EXPOSURE OF THE FRENCH POPULATION TO 50 HZ MAGNETIC FIELD: GENERAL RESULTATS AND IMPACT OF ELECTRIC NETWORKS

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ABSTRACT

To study the exposure of the French population to 50 Hz magnetic fields (MF), two samples (children and adults) representative of this population were created. Each person wore an EMDEX II measuring and recording the MF to which he/she was exposed during 24h, and has progressively filled in a timetable and a questionnaire with information about themselves and their homes. When returning the meter, the pollster recorded the GPS coordinates of their homes.
In total, 977 series of MF were validated for children and 1052 for adults. The arithmetic and geometric means observed were respectively 0.09 and 0.02 µT for children and 0.14 and 0.03 µT for adults.
Electric networks were identified as factors influencing the mean exposure: not only power lines, but also middle and low voltage networks.

INTRODUCTION

In 2001, the International Agency for Research on Cancer classified ELF magnetic field (MF) as "possibly carcinogenic to human". These conclusions were based on a statistical association found in some epidemiological studies, unconfirmed by experimental results, between childhood leukaemia risk and a 24h mean exposure to MF higher than 0.4µT.
The crucial question of epidemiological studies is the exposure assessment. Another is to know the relative contribution of all field sources in the daily environment.
In 2006 the French Ministry of Health initiated a large study of personal exposure of the French population to 50 Hz magnetic field. The objective was to collect a database with data for 1000 children (0-14 years) and 1000 adults. We present here the main results, and give more details about the influence of electric networks on the French population exposure.

METHOD

The exposure situations can be very different in the French population, taking into account various ages and activities. That is why we focus on the personal exposure, that is measuring the magnetic field at the closest point to the person, over 24h. It is also well known that the situations of means exposure higher than 0.4 µT are quite rare, and most of the personal exposure studies gave observed proportions varying between 0.38 and 4.27 % [1,2,3]. In order to have information about these highest exposures, the sample of the study had to be large enough. With the assumption that the proportion of children exposed to a mean magnetic field higher than 0.4 µT is less than 5 %, it was evaluated that a sample size of 1000 children was a good compromise between the number of measurements to perform and the precision of the results [4].

The exposure data were collected during 3 measurement campaigns between 2007 and 2009. The MV2 Conseil survey institute was in charge of the selection of subjects and of the collection of data. In order to represent the French population, the subjects were randomly selected from telephone list, with the criteria to have the same proportion of subjects in each of the 22 French administrative regions than in the French general population.

The EMDEX II meter (Enertech, USA) was chosen for magnetic field measurements after comparison with other meters available. The main argument for this choice was the fact that this device measures and records two kinds the broadband (40-800 Hz) and the harmonic component (100-800 Hz) of the magnetic field. This is be very useful for the analysis of measurements and the determination of the types of exposure sources.
For the study, 65 EMDEX II were used. They were calibrated in a Supelec laboratory each year, and checked between each measurement with a dedicated portable system, developed by Thanh Dovan (SWPnet). During the whole study, no dysfunction of EMDEX II was seen, even if the EMDEX experienced curiosity of children.

Each subject wore an EMDEX II, measuring and recording every 3 s the magnetic field he/she was exposed to, during 24h. Figure 1 gives an example of measurements recorded by a subject . In the same time, the subjects filled in a timetable. In addition, all subjects answered to a questionnaire about socioprofessional status and home data.

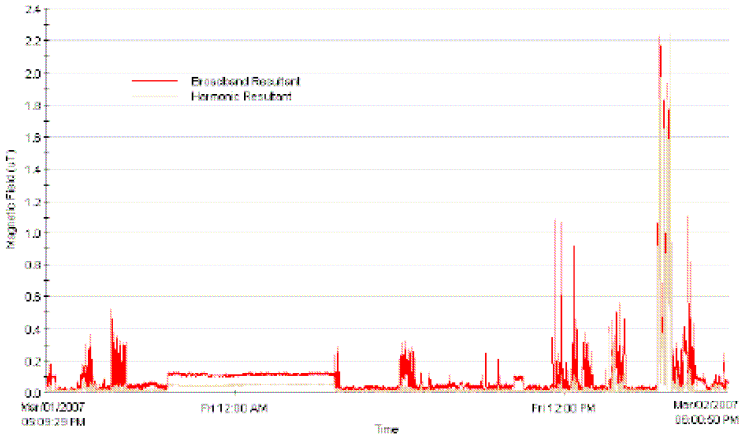

Figure 1: example of MF record for a subject

The GPS coordinates at the volunteer's home front door were given to ERDF (the French electricity distribution network operator) and RTE (the French electricity transmission network operator) in order to identify all the electric networks close to each home. Table 1 gives the maximum distance around networks at which the networks is considered to influence magnetic field at home [5]. So RTE and ERDF identified all subjects located at a distance of their networks less than the values given in table 1.

Type of network	Distance (m)
400 kV overhead line	200
225 kV overhead line	120
150 kV overhead line	100
63 and 90 kV overhead line	70
Low voltage to 20 kV overhead line	20
Train line	200
Underground line 225 kV	20
Underground line 63 to 150 kV	20
Underground line low voltage to 20 kV	20
MV/LV substation	20

Table 1 : definition of corridors around electric networks

RESULTS

After the collection of data, a put into format work was done. Measurement data were compared to timetable. Some subjects were taken out of the database because on data inconsistent or missing. In total, 977 series of magnetic field were validated for children and 1052 for adults.

Descriptive analysis

The arithmetic mean (AM) and geometric mean (GM) are respectively 0.09µT and 0.02µT for children, 0.14µTand 0.03µT for adults. Table 2 gives the repartition of the exposure.

	children		adults	
quartile	AM (µT)	GM (µT)	AM (µT)	GM (µT)
25 %	0.01	0.00	0.03	0.00
50 %	0.03	0.01	0.05	0.02
75 %	0.06	0.02	0.11	0.04
99 %	1.22	0.19	1.54	0.26

Table 2: some quartiles of 24h mean exposure

We have differentiated 24h exposure and out of sleep period exposure, and we explain the reasons hereafter.

Out of sleep period exposure is 0.05 µT in AM and 0.02 µT in GM for children, and is 0.10 µT and 0.03 µT for adults. Table 3 gives the repartition of the exposure.

	children		adults	
quartile	AM (µT)	GM (µT)	AM (µT)	GM (µT)
25 %	0.01	0.00	0.03	0.01
50 %	0.03	0.01	0.05	0.02
75 %	0.05	0.02	0.09	0.04
99 %	0.41	0.15	0.83	0.21

Table 3: some quartiles of 24h mean exposure

For children, we look more in details at the highest exposures, i.e. the mean exposures higher than 0.4µT. For adults, this 0.4 µT value has no sense since it come from epidemiological studies on childhood leukaemia. So for adults we defined the highest exposures as the 1% highest mean exposures.
The number of children with a 24h mean exposure higher than 0.4 µT is 30 (3.1%) for AM, and 2 (0.2 %) for GM.
The highest exposures for adults represent 11 adults, with a 24h mean exposure higher than 1.54 µT in AM, and than 0.26 µT in GM.
Taking into account the exposure out of period of sleep, 11 children (1.1%) have a mean exposure higher than 0.4 µT in

AM, and 2 (0.2%) in GM. For adults, 11 adults have a mean exposure higher than 0.,82 µT in AM, and than 0.21 µT in GM.

Comparison of mean exposures

In order of comparing mean exposures for subpopulations of our sample, we use rank testes, like shown in figure 1.

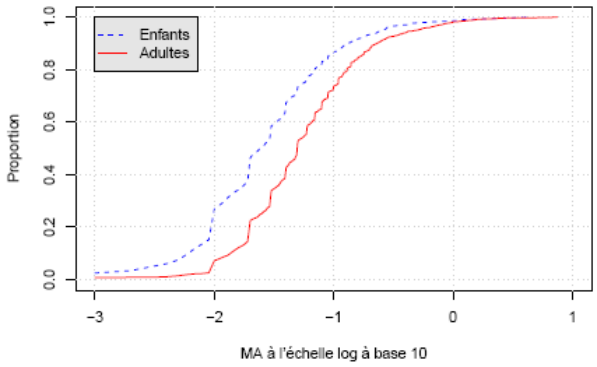

Figure 2 : repartition of 24h mean exposure for MA (children and adults)

The main results show that:

- children are less exposed than adults, in AM and in GM, over 24h and out of period of sleep
- the exposure is higher in Ile-de-France (Paris region) than in the other regions, in AM and in GM, over 24h and out of period of sleep
- children are more exposed inside home than outside, in AM and in GM, over 24h and out of period of sleep
- adults are more exposed outside home than inside, in AM and in GM, over 24h and out of period of sleep
- at home, children are more exposed during the day than during the night, in AM and in GM
- there is no difference in mean exposure (AM and GM, adults and children, over 24h and at home) for people living close to a high voltage network (63 kV to 400 kV) and for people living close to an AC electrified train network. These people are more exposed than people living far away from these networks (the low voltage and 20 kV networks have not been taken into account in these calculations yet)

Variables influencing the mean exposure

Continuous and categorical variables were defined from the questionnaires and timetable. A first study showed the existence of a relationship between some of these variables and the mean exposure. So we firstly studied a linear model, which results in a low level of explained variance. This means that the model is not linear or that the variables are not the only factors influencing the exposure. We decided then to use non parametric multidimensional models.
Some factors influencing the mean exposure have been identified. They are linked to characteristics of subjects (ex age), to urbanisation (ex city of more than 2000 habitants), to the home (ex type, heating), to the vicinity of electric network (ex close to 20 kV or low voltage overhead line), or to the activity of the subjects (time spent in some activities). All these factor do not influence the mean exposure of adults and children, in AM and in GM, over 24h and out period of sleep. In all cases, the level of explained variances remains very low (between 13.4% and 32.8 %). This means that the obtained model is not predictive.

The repartition of the subjects around electric networks is discussed in another paper [5].

DISCUSSION

The mean time to recruit one subject was 70 minutes. The recruitment of children was even more difficult than those of adults. This led to modifying the recruitment protocol by privileging children from the second campaign.

The repartition of the subjects over the French territory was studied more in detail, at the scale of the French departments, after the measurement campaigns [5]. Out of 96 departments, 11 contain no subject. Eleven departments out of 96 contain no volunteer. Statistic tests show that this fact is not due to a bias of selection but due to the randomness and the fact that these departments are sparsely populated (because they include rural areas).

One the one hand, the analysis of volunteer profiles does not show any difference in the ratio boy/girl in the children compared to the French population. On the other hand, women are more represented than men in our sample. In the same way, the profile of ages show a deficit of children under 6 years of age, and a surplus of 35 to 50 year old adults. This can be explained by the modification of recruitment protocol: we suggested to the adult to record the measurements at the same time as the child, often it was probably the mother who accepted.

The proportion of children exposed to a mean magnetic field higher than 0.4 µT over 24 h is larger than what can be found in the literature, that is why we tried to explained these high exposures. After the first measurement campaign, we observed that most of these exposures correspond to signals with values sometimes high (up to several µT) and constant during the night, and a level of harmonics around 1/3. These signals correspond to magnetic field emitted very close to clock radios or to other electric appliances with small transformers inside.
Additional measurements have shown that:

- magnetic field varies a lot from a clock radio to another
- the source of the magnetic field is the transformer, which can be inside the clock radio or deported

into the socket
- the level of magnetic field decreases rapidly with the distance to the source
- at 50 cm, the level of magnetic field emitted by the clock radio is negligible

The highest exposure over 24h can be explained by the presence of a clock radio or of another electric appliance with a transformer inside very close to the EMDEX II. But are these measurements representative of the exposure of people? In order to avoid measuring the magnetic field at contact to clock radio during the night, and to be sure to measure personal exposure, subjects were asked to put the EMDEX II during the night at 50 cm to any electric appliance. When recovering the EMDEX II, they were asked whether they respect this consign: all did not do it.
When considering the exposure out of period of sleep, the proportion of children exposed to a mean magnetic field higher than 0.4 µT is coherent with the data found in the bibliography. Thus there may be a measurement bias in our 24h data, which overestimates the 24h exposure. That is the reason why we have analysed separately the 24 h exposure and the exposure out of period of sleep.

Among the 30 children with a 24h mean exposure higher than 0.4 µT in AM, we found only one child with an overhead power line close to the home (225 kV), but the high value of the exposure is due to a clock radio and not to the line. None of these children was living close to an underground power line. These exposures can be explained by:
- 24 cases of EMDEX II put close to a clock radio during the night
- 2 cases of EMDEX II put close to an electric appliance with a transformer during the day
- 1 case of EMDEX II put close to an unknown electric appliance during the night and the day
- 1 case of EMDEX II put close to an electric appliance with a transformer at school
- 1 case of AC electrified train network close to the home and the school
- 1 case of low voltage overhead line close to the home

Among the 11 children with a out of period of sleep mean exposure higher than 0.4 µT, none is living close to high voltage power line. The high exposures can be explained mainly by EMDEX II put close to electric appliances with transformers, but one is explained by low voltage overhead line close to the home, and another could be explained by the vicinity of a electric network, probably distribution network, at school (to be confirmed).

The results are similar for adults, except 2 cases of use of train transports for out of period of sleep mean.

CONCLUSIONS

This study is the first assessment of the personal exposure to 50 Hz magnetic field of the French population. The objective to collect the data for a sample of 1000 adults and 1000 children was reached in 3 years.
Among the large number of results, we can remember that the 24h mean exposure is higher than 0.4 µT for 3.1 % of the children and that this high proportion is due to a measurement bias which overestimates the exposure (the measurement device is put during the night close to an appliance like a clock radio and do not measure the personal exposure of the subject). The mean exposure out of period of sleep is higher than 0.4 µT for 1.1 % of children, which is coherent with data found in the bibliography.
Children are less exposed than adults. This may be explained by the fact they are less moving (the measurements were performed during school periods)
Factors influencing the mean exposure have been identified, but the statistical analysis has shown that these factors do not alone explain the mean exposure.
The analysis of the database will continue.

Acknowledgments

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