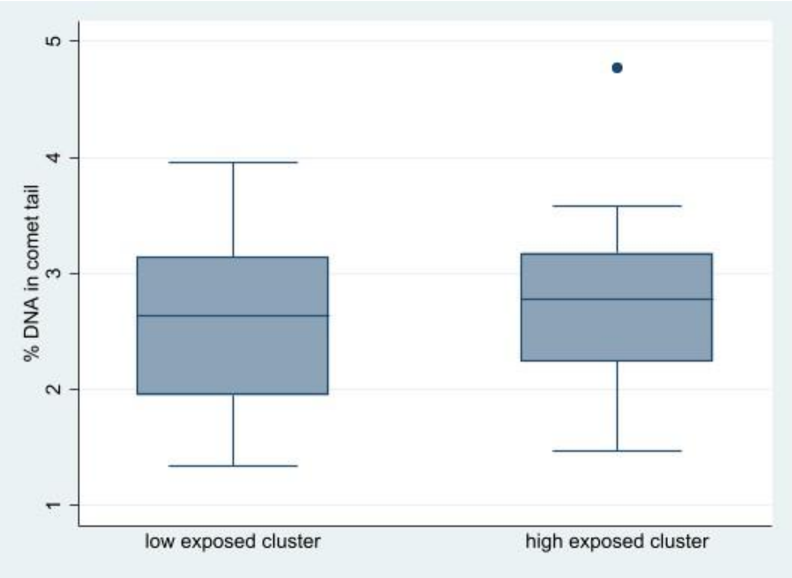


Compare results of Micronucleus test

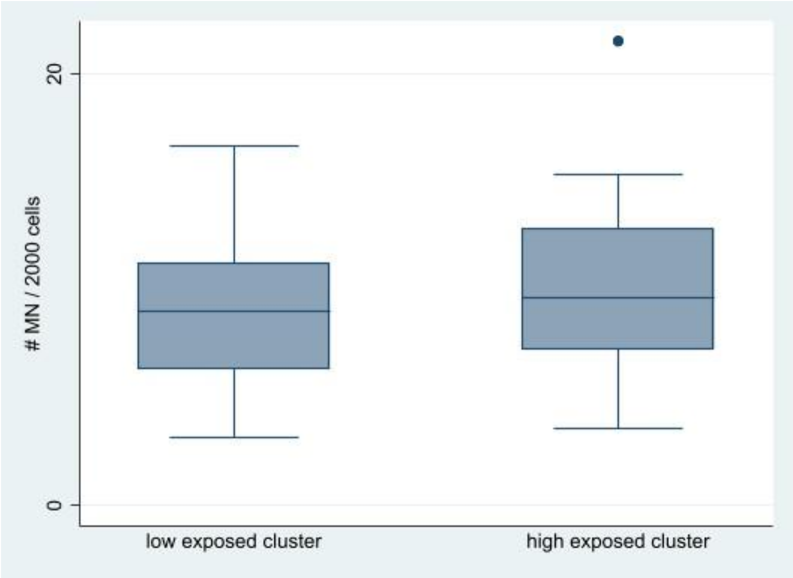
Wilcoxon Rank Sum tests ($p= 0.2384$)

=> Observe no significant difference between job groups

Comparison of cytogenetic test results in the low and high exposed clusters



Compare results of comet assay
Wilcoxon Rank Sum tests ($p = 0.9283$)

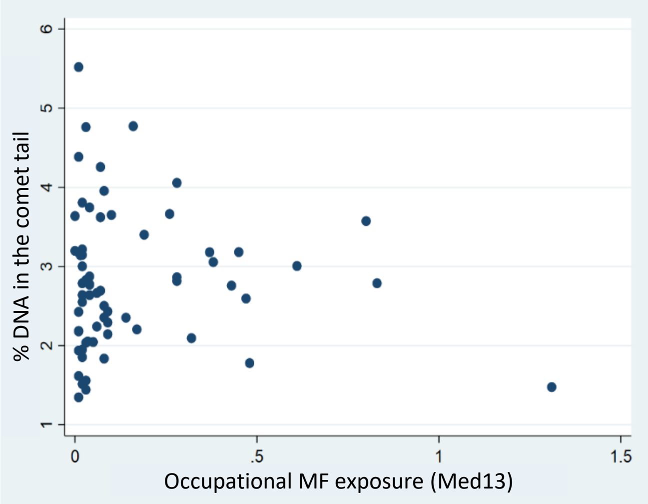


Compare results of Micronucleus test
Wilcoxon Rank Sum tests ($p = 0.5455$)

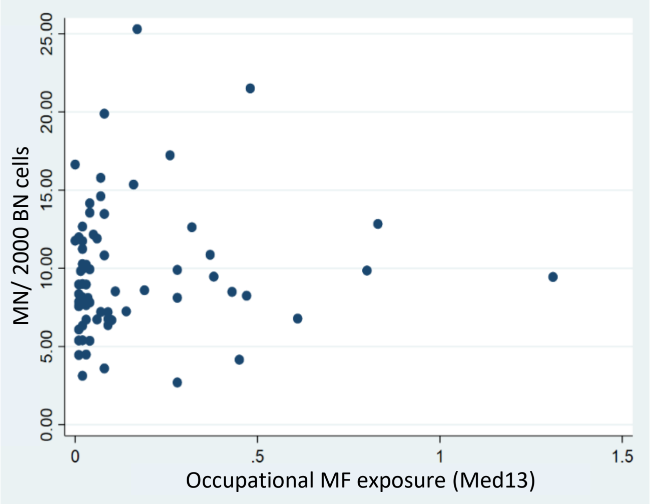
→ Observe no significant difference between low exposed cluster and high exposed cluster

Correlation between exposure and cytogenetic test results (whole population)

Correlations including the whole study population
(67 employees)



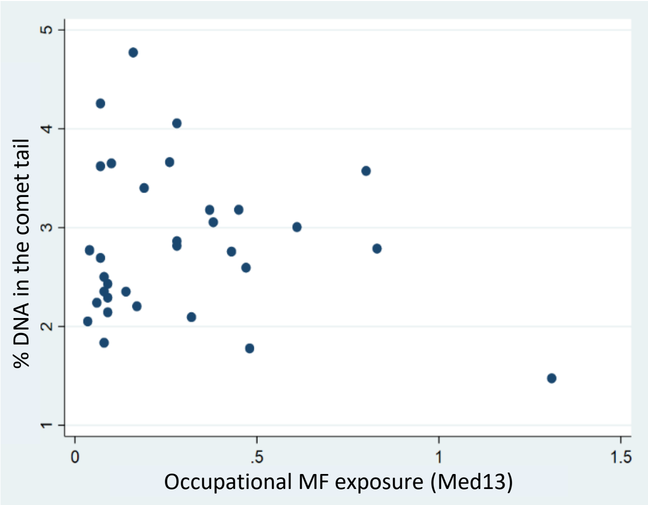
Comet assay results as function of magnetic field exposure level



Micronucleus test results as function of magnetic field exposure level

Correlation between exposure and cytogenetic test results (Technician group only)

Correlations including Technicians only
(37 employees)



Comet assay results as function of magnetic field exposure level

Micronucleus test results as function of magnetic field exposure level

Exploratory analysis: Multivariate analysis

- Multivariate analysis could combines several possible explanatory variables into analysis → Help explore the extent to which these variables associate with the test outcome.

- Explanatory variables considered:
  - Age (Adjustment)
  - Months of experience in the job (Adjustment)
  - Gender (Adjustment)
  - Number of X-Ray examinations (Adjustment)
  - Smoking habits (Adjustment)
  - Refined clusters (groups defined by both cluster analysis and job title) including Office staffs in low exposed group and Technicians in high exposed group.

Exploratory analysis: Multivariate analysis

- **Multivariate analysis for Comet assay results**
  - Age and Smoking habits have a significant association with the outcome of comet assay
  - Job titles and clusters (exposure level) does not show a significant association

- **Multivariate analysis for Micronucleus test results**
  - Gender and Age have significant association with the test outcome
  - Job titles showed borderline significant association with the test outcome (p-value at 0.056)
  - No significant association between clusters (exposure level) and MN test results was found

Conclusion

- **No link between occupational magnetic field exposure and cytogenetic damage were detected**
- Level of occupational exposure to magnetic field in our studied population was lower than reported elsewhere (10-20 times)

  Median TWA13 in the Office staffs and Technicians are 0.02 and 0.17 µT

  Mean TWA13 in the Office staffs and Technicians are 0.02 and 0.27 µT
- In exploratory multivariate analyses: **age, gender and smoking habit rather than Magnetic field exposure** might have an impact on the outcome of cytogenetic tests

Thank you for your attention!

Contact

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Study of individuals multiple exposures to environmental nuisances : Electromagnetic Fields-50Hz, Air, Noise and Endocrine Disrupting Chemicals [ExpoHealth-1]

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Main objectives

1. Assess the health perception/impact of ELF-EMF in the population
   - Case study Brussels
   - Via the individual perception of ELF-EMF exposure (visible and non-visible equipment)
   - Via the reporting of non specific symptoms related to (1) exposure, (2) knowledge of exposure and (3) modern health worries

2. Characterize multiple pollutants exposure : ELF-EMF, noise, PM and endocrine disrupting chemicals

3. Analyse and compare residential exposure in the area of interest between streets with and without direct sources of pollution (ex: houses near or far from electrical equipment, houses in streets with much or low traffic, …)

4. Evaluate the contribution of cumulative exposure to health and NSS

50Hz MF exposure : Objectives

1. Contribution of perceived vs measured exposures to the reporting of non-specific symptoms (NSS) and electro-hypersensitivity (EHS)
2. Impact of the visibility of electrical equipment (lines, underground cables, transformers, etc.) *contributing to similar environmental exposures* to the report of NSS and EHS
3. Contribution of environmental exposure of buried networks to residential exposure, by statistical sectors (feasibility study)

Steps of the study

- Protocol design
- Approval of the Ethic Committee

- Test-run
- Areas selection

- Training of the investigators team
- Recruitment of participants

Data collection

Data analysis and publication of the results

Inclusion Criteria:
- Age: 18-65 year old
- Inhabitant of the areas of interest
- Non-smoker or occasional smoker

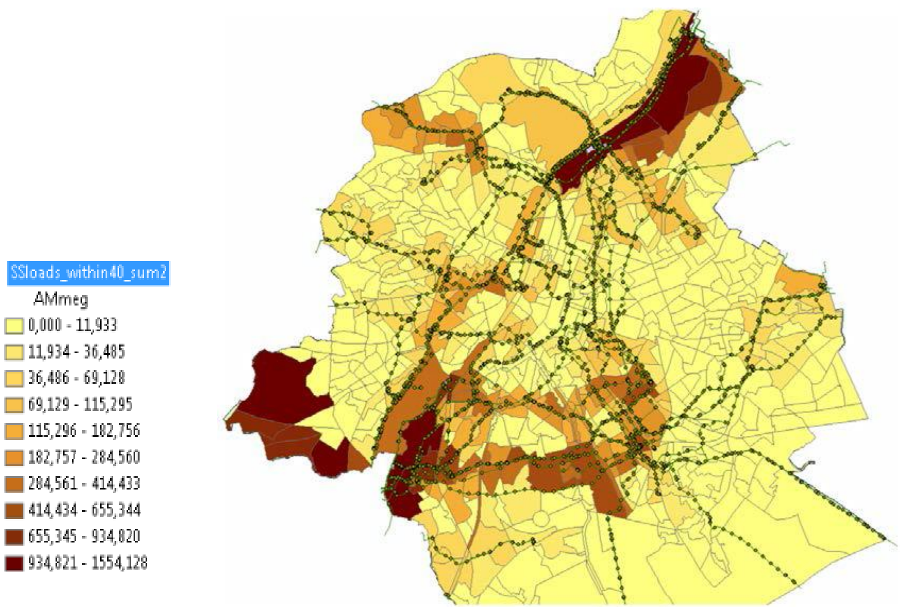
Ongoing
(10/20 to 08/22)
→ 600 participants

Participants implications

- 24 hours measurements :
  - ELF-EMF
  - Noise
  - Particulate matters
- Diary of environments (24h)
- Questionnaire
- Tap water for EDC's tests

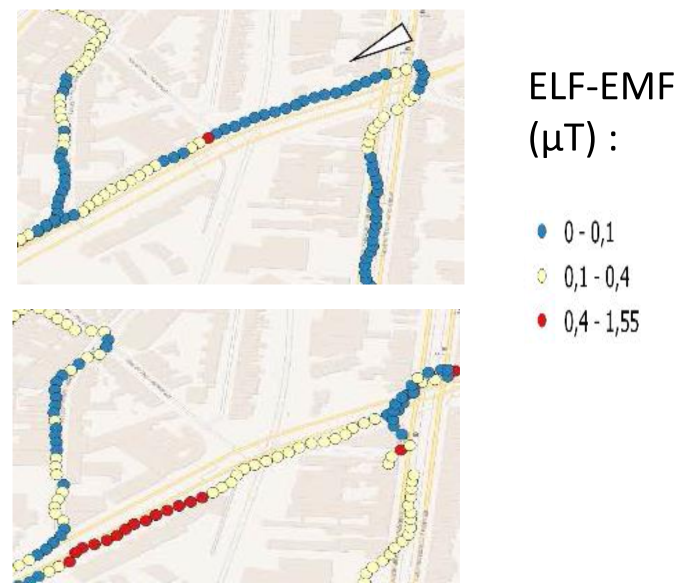
Preliminary results

Areas of interest



Sum of the load (MW) within each statistical sector (data provided by Elia)

On-street measurements

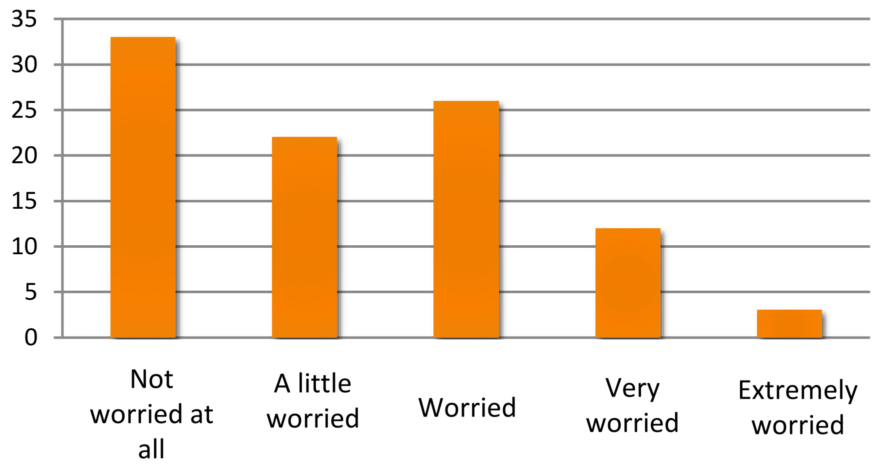


Preliminary results: Participants perception on their ELF-EMF exposure

Assess how worried you are about the impact of the following factors on health agents:

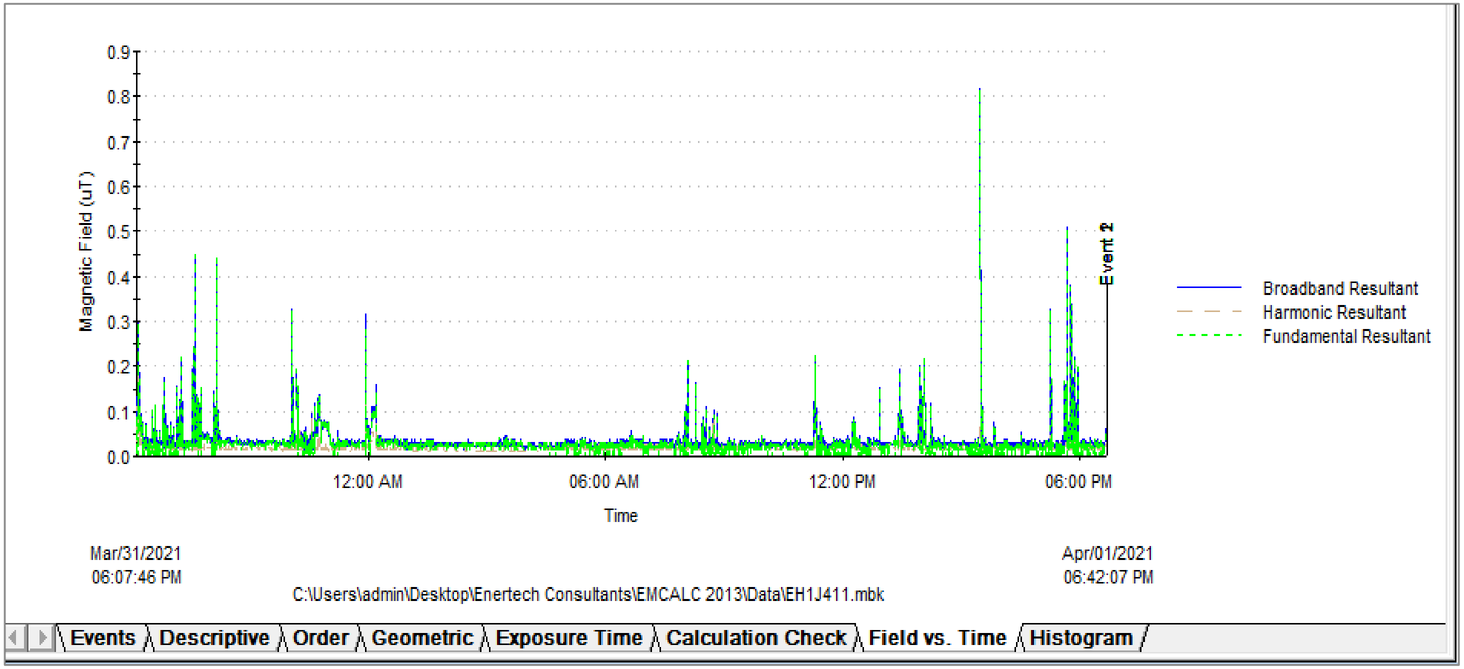
High Voltage Power Lines

Electromagnetic fields generated **by electric devices**



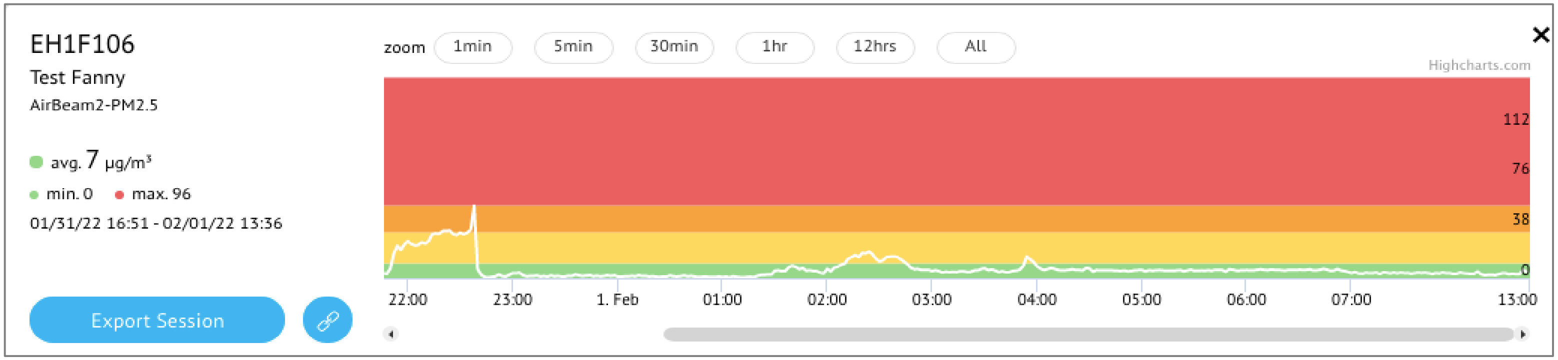
Environmental data collected : example of one participant

Electromagnetic fields -50Hz- (µT)

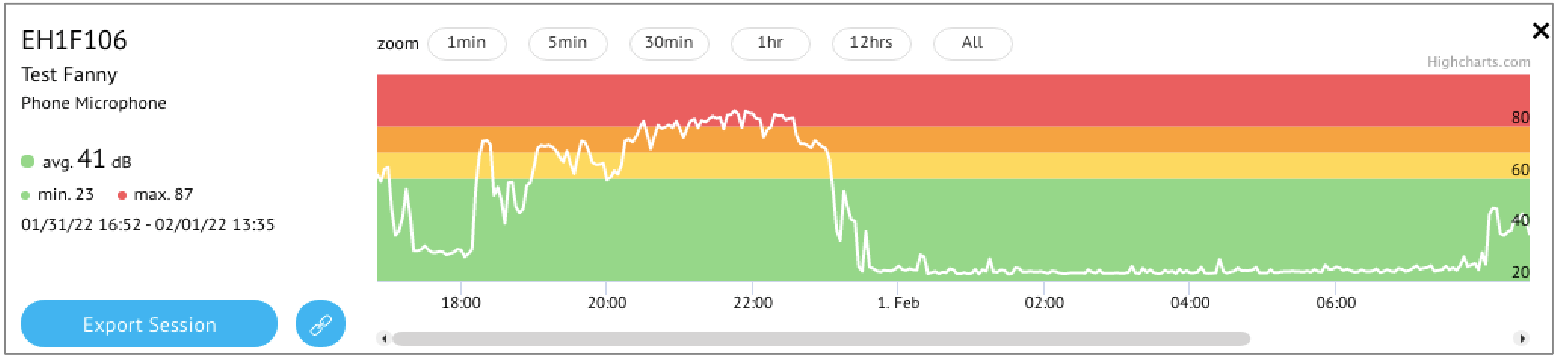


Environmental data collected : example of one participant

Particulate Matters (PM 2,5 in µm/m³)



Noise (dB)



Diary: Example for one participant

Type of environment	Time spent in each environment (min)	Brd mean (µT)	Hrm mean (µT)
1a Kitchen	165	0.04	0.015
1b Living room	1095	0.029	0.013
1d Bathroom	45	0.044	0.014
1h Basement	15	0.035	0.015
1l Library	45	0.032	0.013

Goals → Associate means of exposures by type of environment

→ For each type of exposure (Air, Noise, MF)

Exposure to magnetic fields and childhood leukemia: a systematic review and meta-analysis of case-control and cohort studies

DEPARTMENT OF PUBLIC HEALTH AND EPIDEMIOLOGY

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- In 1979, Wertheimer and Leeper have found an association between living near power lines and the occurrence of leukemia in children (American Journal of Epidemiololgy, 109, 273-84).
- They believed that the extremely low frequency (ELF) magnetic fields from the power lines were responsible.

Electromagnetic spectrum

Radio waves				Visible light		Ionizing radiation
ELF		RF				
Ex: power lines		Ex: mobile phones				Ex: X-rays, gamma rays
~ 3 - 100 Hz		~ 20 KHz – 300 GHz		~ 300 THz		~ 30 PHz – 300 EHz

Frequency (Hz)

- Extremely low frequency magnetic fields (ELF) are lower than 100 Hz and can be generated by power lines
  - After 1979, many studies have investigated the relation between these magnetic fields and childhood leukemia
  - However, there are <u>many</u> conflicting results
  - Therefore, we have performed a meta-analysis

Radio waves				Visible light		Ionizing radiation
ELF		RF				
Ex: power lines		Ex: mobile phones				Ex: X-rays, gamma rays
~ 3 - 100 Hz		~ 20 KHz – 300 GHz		~ 300 THz		~ 30 PHz – 300 EHz

Frequency (Hz) →

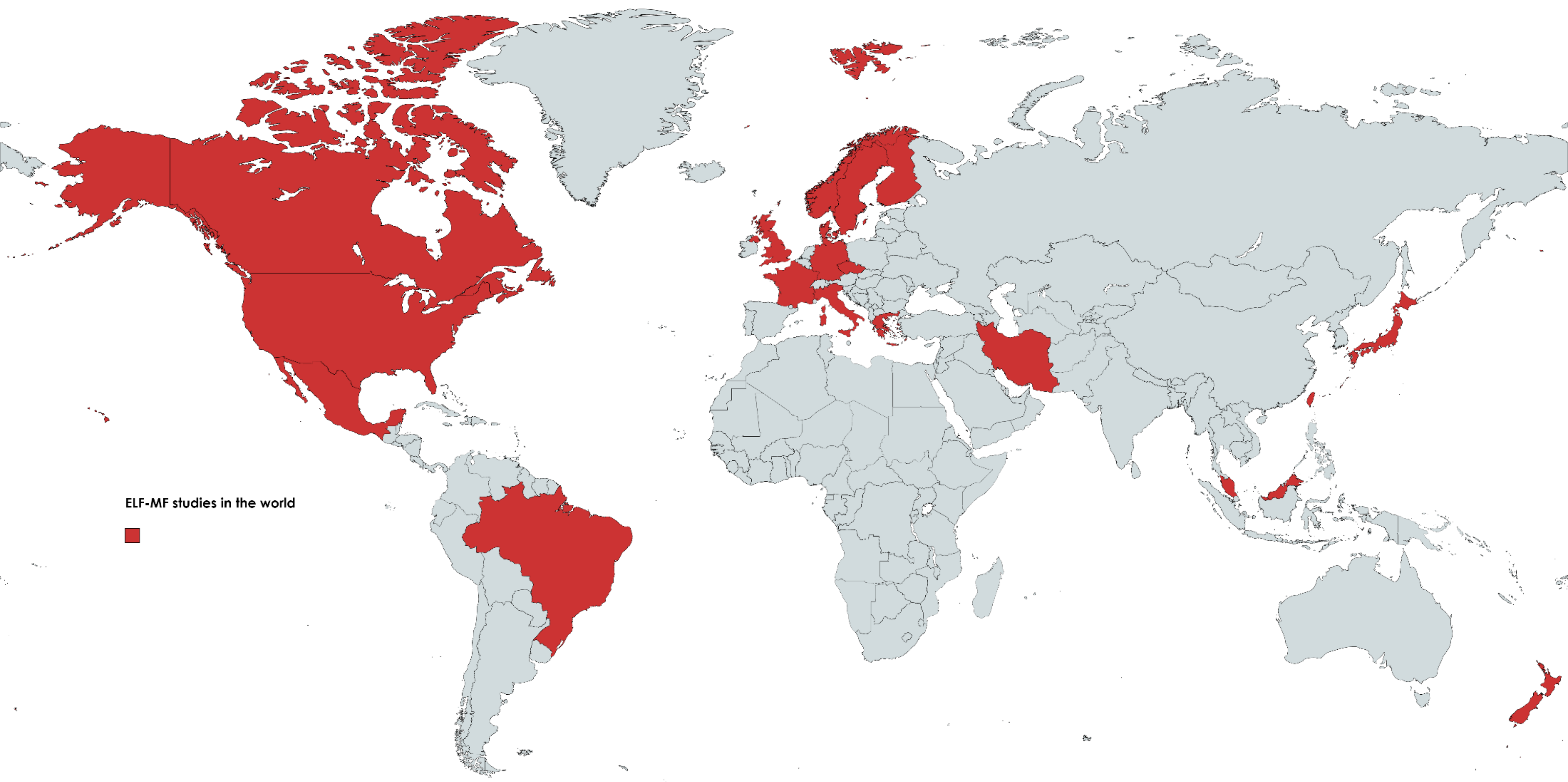
Meta-analysis = statistical analysis that combines the results of several studies

- Goal of our meta-analysis = synthesize all the studies that have examined the relation between extremely low magnetic fields and childhood leukemia
- Our meta-analysis is limited to magnetic fields lower than 100 Hz: 50 Hz in Europe, 60 Hz in North America
- All the studies in the 50-60 Hz range are included in our systematic review
- 29 articles have been included in the meta-analyses

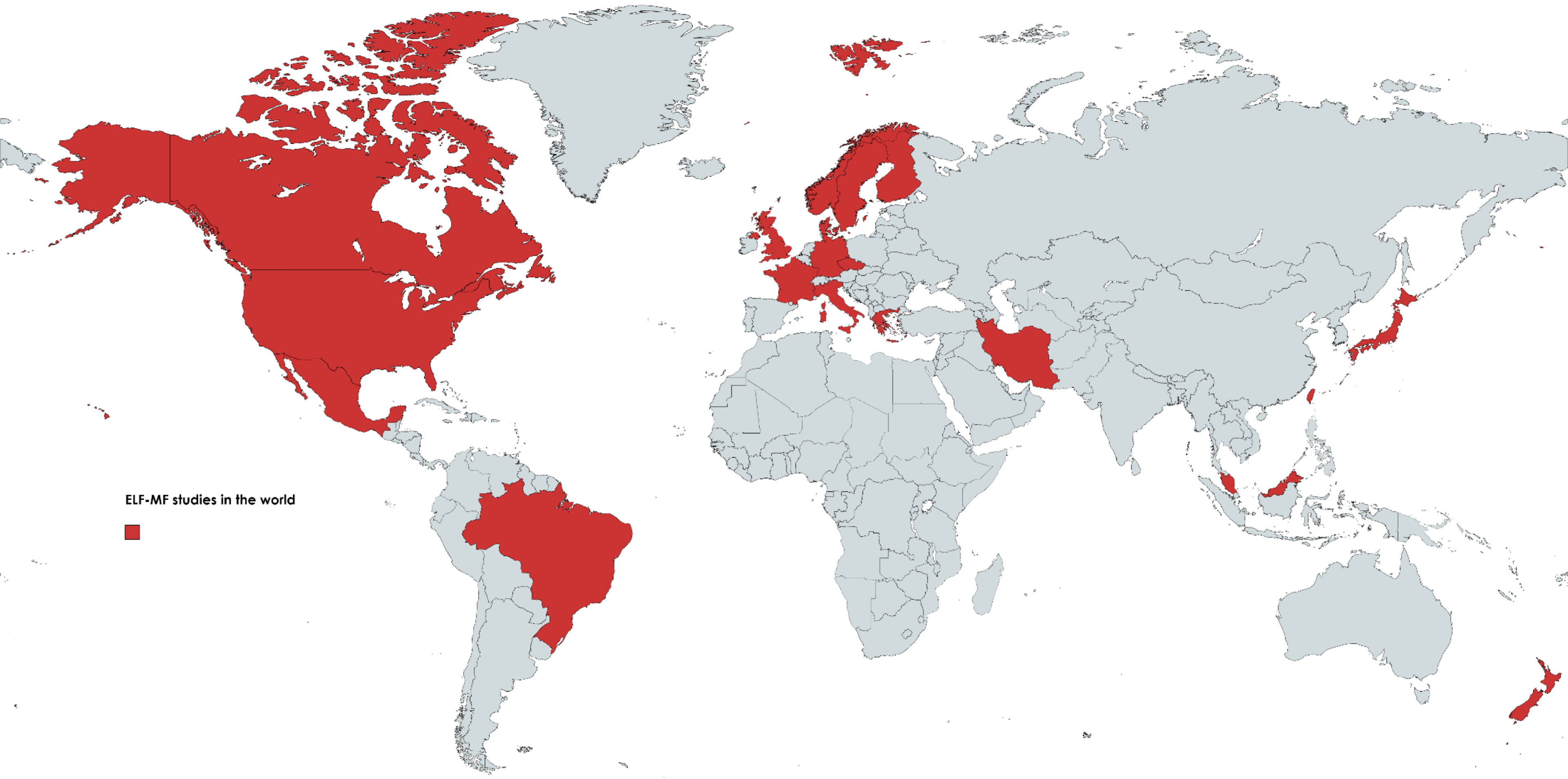
Our meta-analysis includes all the studies published between 1979 and 2020 and includes the pioneer study of Wertheimer and Leeper

Wertheimer and Leeper (1979)	American Journal of Epidemiology 109, 273-84.
Savitz et al. (1988)	American Journal of Epidemiology, 128, 21-38.
Savitz et al. (1990)	American Journal of Epidemiology, 131, 763-73.
London et al. (1991)	American Journal of Epidemiology, 134, 923-37.
Feychting and Ahlbom (1993)	American Journal of Epidemiology, 138, 467-81.
Linet et al. (1997)	New England Journal of Medicine, 337, 1-7.
Hatch et al. (1998)	Epidemiology, 9, 234-45.
Dockerty et al. (1998)	Cancer Causes & Control, 9, 299-309.
Dockerty et al. (1999)	Lancet, 354, 1967-8.
McBride et al. (1999)	American Journal of Epidemiology, 149, 831-42.
Green et al. (1999)	Cancer Causes & Control, 10, 233-43.
UK Childhood Cancer Study Inve	Lancet, 354, 1925-31.
Schüz et al (2001)	International Journal of Cancer, 91, 728-35.
Kabuto et al. (2006)	International Journal of Cancer, 119, 643-50.
Mejia-Arangure et al. (2007)	Epidemiology, 18, 158-61.
Malagoli et al. (2010)	Environmental Health: A Global Access Science Source, 9, 16.
Wunsch-Filho et al. (2011)	Cancer Epidemiology, 35, 534-9.
Does et al. (2011)	Radiation Research, 175, 390-6.
Jirik et al. (2012)	Biomedical & Environmental Sciences, 25, 597-601.
Abdul Rahman et al. (2008)	Asian Pacific Journal of Cancer Prevention: Apjcp, 9, 649-52.
Sermage-Faure et al. (2013)	British Journal of Cancer, 108, 1899-906.
Salvan et al. (2015)	International Journal of Environmental Research & Public Health, 12, 2184-204.
Pedersen et al. (2014)	Cancer Causes & Control. 25, 171-7.
Pedersen et al. (2015)	British Journal of Cancer, 113, 1370-4.
Bunch et al. (2014)	British Journal of Cancer, 110, 1402-8.
Bunch et al. (2015)	Journal of Radiological Protection, 35, 695-705.
Crespi et al (2016)	British Journal of Cancer, 115, 122-8.
Kheifets et al (2017)	Cancer Causes & Control, 28, 1117-1123.
Nunez-Enriquez et al (2020)	Bioelectromagnetics, 41, 581-597.

This figure shows in red the countries in which magnetic fields and childhood leukemia have been studied



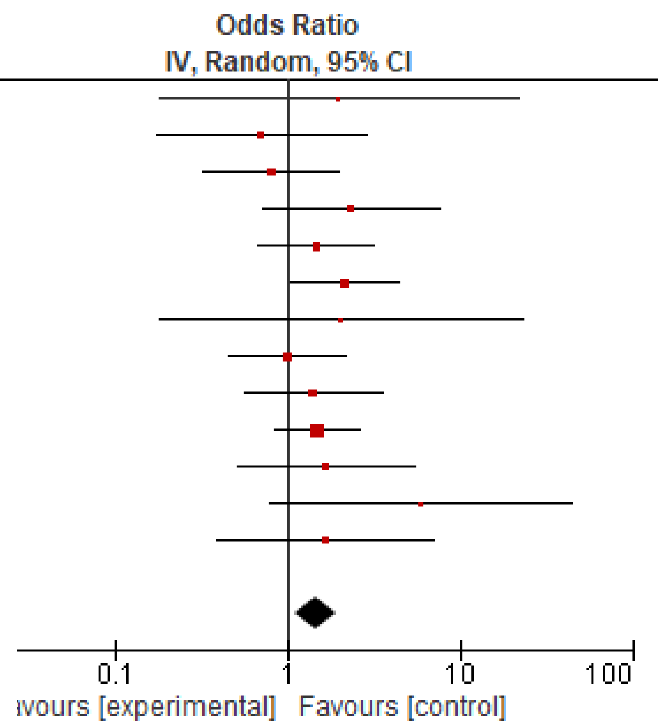
Magnetic fields and childhood leukemia have mostly been studied in Europe (UK, Germany, Italy) and in America (USA) but also in Asia (Japan) and in New Zealand



Meta-analyses based on magnetic flux densities

Exposure to magnetic fields higher than 0.4 µT is associated with an increased risk of childhood leukemia

Study or Subgroup	Leukemia cases Total	Controls Total	Weight	Odds Ratio IV, Random, 95% CI
Bunch et al (2015)	17306	20953	1.3%	2.00 [0.18, 22.06]
Green et al (1999)	53	90	3.7%	0.71 [0.18, 2.88]
Jirik et al (2012)	44	41	8.9%	0.81 [0.33, 1.99]
Kabuto et al (2006)	282	547	5.1%	2.36 [0.72, 7.79]
Kheifets et al (2017)	5750	5746	12.2%	1.48 [0.69, 3.19]
Linet et al (1997)	413	413	13.6%	2.16 [1.04, 4.48]
Malagoli et al (2010)	45	183	1.2%	2.06 [0.18, 23.19]
McBride et al (1999)	189	206	11.8%	1.01 [0.46, 2.21]
Mejia-Arangure et al (2007)	26	69	8.7%	1.42 [0.57, 3.53]
Núñez-Enríquez et al (2020)	210	280	23.1%	1.50 [0.86, 2.62]
Pedersen et al (2015)	1531	3059	5.1%	1.67 [0.51, 5.47]
Schüz et al (2001)	459	1191	1.8%	5.94 [0.80, 44.13]
UK Childhood Cancer Study (1999)	1000	980	3.5%	1.68 [0.40, 7.10]
Total (95% CI)	**27308**	**33758**	**100.0%**	**1.47 [1.12, 1.92]**



Heterogeneity: Tau² = 0.00; Chi² = 7.37, df = 12 (P = 0.83); I² = 0%
Test for overall effect: Z = 2.80 (P = 0.005)

OR = 1.47 [1.12, 1.92]; P = 0.005; 13 studies

Magnetic field categories lower than 0.4 µT were not associated with childhood leukemia

Magnetic field category	Number of studies	OR (95% CI)	Overall effect
0.1 – 0.2 µT	14	1.05 [0.88, 1.24]	P = 0.61
0.2 – 0.3 µT	6	0.93 [0.69, 1.24]	P = 0.62
0.3 – 0.4 µT	4	1.10 [0.72, 1.66]	P = 0.67

⇒ Our meta-analyses suggest that magnetic fields lower than 0.4 µT do not increase the risk of leukemia in children

Conclusions

- Our meta-analyses indicate that only magnetic fields higher than 0.4 μT could increase the risk of leukemia in children (OR = 1.47; 95% CI 1.12 – 1.92)
- Magnetic fields higher than 0.4 μT are usually found within 50 m of power lines and rarely within 200 m of power lines

Conclusions

- In 2002, the International Agency for Research on Cancer classified residential magnetic fields as possibly carcinogenic to humans (Group 2B) (IARC, 2002)
- Our results support the carcinogenic potential of residential magnetic fields higher than 0.4 μT
- Our results are in agreement with the Belgian Superior Health Council that recommends to limit residential magnetic field exposure to 0.4 μT (Conseil supérieur de la santé, mai 2020)

Thank you for your attention

Application of the Precautionary Principle in the field of ElectroMagnetic Fields

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Overview

1. Dealing with scientific uncertainty and risk
2. The Precautionary Principle: Fit for the job?
3. Application of the Precautionary Principle to Extreme Low Frequency Electromagnetic Fields: benefits, shortcomings, and concerns
4. Conclusion

1. Dealing with scientific uncertainty and risk

- **Scientific uncertainty**: inherent "part of the game"

Epistemological uncertainty: hypotheses can be confirmed as likely to be true, given the evidence, but never as true with absolute certainty

- **Dealing with risk**: no measures / avoidance / minimization / mitigation / various combinations

1. Dealing with scientific uncertainty and risk

- **Things we want to avoid when allowing** a new technology/activity/agent:
  - harming public health/society/environment
  - here & now, as well as globally & in future generations
  - e.g. “too little too late”: asbestos, PCBs,.
- **The things we want to avoid when restricting** a new technology/ activity/agent :
  - foregoing societal and economical benefits and opportunities
  - stifle scientific progress

2. The Precautionary Principle

2.1 Definition of the Precautionary Principle (PP)

- Common sense idea of “better safe than sorry”
- Developed as an alternative in dealing with risk to evidence-based approaches, such as risk assessment
- Many different interpretations (weak to very strong)
- Key insight: we may need to take action to deal with possible harms even when scientific evidence concerning those harms is lacking or inconclusive (Resnik, 2021)

2. The Precautionary Principle

2.2. Critical elements

- **proactive strategy**: the willingness to take action before the proof of harm is established, instead of reactive strategy (WHO, 2004)
- **proportionality**: precautionary measures balance plausible risks and benefits proportionally (European Commission, 2000)
- **shift in burden of proof** to the proponents of the possibly harmful activity (European Commission, 2000 & 2017)
- Investigation of a broad range of **alternatives** to the possible harmful activity
- Increasing **public participation** in decision-making

2. The Precautionary Principle

2.3 Application

- In case of "scientific uncertainty"
- Predominantly used in Europe
- e.g. Extreme Low Frequency Electromagnetic Fields (ELF-EMF): safety factors beyond ICNIRP guidelines

3. Application to Extreme Low Frequency Electromagnetic Fields

Benefits

- Broad scope: the PP considers more than the scientific evidence
- Consideration & involvement of more stakeholders
- Promotes a multidisciplinary approach

-> BBEMG: multidisciplinary team – cytogenetic monitoring, meta-analysis, epidemiology, EHS, ..

3. Application to Extreme Low Frequency Electromagnetic Fields

Shortcomings and critiques (1)

- Practical application is vague, e.g. proportionality: risk and benefits are not quantified
- Under critique for being opposed to scientific, technological and economical progress: in too many cases the PP is used to legitimize a bias against change (Conko, 2003)

3. Application to Extreme Low Frequency Electromagnetic Fields

Shortcomings and critiques (2)

- Can be used as an excuse for the blocking of free trade between countries/continents: hidden protectionism
- Cost of false positives (Type I error)
- Feeds fear: there's no smoke without a fire

3. Application to Extreme Low Frequency Electromagnetic Fields

Concerns (1)

? Can ELF-EMF still be considered as a new technology: when is there enough evidence to make the transition from ’dealing with risk under uncertainty’ to ‘dealing with known risk’

? When/how is the PP adjusted in case of new evidence: lack of clear criteria/guidelines/procedures for revising precautionary action

3. Application to Extreme Low Frequency Electromagnetic Fields

Concerns (2)

? Influence on the distribution of financial resources for different types of scientific research when using PP: when to stop focussing on certain amounts of uncertainty/risk

e.g. other possible/supposed risks of ELF-EMF than childhood leukaemia are still being investigated at great financial cost

3. Application to Extreme Low Frequency Electromagnetic Fields

Concerns (3)

? PP as a democratic process

- what about the influence of lobbying groups, the industry, ..
- public participation: influence of ideological groups, fake news,..
- public participation: need for scientific literacy? To what extent?
- inequity: the most affected populations are often less represented/involved in decision-making processes

3. Application to Extreme Low Frequency Electromagnetic Fields

Concerns (4)

? Dealing with expert disagreement in defining uncertainty and providing evidence

- Jordan & O'Riordan (2004): "*Even if scientific advice is supported by a minority fraction of the scientific community, due account should be taken of their views, provided the credibility and reputation of this fraction are recognized*"
- applies to ELF-EMF: ongoing debate among scientists
- BBEMG contribution: Expo-Health Project

3. Application to Extreme Low Frequency Electromagnetic Fields

Concerns (5)

- however: what to think of scientists who make profit of this “minority opinion”?

Are they “credible” and should their views be able to justify precautionary action?

e.g. offering (expensive) therapy for electrohypersensitivity based on their own research on ELF-EMF

4. Conclusion

- PP has a definite value in guiding decision-making when introducing a new technology, but this should not equal avoiding or stifling progress and change
- The level of conclusiveness of evidence needs to be specified on a case-to-case basis

ELF-EMF: when do we consider the effects/risks as established?

4. Conclusion

- Risk management should by seen as a dynamic process, allowing re-evaluation and application of PP or alternative approaches in different phases and different contexts
- The legimitization and advantage of involving the public in the PP approach can only be warranted when more attention goes to the scientific literacy of lay-people

  e.g. knowledge on the limits of science, handling sources of information, meaning of statistical claims,..

  ELF- EMF: responsibility of both science and governments to guide this proces through education and societal outreach

  BBEMG: website to inform the public

5. Contact

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Panel discussion

Analysis of the effects of long-term exposure to 50 Hz magnetic field (MF) on a TK6 cell line

H. NGUYEN, S. SEGERS, M. LEDENT, R. ANTHONISSEN, JF. COLLARD, M. HINSENKAMP, L. VERSCHAEVE, V. FEIPEL, E. DE CLERCQ, B. MERTENS

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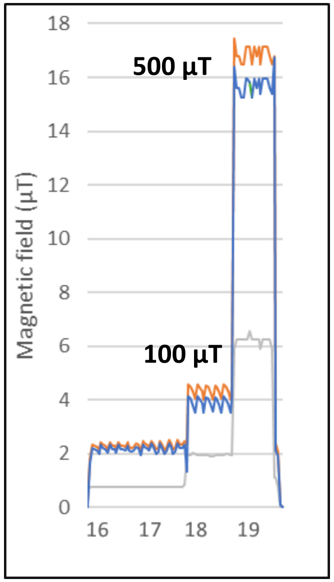
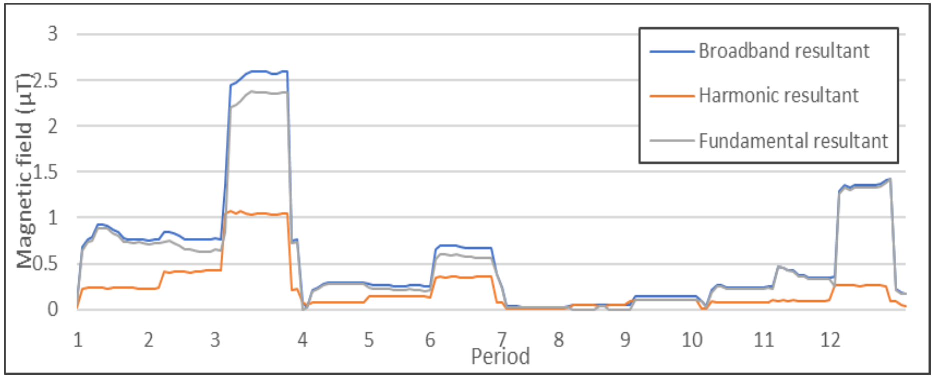
Validation of shielding system (mu-metal cylinder)





MF levels in control cells before and after using the mu-metal cylinder

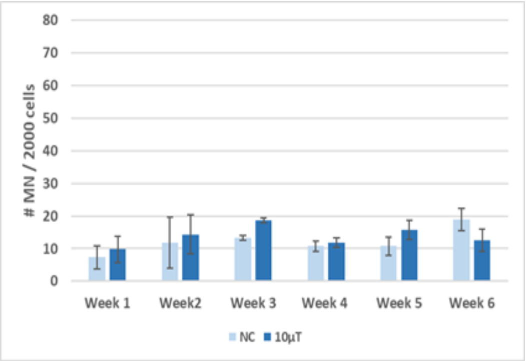
- Period 1-3: EMDEX at the bottom of cylinder, MF: 0, 100, 500 µT
- Period 5-7: EMDEX at the middle of cylinder, MF: 0, 100, 500 µT
- Period 10-12: EMDEX at the top of cylinder, MF: 0, 100, 500 µT
- Period 17-19: EMDEX at the right side of incubator, MF: 10, 100, 500 µT

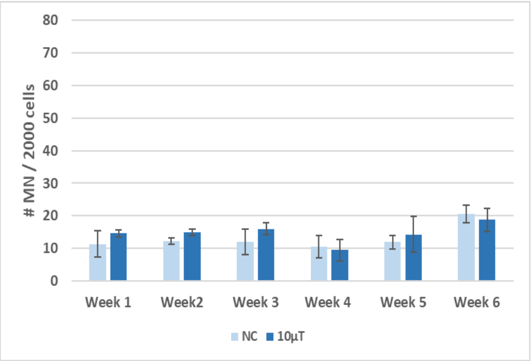
Examples of incoherent results

Repeat 1

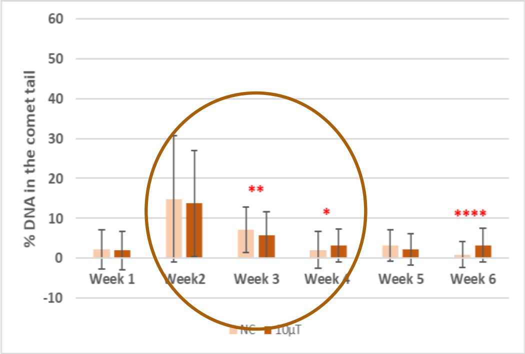
Repeat 2

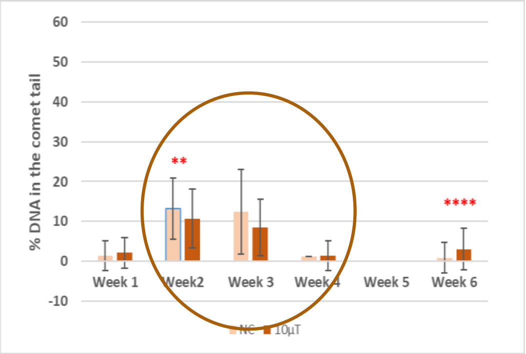
MN test results





Comet assay results





Analysis of cytogenetic damage in blood samples of electrical employees

H. NGUYEN, M. LEDENT, G. VANDEWALLE, J. VAN DE MAELE, JF. COLLARD, M. HINSENKAMP, L. VERSCHAEVE, V. FEIPEL, E. DE CLERCQ

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Group based on Cluster analysis approach

- Hierarchical agglomerative clustering
- Euclidian distance
- Ward's method of aggregation

Cluster analysis approach

Clusters	Exposure metrics	Average	SD
1	W13-mean	0,09	0,08
	W13-median	0,05	0,05
	W13-GeoM	0,04	0,04
	W13-SD	0,16	0,15
	W13-GeoSD	3,05	1,08
	W13-max	2,99	4,10
	W13-P75	0,09	0,11
	W13-p1	1,03	2,15
2	W13-mean	0,51	0,19
	W13-median	0,16	0,13
	W13-GeoM	0,14	0,09
	W13-SD	1,25	0,97
	W13-GeoSD	5,53	2,33
	W13-max	16,49	11,60
	W13-P75	0,39	0,23
	W13-p1	10,70	5,46
3	W13-mean	1,39	0,51
	W13-median	0,46	0,34
	W13-GeoM	0,45	0,33
	W13-SD	3,80	5,15
	W13-GeoSD	6,57	5,23
	W13-max	69,79	105,16
	W13-P75	1,39	0,55
	W13-p1	31,78	15,89

Different approaches to define exposure groups

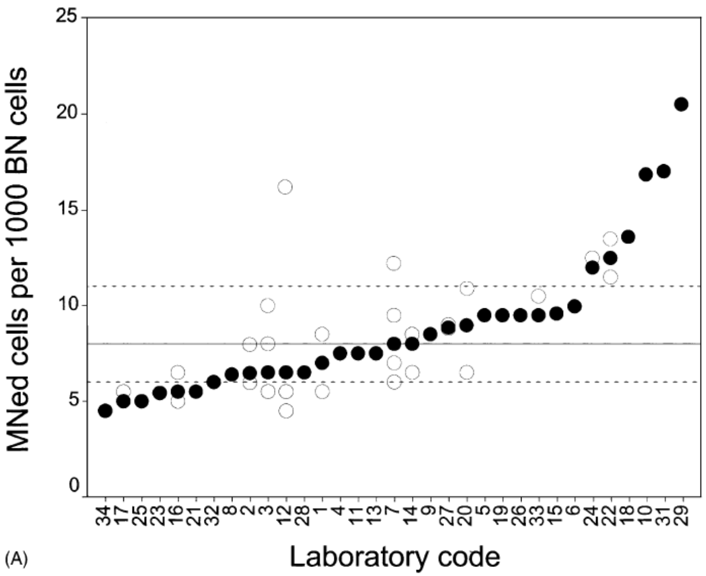
- Groups based on cut-off values in literature

Groups	n	Job title
Low exposed group < 0.1 μT	46	33 office workers 13 technicians
Medium exposed group >= 0.1 μT and 1 μT	20	20 technicians
High-exposed group >=1 μT	1	1 technicians

- Groups based on percentiles

Groups	n	Job title
Low exposed group (< P50)	34	31 office workers 3 technicians
Medium exposed group (≥ P50 and < P75)	17	2 office workerss 15 technician
High exposed group (≥ P75)	16	16 technicians

Distribution of cytogenetic test results in general public (people who do not exposed to any kind of physical or chemical damaging agents)



The HUMN Project (Fenech et al., 2003)
international collaborative project; compilation and comparison of base-line micronucleus (MN) frequencies in human lymphocytes
Data from **34 laboratories from 21 countries**

Micronucleus test

1b) Tail Intensity (%)

Laboratory	N	Mean (SD)	Median	25°-75° Percentile
AS4	77	4.5 (1.4)	4.2	3.6–5.0
EU12	42	0.01 (0.01)	0.02	0.01–0.02
EU15	101	24.0 (9.1)	23.6	18.8–31.1
EU17	115	7.4 (4.6)	5.4	4.6–9.1
EU18	57	6.7 (2.1)	6.0	5.5–7.0
EU22	752	8.1 (7.3)	7.2	1.1–14.6
⋮				
EU50	37	6.4 (1.5)	6.2	5.8–7.1
EU6	325	1.1 (1.0)	.9	0.3–1.6
OCNA1	202	9.5 (5.6)	7.7	6.2–11.0
TOTAL	8,293	**7.4 (8.8)**	**4.5**	**1.6–9.9**

The hCOMET project (Milić et al., 2021)
International database comparison of results with the comet assay in human biomonitoring.
Data from a total number of **8293 subjects** and measured by **28 laboratories**

Comet assay