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FRENCH POPULATION EXPOSURE TO 50 HZ MAGNETIC FIELDS: INTERMEDIATE RESULTS

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Introduction

For the last thirty years, the electricity related 50 Hz magnetic fields (MF) have been suspected of being responsible for several pathologies, in particular childhood leukemia [1]. The most recent collective expertise (WHO 2007 and SCENHIR 2009) concluded that the last major interrogation with regard to low frequency MF is the statistical association observed in several joint analyses between the increase of risk of the childhood leukemia and a higher than 0.4 µT exposure to MF on average in a 24-hour period [2]. Currently, the exposure of the French population to these magnetic fields is only approximately known. A study carried out in residences located near high voltage power lines in the "département[1] de la Côte d'Or" made it possible to assess the MF background level inside these residences [3]. However, these residences are a limited sample compared to the diversity of the housing developments in France and the study characterized the exposure of the houses and not of the resident people.

We are all exposed to many sources of magnetic fields due the fact that we do not remain at home 24 hours a day. Transportation in particular, significantly contributes to the individual exposure. Other places or activities can also constitute sources of exposure such as the workplace, sport activity areas, shopping centers or schools.

Should the MF in excess to 0.4 µT on average carry health risk, would the authorities be able to manage it, i.e. estimate the proportion of the French population at risk and identify and mitigate the main sources causing the exposure? To answer this question the Ministry of Health and Solidarities initiated a study on the exposure of a representative sample of the French population to 50 Hz MF. The major issues of this study were to select randomly a representative sample and to collect all of necessary data. Measurements were performed in three campaigns at winter time (October to April). The present paper gives the results of the two first campaigns.

Materials and Methods

Constitution of the study sample

To study the exposure of the French population to 50 Hz MF, a representative sample of 1 000 children from 0 to 14 years old and 1 000 adults has been created randomly. This sample phase and the information collecting phase were entrusted to the polling institute "MV2 Conseil" which was selected after

[1] France is divided into 96 ''départements" + oversee islands

a call to tender. The collection of data required significant workforce and financial costs and was conducted in three phases (February-April 2007, October 2007-April 2008 and October 2008-January 2009).

MV2 first created a data base of 95 362 telephone numbers, which were extracted in a completely random way from the national file of the telephone numbers existing in France, excluding professional numbers. No quota was applied during this drawing of lots. The telephone numbers distributed on the whole of the territory including the unlisted numbers[2] and those of the "cellular phone only" were, at this stage, all potentially eligible to take part in this study.

A contact with "the adult reference of the household" was established by telephone in order to ask for volunteering for the study. All these contacts followed strictly a single recruitment screener (recruitment questionnaire by telephone) previously elaborated. If the contact accepted the principle of the study, the recruiter asked for the birthdates of all the members of the household. The person who had date of birth closest to the phone contact date (day and month only) was the person elected to carry the magnetic field measuring device. Therefore, only random chance selected the person included in the collection of measurements of MF. In this stage, only the age of the recruited person, the telephone number and address are known. If the elected person refused or was not able to carry out the 24-hour test, the contact was regarded as definitively invalid. For the first campaign the recruitment of children proved to be much more difficult than adults. They were given preference in the two other campaigns of measurements. The recruitment was carried out by region until was obtained a quota of participation per region representing the pattern of the settlement on the French territory. No measurement was achieved during weekends, public holidays (Chrismas, spring and Easter) and Wednesdays (this is a day off from school for French children).

The 2 000 individuals recruited constitute a representative sample of the French population, covering all the sociodemographic characteristics (age, sex, region, size of the household, cut agglomeration, type of residence, socio-professional status, etc). These households are representative of the ways of life of the French population in all its diversity (life style, type of habitat, domestic equipment, etc).

Measurements of MF and data collection

Each elected volunteer carried an EMDEX II (Enertech, USA) meter, measuring and recording every three seconds the magnetic fields which he was exposed to during a minimal length of a 24-hour period. This device measures two kinds of MF: the broadband and harmonic resultants. The EMDEX II calculates and records the magnetic induction obtained on the three axes, by step of time fixed, according the formula (1).

$$B = \sqrt{B_x^2 + B_y^2 + B_z^2} \qquad (1)$$

To achieve this study, 65 EMDEX II were used.

Calibration and check procedures

All the EMDEX were calibrated before and after each winter campaign of measurements in a laboratory of the department of electromagnetism of SUPELEC. In this laboratory, the background MF was very weak (between 0.03 and 0.05 µT). A dedicated semi-automatic system of calibration was

[2] In France, the unlisted numbers are telephone numbers that are not in the phone book for privacy protection

developed. It is made of two sets of Helmholtz coils (Leybold), a programmable low frequency generator and an calibrated ammeter. In the center of each Helmholtz system, the magnitude B of the MF (in µT) is given by (1) where N is the number of turns, R radius of the coils is equal to the distance between the centers of the two coils of each system (in meter), I the intensity of the current (in Amp) flowing in the coils and $\mu_0 = 4\pi \times 10^{-7}$.

We checked that the values read on the meter are practically identical to those given by (2), therefore no correction factor was needed.

$$B = \mu_0 \frac{0.716 \times N \times I}{R} \tag{2}$$

Another portable system was developed to check in situ the correct operation of the EMDEX before and after each 24-hour measurement. This system was copied, with the kind authorization of the original designer, from an device developed by the Australian Thanh Dovan (SWPNet). It is composed of one square solenoid of 25 cm of side with 225 turns, which can be fed by 4 different currents, therefore generating 4 MF magnitudes. It permits to compare the generated value to the one read on the screen of the EMDEX II.

Collection of data

During the period of individual measuring, each volunteer progressively filled out a timetable, noting the activities carried out and the corresponding beginnings and endings. For the volunteers unable to write (infants, etc), the timetables were filled out by the supervisor (parents or the babysitter for the children). At the recovery time of the device, the pollster filled out a questionnaire with the help of the volunteer containing information relating to the volunteer (age, sex, socio-professional code...) and his/her residence (year of construction, numbers years in the residence, number of persons living in the residence, type of heating energy used, mode of heating of the residence, mode of water heating, etc). The pollster noted the GPS coordinates at the entry of the residence volunteer. Before sending all the information for analysis, MV2 Conseil checked their validity (information sheets and timetables were well filled out, duration of measurements, etc). All the information in paper version were captured by means of computer and each series of MF was virtually cut out according to the associated timetable. In these two first campaigns, 1 500 volunteers took part, whose 996 series of measurements have been analysed yet.

To have all the information relating to the power lines (overhead or underground) and to the power stations positioned near the residence, the GPS coordinates will be transmitted to EDF (Électricité de France, operating the distribution network) and RTE (Transmission System Operator). They will inform us of the presence (possibly the number) or not of power lines at a distance to the residence less than or equal to 200 m for the 400 kV lines, 120 m for the 225 kV lines, 100 m for the 150 kV lines, 70 m for the 63 or 90 kV lines and 20 m for the underground cables. This information is not yet available and the analysis presented here under does not takes it into account.

Statistical analysis

The aim of the statistical analysis is to identify the factors explaining the intensity of MF by integrating information drawn from the questionnaires and timetables. After having checked the homogeneity of each series compared to the timetable and, having done a descriptive analysis for the validated series, the study is mainly directed towards three points:

1. Estimate of the exposure of the population in terms of average values,.
2. Characterization of the average exposures and identification of the factors contributing to the exposure
3. Search of exposure classes and identification of the factors explaining the probability of belonging to the most exposed classes.

All the analysis is based on the broadband resultant recordings.

Results

Out of the 996 fact sheets analyzed, 6 series were definitively eliminated for inconsistencies in the associated questionnaires. On the 990 remaining others, 437 are recordings of children and 553 are recordings of adults.

The results of the descriptive analysis showed that 15 children (3.4%) are exposed to a MF higher than 0.4 µT in arithmetic mean (AM). Only one of them observed a geometric mean (GM) higher than this value. The principal sources of these exposures are clock radios. In fact 13 of these children declared in the questionnaire to have placed the EMDEX beside a clock radio during the night. For the 2 others, the identified sources are a railway line which passes beside the school and the residence and a low power domestic transformer, perhaps in a desk lamp. The average exposures are 0.106 µT for AM and 0.029 µT for GM for the children and 0.148 µT and 0.044 µT respectively for the adults. The of comparison tests carried out (test of Wilcoxon-Mann-Whitney) showed that the children are overall less exposed than the adults and that the exposure is higher in the Paris region than in the other regions in terms of arithmetic and geometric means (p_values are lower than 0.1%).

To characterize or identify the factors of exposure in terms of AM and GM, two steps were adopted :

1. In the first step, linear models [4] and nonparametric regression models (generalized additive models) were developed [5, 6]. The results showed that the most significant variables are linear with regard to the MF exposure. The nonparametric models did not give additional information compared to the linear models in terms of explained variance (tables 1, 2, 3 and 4). The factors identified are 1) having placed the EMDEX near a clock radio and 2) spending more time in railway transportation (tables 1 and 2). Other information appears according to the population and the average considered (arithmetic or geometric). The adults GM increase with working time on computer. The children living in apartments are more exposed than those who live in individual households. This result is also observed on the GM of the adults. To live in a city of more than 2 000 inhabitants contributes to increase the exposure of the adults.

2. In the second step, other descriptors were calculated for each series. An ascending hierarchical clustering is applied to the centered and reduced descriptors [7]. To measure the similarities, we used the Euclidean distance for individuals and the linkage of Wald for the classes. It led to a classification of each population in three classes noted " *class 1* ", " *class 2* " and " *class 3* " (figures 1 and 2). To characterize these classes, a logistic regression was applied [7]. The aim was to model the probability from the class where an individual is showing to be more exposed taken from the information drawn from the fact sheets and the timetables
   The most discriminating variables and the Odds ratio (OR) associated are represented in tables 5 and 6.

Discussion

The magnetic fields we are exposed to, can be associated with several sources. The majority of the studies carried out on this subject are centered on the MF recorded in the residence or in the bedrooms. The originality of this study is characterized by the method used for the selection of the individuals constituting the study sample (method of random polling) and by the fact that measurements are individual exposures in a 24-hour period.

The GM measured on each type of population (GM) is lower than the GM observed on the French dwellings located near power lines (0.05 µT) but largely higher than those measured on the other dwellings (0.01 µT) [8]. The 99% percentile of the adults AM is 1.529 µT. The Paris region is the most industrialized area and the most equipped with railway transportation. Thus the exposure is higher than in the whole of the other regions.

A higher exposure is also observed on the people who placed the EMDEX near a clock radio. Six adults (out of 553) are exposed to an AM higher than this value. They all have declared to have placed the EMDEX meter near a clock radio when sleeping. The clock radios are supplied by a low power transformer, which is the source of MF. During the night, it works normally in a single way (clock but no radio) and in this case, the MF magnitude is stable and characterized by a ratio of 3 between the broadband and the harmonic measurements. Figure 3 represents the MF series recorded by a 3-year old child whose EMDEX was placed beside a clock radio between 20:20 and 10:43. The volunteers indicated on the questionnaire if the EMDEX was placed beside a clock radio or not during time of sleep.

The electric railway transportation systems are sources which can influence the average exposures over a 24- hour period. The averages increase with the time spent in these types of transportation. If we consider GM (less sensitive to the peaks), the adults exposure increases with the time spent in front of the computer (working time on computer). The adults who live in cities of more than 2 000 inhabitants are more exposed then those who live in the smaller cities. The individuals who live in multifamily apartments (buildings or apartments) are more exposed than those who reside in individual households. AMs decrease with the time spent in school. However, these factors explain only partially the variations of the MF which we are exposed to over a 24-hour period (tables 1, 2, 3 and 4). The future introduction of the information related to the presence of power lines (transmission and distribution) in the residence neighborhoods could improve the rates of the variance explained by the different models.

The comparison tests applied to the average exposures of the classes resulted in concluding that the adults of class 1 are less exposed than those of the second. These latter are less exposed than those of class 3 in terms of arithmetic and geometric means (p-values lower than 0.1%). These results were obtained for classes 1 and 2 for the children (the size of class 3 is weak and the test was not carried out). The classes of the most exposed (class 3) are mainly formed by the people who declared to having placed the EMDEX beside a clock radio (6 out of 6 for the children and 21 out of 33 for the adults, table 5).

The results of the logistic regression enabled us to retain that in addition to placing the EMDEX near the clock radio, living in a multifamily apartment and/ or spending more time in front of computer increase the probability of belonging in classes 2 or 3 for the children (table 6). For the adults, having an individual mode of water heating and/ or placing the EMDEX near the clock radio increase the probability of being in class 3 (class of the most exposed). This probability decreases with the time spent in nonrailway transports (table 7).

Conclusion

For the first time in France, this study was made possible to assess the population exposure to 50 Hz magnetic fields. It also made possible identifying some sources of exposure even if these latter do not alone explain the average exposures. In the continuation, other measurements will be done and included to the data base. Information relating to the presence or not of power lines and power stations in the vicinity of the residence will also be introduced in the analysis. To ensure the validity of the results, robustness tests will be carried out.

	Linear model		Nonparametric model	
Variable	Estimate	P_value	Estimate	P_value
Intercept	-3.379	< 0.001	-3,322	< 0.001
Time spent in railway transports	0.617	0.046		0.139
Age	0.038	0.025		0.026
Time spent at school	-0.044	0.034		0.034
Clock radio (Yes)	2.563	< 0.001	2.563	< 0.001
Habitation (Apartment)	0.534	< 0.001	0.533	< 0.001
Variance rate explained	25.3%		25.4%	

Table 1: Variables characterizing the children AM (log scale).

	Linear model		Nonparametric model	
Variable	Estimate	P_value	Estimate	P_value
Intercept	-4.235	< 0.001	-4.135	< 0.001
Time spent in railway transports	1.027	0.007		0.032
Working time on computer	0.130	0.022		0.022
Clock radio (Yes)	1.892	< 0.001	1.893	< 0.001
Habitation (Apartment)	0.886	< 0.001	0.884	< 0.001
Variance rate explained	16.2%		16.3%	

Table 2: Variables characterizing the children GM (log scale).

	Linear model		Nonparametric model	
Variable	Estimate	P_value	Estimate	P_value
Intercept	-3.322	< 0.001	-3.268	< 0.001
Time spent in the railway transports	0.371	< 0.001		< 0.001
Clock radio (Yes)	1.523	< 0.001	1.523	< 0.001
Population (> 2 000 inhabitants)	0.281	0.011	0.281	0.011
Variance rate explained	25.2%		25.6%	

Table 3: Variables characterizing the adults AM (log scale).

	Linear model		Nonparametric model	
Variable	Estimate	P_value	Estimate	P_value
Intercept	-4.175	< 0.001	-4.059	< 0.001
Time spent in the railway transports	0.218	0.026		0.026
Clock radio (Yes)	1.356	< 0.001	1.356	< 0.001
Habitation (Apartment)	0.555	< 0.001	0.555	< 0.001
Population (> 2 000 inhabitants)	0.425	0.003	0.425	0.003
Variance rate explained	21.0%		21.7%	

Table 4: Variables characterizing the adults GM (log scale).

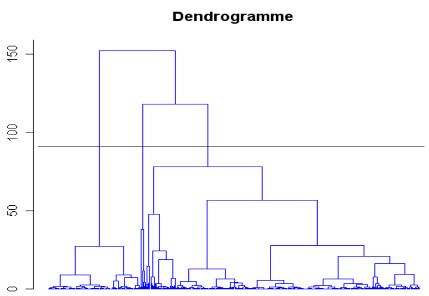

Fig. 1: Children classification.

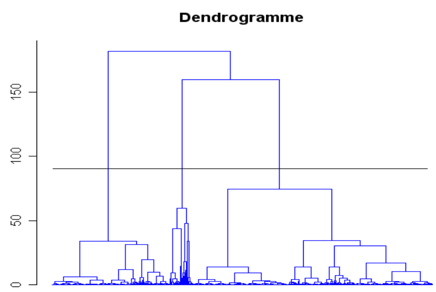

Fig.2: Adults classification.

	Children			Adults		
Class number	1	2	3	1	2	3
AM in µT (size)	0.015 (109)	0.080 (322)	3.128 (6)	0.046 (171)	0.101 (349)	1,171 (33)
GM in µT	0.008	0.032	0.210	0.023	0.038	0.224

Table 5: Comparison of the classes averages exposures.

Variable	Estimate	P_value	OR (CI 95%)
(Intercept)	1.472	< 0.001	
Working time on computer	0.257	0.031	1.29* (CI=[1.02 , 1.63])
Clock radio (Yes)	2.646	0.010	14.10 (CI=[1.89,105.32])
Habitation (Apartment)	0.910	< 0.001	2.48 (CI=[1.52, 4.05])

* OR associated to an increasing of one hour.

Table 6: Variables characterizing the probability of belonging in classes 2 or 3 for the children.

Variable	Estimation	P_value	OR (CI 95%)
(Intercept)	-4.684	< 0.001	
Time spent in nonrailway transport	-0.500	0.042	
Clock radio (Yes)	2.440	< 0.001	11.47 (CI= [5.31, 24,80])
Mode water heating (Individual)	0.629	0.035	5.10 (CI= [1.13, 23,06])

Table 7: Variables characterizing the probability of belonging in class 3 for the adults.

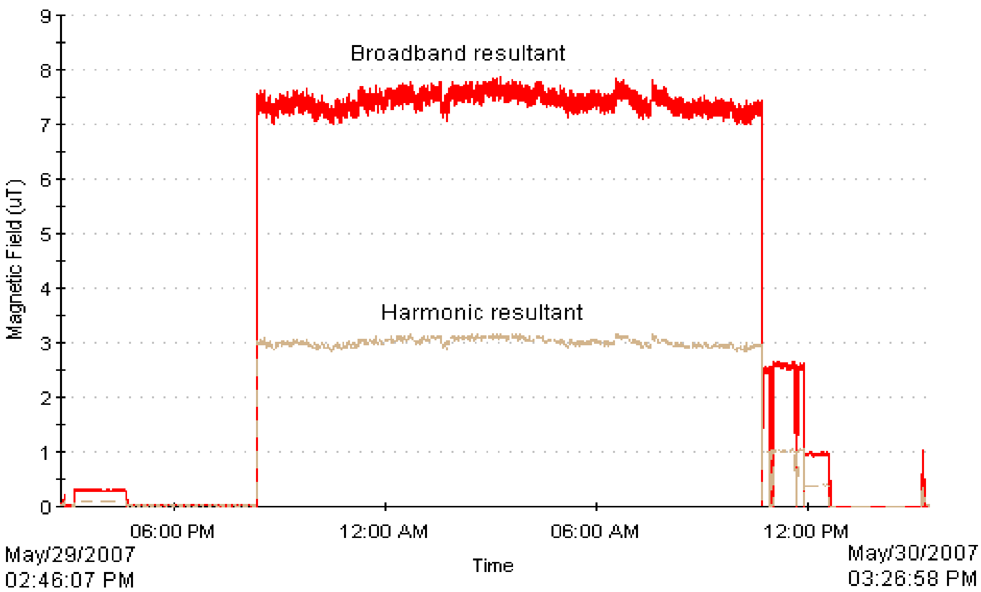

Fig.3: Example of a MF series which an important part was generated by a clock radio. AM=4,490 µT and GM=0,780 µT.

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