French children exposure to 50 Hz magnetic field

Isabelle Magne¹, Martine Souques², Jacques Lambrozo², Mfoihaya Bedja³, Gilles Fleury³, Laurent Le Brusquet³, Alexandre Carlsberg⁴, François Deschamps⁵, Gilbert Belardi⁶

¹ EDF R &D, Moret sur Loing, France
² EDF Service des Etudes Médicales, Levallois-Perret, France
³ Supelec, Gif-sur-Yvette, France
⁴ MV2, Montrouge, France
⁵ RTE, Paris La Défense, France
⁶ ERDF, Paris La Défense, France
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- Recruitment of volunteers and data collection
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Introduction and aim

1979: Wertheimer study

2001: classification II B of ELF magnetic field by IARC (possibly carcinogenic to human)

2007: collective assessment by international expert groups WHO
- Statistic association observed between childhood leukemia and magnetic field exposure higher than 0.4µT in mean over 24h
- No causal relationship demonstrated

Aim of the study: what is the exposure of the French population?
- 2007: EXPERS study initiated by the Health Ministry
Recruitment of volunteers

- Recruit 1000 adults and 1000 children representatives of the French population

- MV2 Conseil in charge of data collection
  - Method of random lottery
  - Start file 95 362 phone numbers (no professional)
  - Recruitment by phone, then pollster on site
  - Criteria of distribution according to the distribution of the French population by region
Collection of data

- Measurements during 24h with an EMDEX II worn by the volunteer
  - 1 measurement every 3 s
  - Measurement of broadband (40-800 Hz) and harmonics (100-800 Hz)
  - Measurement range: 0.01 to 300µT
  - Not disturbed by GSM

- Timetable filled in by the volunteer
  - Activities
  - Locations
  - Hours

- Questionnaire filled in at the end with the pollster
  - Information on the volunteer (age, profession, etc..)
  - Information on the home (year built, heating, etc...)

- Measurement of GPS coordinates at the home front door
  - Search afterwards of proximity of electric networks
Electric networks close to home

Definition of distance “close to home”

<table>
<thead>
<tr>
<th>Type of network</th>
<th>Distance (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overhead line 400 kV</td>
<td>200</td>
</tr>
<tr>
<td>Overhead line 225 kV</td>
<td>120</td>
</tr>
<tr>
<td>Overhead line 150 kV</td>
<td>100</td>
</tr>
<tr>
<td>Overhead line 63 and 90 kV</td>
<td>70</td>
</tr>
<tr>
<td>Overhead line LV and 20 kV</td>
<td>20</td>
</tr>
<tr>
<td>Train network</td>
<td>200</td>
</tr>
<tr>
<td>Underground cable 225 kV</td>
<td>20</td>
</tr>
<tr>
<td>Underground cable 63 to 150 kV</td>
<td>20</td>
</tr>
<tr>
<td>Underground cable LV and 20 kV</td>
<td>20</td>
</tr>
<tr>
<td>MV/LV substation</td>
<td>20</td>
</tr>
</tbody>
</table>
Description of the database (1/2)

Summary of the phone numbers called
- 95 362 numbers called:
  - 47% answered
  - 3047 agreements on principle (3%)
  - 2148 measurements performed (2.25%)

Mean time to recruit 1 volunteer = 70 min

Pertinence of data
- 2148 measurements performed
- 2048 measurements validated par MV2 Conseil
- 1525 addresses (523 paired adult/child)
Description of the database (2/2)

Distribution by age

Distribution by gender

<table>
<thead>
<tr>
<th>% M/F</th>
<th>French population</th>
<th>database</th>
</tr>
</thead>
<tbody>
<tr>
<td>children</td>
<td>51/49</td>
<td>49/51</td>
</tr>
</tbody>
</table>
Analysis of the database

- 2048 measurements validated par MV2 Conseil
- Keying in of timetable and questionnaires
  - 19 series deleted for different reasons
  - 2029 measurements analysed
    - 977 measurements recorded by children (0-14 years).
    - 1,052 measurements recorded by adults (15 years and over)
- Example of refined temporal cutting

1 - home
2 – work on PC
3 – train
4 – meeting room
5 – bus
6 – home
7 – housework
8 - shopping
Mean exposures over 24 h – arithmetic mean (AM)

$B_{\text{mean}} = 0.09 \mu T$

- 30 children with AM > 0.4 $\mu T$ (3.1%)

<table>
<thead>
<tr>
<th>Proportion (%)</th>
<th>25</th>
<th>50</th>
<th>75</th>
<th>99</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quartile in $\mu T$</td>
<td>0.01</td>
<td>0.03</td>
<td>0.06</td>
<td>1.22</td>
</tr>
</tbody>
</table>
Mean exposures over 24 h – geometric mean

\[ B_{\text{mean}} = 0.02\mu T \]

<table>
<thead>
<tr>
<th>Proportion (%)</th>
<th>25</th>
<th>50</th>
<th>75</th>
<th>99</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quartile in ( \mu T )</td>
<td>0.00</td>
<td>0.01</td>
<td>0.02</td>
<td>0.20</td>
</tr>
</tbody>
</table>

2 children with GM > 0.4\( \mu T \)
Exposures of type “clock-radio”

- Proportion of children with AM > 0.4µT higher than in literature
- Search for explanations for these high exposures
  - Signal high during the night
  - 1/3 of harmonics
  - Correspond to the field measured close to a clock-radio
- Additional investigations
  - High variation of B from a clock-radio to another
  - Source = transformer
  - B decreases very quickly with the distance (negligible at 50 cm)
- Are these measurements representative of the personal exposure?
  - Respect a distance of 50 cm between the EMDEX and any electric appliances during the night
  - Question asked in the questionnaire in order to check
  - The measurements over 24h overestimate the exposure
- Distinguish the exposure over 24h and the exposure outside sleep period
Mean exposures outside sleep period

\[ \text{AM} = 0.05 \, \mu \text{T} \]
- 11 children with \( \text{AM} \) > 0.4 \( \mu \text{T} \) (1.1%)

\[ \text{GM} = 0.02 \, \mu \text{T} \]
The sources of high mean exposures

Example of children, AM over 24h
- 24 cases of EMDEX put very close to clock-radios during the night
- 2 cases of EMDEX put close to electric appliance with a transformer during the day
- 1 case of EMDEX put close to unknown electric appliance at home during the night and the day
- 1 case of EMDEX put close to electric appliance with a transformer at school
- 1 case on AC electrified train network close to the home and the school
- 1 case of overhead low voltage line close to the home

Example of children, AM outside period of sleep
- 5 cases of EMDEX put close to electric appliance with a transformer during the day
- 1 case of EMDEX put close to unknown electric appliance at home the day
- 1 case of EMDEX put close to electric appliance with a transformer at school
- 1 case on AC electrified train network close to the home and the school
- 1 case of overhead low voltage line close to the home
- 1 case of electric network close to the school (to be confirmed)
- 1 case of EMDEX put close to electric cable on the floor of a car
Comparison of exposures (1/2)

- **Children / adults**
  - Children are less exposed than adults (over 24h and outside sleep period)

- **Home / outside**
  - Children are more exposed at home than outside (over 24h and outside sleep period)

- **Day / night**
  - At home, children are more exposed during the day than during the night

- **Region**
  - Children living in Ile-de-France are more exposed than in the other regions (over 24h and outside sleep period)
Comparison of exposures (2/2)

Results electric networks

- Mean exposures (at home and over 24h) are higher for children living close to electric networks than for those living far away from these networks.

- Mean exposures (at home and over 24h) are not different for children living close to high voltage networks and for those living close to 50 Hz train networks.

- Calculation to be done for distribution network (low voltage and 20 kV).
## Characterisation of exposure

### Example of children (distribution network and type of train alimentation not taken into account yet)

<table>
<thead>
<tr>
<th>Name of the variable</th>
<th>Children over 24h</th>
<th>Children outside period of sleep</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>AM</td>
<td>GM</td>
</tr>
<tr>
<td>Density of population of the department</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>To have put the EMDEX close to a clock-radio</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Home close to high voltage overhead power lines</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Home close to electric train networks</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Population of the city (&gt; 2 000 inhabitants)</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Age</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>To live in a building</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Heating energy = electric</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Time spent on computer</td>
<td></td>
<td>+</td>
</tr>
<tr>
<td>Time spent in shopping centre</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time spent in train transports</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Time spent watching TV</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time spent in non electric transports</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Time spent at school</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td><strong>Level of explained variance</strong></td>
<td><strong>17,2%</strong></td>
<td><strong>27,2%</strong></td>
</tr>
</tbody>
</table>
Repartition to children around electric networks

Number of children living “close to electric networks”

<table>
<thead>
<tr>
<th>Type of network</th>
<th>Number of children</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overhead line 400 kV</td>
<td>4</td>
</tr>
<tr>
<td>Overhead line 225 kV</td>
<td>7</td>
</tr>
<tr>
<td>Overhead line 63 to 150 kV</td>
<td>11</td>
</tr>
<tr>
<td>Overhead line 20 kV</td>
<td>24</td>
</tr>
<tr>
<td>Overhead line LV</td>
<td>371</td>
</tr>
<tr>
<td>50 Hz train network</td>
<td>41</td>
</tr>
<tr>
<td>Underground cable 225 kV</td>
<td>11</td>
</tr>
<tr>
<td>Underground cable 63 to 150 kV</td>
<td>10</td>
</tr>
<tr>
<td>Underground cable 20 kV</td>
<td>331</td>
</tr>
<tr>
<td>Underground cable LV</td>
<td>524</td>
</tr>
<tr>
<td>MV/LV substation</td>
<td>45</td>
</tr>
<tr>
<td>MV/LV substation in building</td>
<td>13</td>
</tr>
</tbody>
</table>

Total of children = 977
How much is the distance indicator conservative?

- Arbitral classification of subjects within the corridors as “exposed” to magnetic fields generated by electric networks
- But the width of the corridors is overestimated

- Do the magnetic field measurements of the “exposed” subjects show the influence of electric networks or not?
- 24h variation of magnetic field generated by electric networks is quite characteristic

- Visual check
Example of a child – source = power line

Signal with little noise and proportional to a load curve of a power line
Example of a child – source = middle voltage underground cable?

Signal with a trend of a load curve during the night, but noisy
Example of a child – source = train network

Very noisy signal, proportional to traffic and with a ratio of harmonic above zero
Measurements with influence of an electric network

<table>
<thead>
<tr>
<th>Type of network</th>
<th>Number of children living close to electric network</th>
<th>Number of children with influence of electric network</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overhead line 400 kV</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Overhead line 225 kV</td>
<td>7</td>
<td>6</td>
</tr>
<tr>
<td>Overhead line 63 to 150 kV</td>
<td>11</td>
<td>3</td>
</tr>
<tr>
<td>Overhead line 20 kV</td>
<td>24</td>
<td>1</td>
</tr>
<tr>
<td>Overhead line LV</td>
<td>371</td>
<td>53</td>
</tr>
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<td>5</td>
</tr>
<tr>
<td>Underground cable 20 kV</td>
<td>331</td>
<td>60</td>
</tr>
<tr>
<td>Underground cable LV</td>
<td>524</td>
<td>75</td>
</tr>
<tr>
<td>MV/LV substation</td>
<td>45</td>
<td>9</td>
</tr>
<tr>
<td>MV/LV substation in building</td>
<td>13</td>
<td>3</td>
</tr>
</tbody>
</table>

Note that:

- $B_{\text{measured}} =$ summation of all sources
- Signal is often at the limit of ground noise and non specific
- Taking into account the floor of buildings, the numbers for underground networks and substation in buildings would decrease
Conclusion (1/2)

- Objective to have a database of 1000 children and 1000 adults attained
- 1\textsuperscript{st} study of personal exposure of a population at the scale of a country
- 3.1\% of children have observed a AM > 0.4 \(\mu\)T
  - Main sources = clock-radio
  - The real exposure of the person was overestimated
- Outside period of sleep, 1.1\% of children have observed a AM > 0.4 \(\mu\)T
  - More coherent with literature
- Children are less exposed than adults
- The analysis of the mean exposures has shown that the retained variables do not allow alone to characterise these means
Conclusion (2/2)

- Factors of exposure were identified
- These factors depend on the population considered (adults or children), the type of mean (arithmetic or geometric), and the scenario (over 24h or outside period of sleep)

- Qualitative analysis of electric networks data show that:
  - The part of the population whose exposure to 50 Hz magnetic field is influenced by high voltage power lines is small
  - The criteria of distance chosen in this study is maximizing and thus overestimates logically the number of people whose exposure to 50 Hz magnetic field is influenced by electric networks
  - It is not conclusive that underground electric networks are really the source of exposure seen in some measurements
Perspectives

- Continue the analysis
  - include electric distribution network
    - Improvement of the characterization of mean exposures (variance explained)?
  - Improve data on train network
    - Take into account the frequency

- Other possible use of these data
  - validation of physical models used to estimate magnetic fields
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THANK YOU FOR YOUR ATTENTION!