

The Director General

Maisons-Alfort, 5 April 2019

## **OPINION** **of the French Agency for Food,** **Environmental and Occupational Health & Safety**

**on the “Health effects associated with exposure to low-frequency electromagnetic fields”**

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*ANSES undertakes independent and pluralistic scientific expert assessments.*

*ANSES primarily ensures environmental, occupational and food safety as well as assessing the potential health risks they may entail.*

*It also contributes to the protection of the health and welfare of animals, the protection of plant health and the evaluation of the nutritional characteristics of food.*

*It provides the competent authorities with all necessary information concerning these risks as well as the requisite expertise and scientific and technical support for drafting legislative and statutory provisions and implementing risk management strategies (Article L.1313-1 of the French Public Health Code).*

*Its opinions are published on its website. This opinion is a translation of the original French version. In the event of any discrepancy or ambiguity the French language text dated 5 April 2019 shall prevail.*

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On 27 February 2013, ANSES received a formal request from the ministries responsible for health, labour, the environment and agriculture to undertake the following expert appraisal: “update to the expert appraisal on extremely low-frequency electromagnetic fields”.

### **1. BACKGROUND AND PURPOSE OF THE REQUEST**

In 2010, the French Agency for Environmental and Occupational Health Safety (AFSSET) published an opinion alongside an expert appraisal report entitled “Summary of the international expert appraisal on the health effects of extremely low-frequency electromagnetic fields”. This expert appraisal highlighted the strong level of convergence in the assessments by international expert appraisals on the possible long-term health effects, particularly the association between exposure to extremely low-frequency magnetic fields and childhood leukaemia.

More recently, the Geocap study examined the influence of various types of environmental exposure in France on the risk of childhood cancer. Among children under the age of five, the study found a statistically significant link between living less than 50m in a straight line from a very-high voltage

power line (over 225 kV) and the risk of developing childhood leukaemia (Sermage-Faure *et al.* 2013).

In the light of these findings, the ministries responsible for health, labour, the environment and agriculture asked ANSES to provide an updated expert appraisal on the health effects associated with exposure to low-frequency electromagnetic fields, in both humans and animals.

In response to the request concerning animal health, ANSES published an opinion and an expert appraisal report in August 2015 on the “consequences of extremely low-frequency electromagnetic fields on animal health and zootechnical performance”. This current opinion concerns the health effects of exposure to low-frequency electromagnetic fields in humans.

For the purposes of this expert appraisal, “low-frequency” electromagnetic fields are defined by the following frequency domain:  $0 \text{ Hz} < f \leq \text{a few kHz}$ .

Note that the term “extremely low frequency” is used in the literature either as a synonym for “low frequencies” or to refer to a more limited frequency band, between 0 Hz and a few Hz.

## 2. ORGANISATION OF THE EXPERT APPRAISAL

### ■ Collective expert appraisal

This expert appraisal falls within the sphere of competence of the Expert Committee (CES) on “Physical agents, new technologies and development areas”. The Agency mandated the Working Group of experts on “Low-frequency electromagnetic fields” to undertake this expert appraisal under the leadership of the CES.

The Working Group was formed following a public call for expert applications on 26 February 2015. The experts in this group were recruited for their scientific and technical skills in the areas of electromagnetic field metrology and exposure measurement, epidemiology, medicine, biology, physiology and regulations in the area of electromagnetic fields.

The methodological and scientific aspects of the expert appraisal work were regularly submitted to the CES. The report produced by the Working Group takes account of the observations and additional information discussed with the CES members.

This expert appraisal work was therefore conducted by a group of experts with complementary skills. It was carried out in accordance with the French Standard NF X 50-110 “Quality in Expertise Activities”.

Interests declared by the experts were analysed by ANSES before they were appointed and throughout their work in order to prevent risks of conflicts of interest in relation to the points addressed in the expert appraisal. The experts’ declarations of interests have been made public via the ANSES website: <https://www.anses.fr>.

### ■ External contributions

In order to make up for a lack of data on environmental exposure to low-frequency electromagnetic fields among the French population, particularly children, a research and development agreement was signed with the U1086 ANTICIPE laboratory at the National Institute of Health and Medical Research (INSERM) on 29 April 2016. This study pursued a twofold aim: to estimate the number of people living close to a high or very-high voltage power line<sup>1</sup> in France ( $\geq 63 \text{ kV}$ ), and to count the

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<sup>1</sup> French standard NF C 18-510 identifies the following AC voltage fields: very low voltages under 50V, low voltages between 50V and 1,000V, and medium/high voltages above 1,000V. Medium voltage (HTA) refers to voltage levels between 1,000V and 50,000V. High voltage (HTB) refers to voltage levels of over 50,000V. The terms high voltage and very-high voltage are sometimes used, particularly by the electricity transmission provider (RTE), to refer to 63 kV and 90 kV lines (high voltage) and to 225 kV and 400 kV lines (very-high voltage).

number of primary schools and other establishments attended by young children close to these power lines, in order to calculate the number of children concerned.

■ **Methods of assessment of the level of evidence for health effects**

To assess the level of evidence associated with each health effect, the Working Group drew upon all the data available:

- the results and conclusions of expert appraisals conducted before 2010 by ANSES, by national organisations in other countries or by international entities;
- a systematic analysis of the scientific studies published since 2010.

***Review and bibliographic analysis of articles published since 2010***

In compliance with the methodological principles applied by ANSES, this expert appraisal is based primarily on an analysis of the scientific literature available. The reference period for the literature search ran from January 2010 to December 2015. A number of publications issued before 2010 or after 2015 were also taken into account, primarily to supplement the knowledge available on the health effects studied.

In view of the significant number of publications identified by the literature search, the Working Group prioritised the work to be conducted as part of this expert appraisal. To this end, after drawing up an exhaustive list of all the health effects explored by the scientific literature, the Working Group decided to give priority to an expert appraisal of the following health effects: childhood leukaemia, other forms of cancer and neurodegenerative diseases. At the same time, taking account of the regulatory exposure limit for workers exposed to magnetic fields of 50 Hz (1,000  $\mu$ T, see expert appraisal report § 4.3.2), only scientific publications involving experimental models exposed to values below or equal to this value were considered in the expert appraisal.

Each study identified was analysed by at least two experts; the part concerning the exposure protocol by an expert physicist, and the part on health effects by expert epidemiologists or biologists, depending on the nature of the study. Each expert reviewer completed an analysis grid with the support of the ANSES scientific coordinator, based on the analytical criteria previously defined. A study analysis table was created, listing in particular the main findings of publications, the expert rapporteurs' comments about the methodologies (mainly on exposure and experimentation), the conclusions advanced by the authors, and the sources of funding for each study. In each case, the quality of the study, i.e. the relevance and rigour of its protocol and the analysis of the results by the authors (statistical analyses in particular), determined its inclusion in the assessment of the level of evidence for each effect studied, regardless of its result.

***Assessment of the level of evidence for health effects from publications issued after 2010***

For each health effect, all the available studies undertaken in humans on the one hand and animals on the other hand were considered using specific flowcharts in order to characterise the evidence provided regarding the connection between exposure to low-frequency electromagnetic fields and the health effect considered. Given the absence of studies in animals concerning the health effects studied in humans, the Working Group looked at *in vivo* and *in vitro* studies on biological effects with an indirect but nevertheless proven link with these health effects. For example, an analysis of studies concerning the influence of low-frequency fields on genotoxic stress or oxidative stress, was included in the analysis of the carcinogenic effect of low-frequency fields. This is because DNA mutations and oxidation are found in many tumours.

The method of assessment of the levels of evidence applied to the expert appraisal referred to previous studies conducted by ANSES, particularly the expert appraisal on "Exposure to radiofrequencies and child health", published in 2016. The method also drew upon the studies conducted by the Working Group on "Methodology of risk assessment", published in 2016. This method was reviewed and adapted by the Working Group to include the specific characteristics of

this expert appraisal, primarily the knowledge provided by studies referring to the biological effects that are indirectly linked to a number of diseases (see paragraph above).

Based on the evidence set out earlier, the level of evidence for the effect studied in humans was then classified into one of the categories below:

- proven effect for humans;
- probable or possible effect for humans;
- it is not possible to conclude from the available data as to whether or not there is an effect;
- probably no effect for humans.

### ***Inclusion of scientific data dating back to before 2010***

Lastly, data published before 2010 were included on an incremental basis in order to modulate previously defined classifications. The overall assessment therefore included the full range of relevant data and was able to provide, for each health effect, a final classification of the level of evidence based on the categories set out above.

## **3. ANALYSIS AND CONCLUSIONS OF THE CES**

The Expert Committee on “Physical agents, new technologies and development areas” adopted the work of the expert group and its conclusions and recommendations at its meeting of 17 May 2018 and informed the ANSES General Directorate accordingly.

### **■ Characterisation of exposure**

The assessment of individual exposure (general population and workers) to low-frequency electromagnetic fields involves identifying the sources of exposure in the environment, and quantifying the exposure to electromagnetic fields emitted by these sources. Given the concomitance and variability of these many sources, a rigorous methodology is required to precisely characterise the electromagnetic environment. Based on the many studies conducted in this field, we now have an increasingly detailed picture of the exposure to low-frequency electromagnetic fields experienced by the general population and workers. This electromagnetic environment is nevertheless changing as a result of upcoming innovations in the field of electricity transmission, with the new smart grids and the development of electric vehicles. These changes could have an impact on the electromagnetic environment with an increase in the number of renewable electricity generation systems that are decentralised to be closer to users, and the deployment of new technologies (sensors and communications networks) in homes and on the grid itself. No studies are available at present to assess the changing levels of population exposure to low-frequency electromagnetic fields in this future context.

Studies conducted outdoors (urban public areas) show that the intensity of low-frequency electromagnetic fields generally varies between 0.05 and 0.2  $\mu\text{T}^2$ . Higher values of around a few microteslas can nevertheless be found, mainly for measurements taken directly under very-high voltage power lines, or next to transformers or electricity substations. Inside the home, it is possible to find magnetic fields with high values of up to one millitesla. These are produced by domestic appliances, of which some are used close to the body, such as hairdryers. Nevertheless, exposure to these appliances is brief and highly localised. The levels of exposure measured in public transport, such as trains and trams, are generally around a few microteslas, either inside carriages or on station

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<sup>2</sup> Regulatory exposure limits depend on the frequency. They are defined for acute levels of exposure. European Council Recommendation 1999/519/EC of 12 July 1999 concerning the general public, recommends a maximum exposure of 100  $\mu\text{T}$  at 50 Hz. Decree No. 2016-1074 of 3 August 2016 on protecting workers against the risks of electromagnetic fields sets a low action level of 1,000  $\mu\text{T}$  (see 5.3.3 in the expert appraisal report).

platforms. In cars, values are generally under 2  $\mu\text{T}$ , regardless of engine type (combustion, electric or hybrid).

At the same time, the study conducted by INSERM for ANSES on levels of exposure around high-voltage and very-high voltage power lines provided a basis on which to estimate the percentage of the population subject to exposure in their homes across metropolitan France. Depending on the exposure scenario, results show that 0.28% and 0.74% of the French population are exposed to magnetic fields higher than 0.4  $\mu\text{T}$  and 0.1  $\mu\text{T}$  respectively. Around 0.35% of children under 15 years of age ( $\approx 40,000$ ) are exposed to a magnetic field of over 0.4  $\mu\text{T}$  in their homes, with significant variability from one region to the next. Around 0.18% of children ( $\approx 8,000$ ) of primary age attend a school exposed to a magnetic field of over 0.4  $\mu\text{T}$ .

Levels of worker exposure vary considerably, depending on the occupation held. In specific circumstances, for example with some industrial machinery, levels of exposure may exceed regulatory limits (see 5.3.3 in the expert appraisal report). Moreover, numerical computations have shown that the induced current density in foetuses may exceed the recommended European exposure limits for the general population<sup>3</sup> (100  $\mu\text{T}$  at 50 Hz) if the mother is exposed in the workplace.

#### ■ Assessment of the level of evidence for health effects associated with exposure to low-frequency electromagnetic fields in humans

The methodology described above was used to classify the different potential effects of exposure to low-frequency electromagnetic fields in humans. The summary of the evidence and the levels of evidence associated with each studied effect are presented in Table 35 of the expert appraisal report.

Drawing upon all the available data on the health effects of exposure to low-frequency electromagnetic fields, the collective expert appraisal work enabled a conclusion to be drawn on a possible effect of exposure to low-frequency electromagnetic fields on childhood leukaemia, even though this link is less frequently found in studies published after 2010.

Two studies out of the four on amyotrophic lateral sclerosis (ALS) show a link between this disease and certain occupations involving electricity. They nevertheless have certain limitations, since the uncertainties associated with assessing levels of exposure makes interpretation difficult. This link could be explained by several exposure factors: magnetic fields, electric shocks or synergies between physical and chemical agents, etc. Moreover, two meta-analyses highlighted a significant link but their publication bias makes them less reliable. Based on the data considered, no conclusion can be drawn today on the possible effect of exposure to low-frequency magnetic fields on ALS, but this question will require further research.

Concerning tumours of the central nervous system in adults, two studies suggest a possible link between occupational exposure to low-frequency electromagnetic fields and the appearance of gliomas or meningiomas. One study mentions an upward trend in the risk of meningiomas with borderline significance, while the other study found no link. Today, the results of the studies available are too heterogeneous for us to draw any conclusion on whether or not there is a link with exposure to low-frequency electromagnetic fields. Further studies will therefore be necessary in this field.

The same applies to studies on Alzheimer's disease (and dementia in general). Two studies and a meta-analysis found an excess risk of dementia associated with exposure to low-frequency electromagnetic fields. Nevertheless, given the heterogeneity of results and the probable publication bias, we cannot currently draw any conclusion on the existence of a link with exposure to low-frequency electromagnetic fields.

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<sup>3</sup> The conditions of exposure of pregnant women in the workplace are governed by decree No. 2016-1074 of 3 August 2016 on protecting workers against the risks of electromagnetic fields. Levels of foetal exposure to electromagnetic fields must comply with the provisions of decree No. 2002-775 of 3 May 2002 concerning the general population, based on European Council Recommendation 1999/519/EC of 12 July 1999.

At the same time, based on the data considered, we cannot draw a conclusion on whether or not there is an effect of exposure to low-frequency magnetic fields on:

- tumours of the central nervous system in children;
- breast cancer; this link was highlighted in the study by Erren *et al.*, (2001) but was not confirmed by subsequent studies;
- haematological malignancies in adults;
- other types of cancer in adults;
- Parkinson's disease.

A number of experimental studies in humans and animals highlight a possible interference between exposure to magnetic fields at low levels (of around one microtesla) and brain electrical activity. There is a level of similarity between these results and those of the “Radiofrequencies and health” expert appraisal published by ANSES in 2013, which observed a change in brain electrical activity (primarily the power of the alpha rhythm) after exposure to radiofrequencies. Complementary studies should be carried out to confirm these results and also to study the possible pathophysiological consequences.

#### ■ Recommendations in terms of exposure to low-frequency electromagnetic fields

##### **Concerning metrology**

Given that traceability and reliability remain a key issue in measuring exposure to low-frequency electromagnetic fields, the CES is adopting the recommendation set out in 2010 by AFSSET to encourage electromagnetic testing and metrology laboratories to obtain accreditation of the type issued by COFRAC (the French accreditation body) for measuring these fields.

The CES also recommends that requests received from public services (*préfectures*, town halls, etc.) to measure levels of exposure should be carried out by organisations that are able to demonstrate their technical expertise in this area through, for example, COFRAC-type accreditation.

##### **Regarding exposure of the general public**

Considering:

- the development of new sources of exposure associated with decentralised energy production, with production sources moving increasingly close to individuals;
- the significant development of new energy-consuming technologies (such as data centres) involving new potentially concentrated sources of exposure;
- the lack of data on some identified sources of exposure (vehicles, public transport, transformers, etc.);
- the many sources of exposure of the general population, particularly in the urban environment (underground power lines, signage, public transport, etc.);

the CES recommends:

- characterising the exposure to low-frequency electromagnetic fields specifically associated with transformer substations, particularly those located close to public buildings, homes or workplaces;
- assessing individual exposure to low-frequency electromagnetic fields in the urban environment, produced by a variety of sources (overhead and underground power lines, public transport, transformer substations, etc.);

- where technically possible, before implementing a new technology, assessing the exposure of future users to low-frequency electromagnetic fields using modelling techniques;
- making it easier for individuals to request characterisation of their electromagnetic environment by an accredited laboratory. To this end, the national programme for measuring electromagnetic fields put in place by the French National Frequency Agency (ANFR) could be extended to low frequencies.

### ***Regarding exposure in the workplace***

Considering the widely varying levels of electromagnetic field to which workers may be subjected depending on their job, the CES underlines the relevance of decree No. 2016-1074 of 3 August 2016, on protecting workers against the risks of electromagnetic fields, and the duty of their employers to characterise the electromagnetic environment of workstations. The CES also underlines the benefits of the coordinated action undertaken by the French National Research and Safety Institute (INRS), the Occupational Health and Pension Insurance Fund (CARSAT), and the Île de France Regional Health Insurance Fund (CRAMIF) to list the industrial equipment involving the highest levels of exposure and measure the exposure levels associated with their use.

Considering the very high levels of magnetic field to which some groups of workers are exposed and in view of the uncertainty surrounding a potential link between exposure to low-frequency electromagnetic fields and the occurrence of certain health effects (such as amyotrophic lateral sclerosis and tumours of the central nervous system) in workers subjected to chronic exposure to high levels of electromagnetic field, the CES recommends that:

- manufacturers of industrial machines emitting low-frequency electromagnetic fields (at least those in the seven categories of machine with the highest levels of exposure, as identified by the INRS) measure the exposure associated with rated conditions of machine operation and use, and include these data in the technical specifications;
- personnel medical files include a record of occupational exposure to electromagnetic fields throughout the worker's career, from one company to the next, to enable longitudinal follow-up of occupational exposure.

### ***Regarding exposure of pregnant women***

Considering:

- Article R. 4152-7-1<sup>4</sup> of the French Labour Code;
- that the induced current density in the foetus in some exposure scenarios may exceed the recommended exposure limits (European Recommendation 1999/519/EC) for the general population (100  $\mu$ T at 50 Hz) when the mother is exposed to these values;

the CES recommends:

- sending out this information to employers, preventionists, occupational doctors and occupational health services;
- that employers and occupational doctors inform women of the regulatory provisions allowing them to adapt their working conditions when they are pregnant, in order to limit foetal exposure to low-frequency electromagnetic fields.

### ***Regarding regulatory exposure limits***

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<sup>4</sup> "Art. R. 4152-7-1. - When a pregnant woman is exposed to electromagnetic fields in the workplace, exposure must be maintained at a level that is as low as it is reasonably possible to expect, taking account of recommendations on existing good practices and, in any event, at a level below the limits of exposure to electromagnetic fields applicable to the general public."

Considering:

- that *in vivo* and *in vitro* experiments have highlighted possible biological effects (oxidative stress, genotoxic stress, effects on cellular physiology) associated with exposure to low-frequency electromagnetic fields at levels of around one millitesla;
- that some categories of worker are exposed to this level of magnetic field;
- that the findings of some epidemiological studies highlight a link between exposure to low-frequency electromagnetic fields and certain diseases in the event of occupational exposure (ALS, tumours of the central nervous system);
- the results of dosimetric studies on foetal exposure;

the CES recommends that the next assessment of exposure limits should take account of all the scientific data available, with particular emphasis on the most recent data, including epidemiological studies and *in vivo* and *in vitro* studies on biological effects.

### **Regarding urban planning**

Considering the potential increase in the incidence of childhood leukaemia close to high-voltage lines and despite the absence of a proven direct causal link between exposure to low-frequency electromagnetic fields and the occurrence of childhood leukaemia, the CES underlines the relevance of the instruction of 15 April 2013 concerning urban planning close to electricity transmission lines<sup>5</sup>. This instruction recommends “avoiding, as far as possible, any decisions or authorisations to build new sensitive facilities (hospitals, maternity clinics, facilities for children, such as day-care centres and infant/primary schools, etc.) in areas close to high-voltage and very-high voltage power lines, underground cables, transformer substations or busbars, exposed to a magnetic field greater than 1  $\mu$ T”.

- **Recommendations concerning studies and research into exposure to low-frequency electromagnetic fields and the biological and health effects potentially associated with this exposure**

### **Regarding exposure**

Considering the results of digital simulation studies on pregnant women and fetuses, the CES recommends continuing studies to model exposure during pregnancy.

Considering that toxicological studies are conducted over short periods of exposure, whereas exposure to low-frequency electromagnetic fields usually takes place over the long term for the general population or workers, the CES recommends the development of a cumulative exposure indicator in order to conduct lifetime toxicological studies.

### **Regarding biological and health effects**

From a general standpoint, the CES strongly recommends creating cohorts of exposed and non-exposed workers, or maintaining existing cohorts, in order to conduct epidemiological studies on the link between exposure to low-frequency magnetic fields and the occurrence of diseases.

Also considering:

- that the number of subjects experiencing high exposure to low-frequency electromagnetic fields among the general population is low, resulting in the low statistical power of epidemiological studies on high-voltage power lines;
- that the link between exposure to low-frequency electromagnetic fields and the appearance of diseases, if it exists, is weak;

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<sup>5</sup> [http://circulaires.legifrance.gouv.fr/pdf/2013/04/cir\\_36823.pdf](http://circulaires.legifrance.gouv.fr/pdf/2013/04/cir_36823.pdf).



The CES recommends:

- studying populations exposed or potentially exposed to the highest levels of low-frequency electromagnetic fields, such as people in specific occupational categories or who live close to transformer substations (see the Transexpo<sup>6</sup> multicentre study). Particular emphasis should be placed on people (children or workers) living or working close to transformer substations and who are subjected to exposure during the day, whether through their attendance of a day-care centre or school, or as part of their job.

The CES underlines the importance of having precise home addresses for subjects in disease registers with their geographical position, to enable study of the health effects associated with environmental exposure. It recommends making these data easily available for research.

### **Childhood leukaemia**

Considering:

- that the link between exposure to low-frequency electromagnetic fields and the appearance of childhood leukaemia has been highlighted in epidemiological studies that estimated exposure to electromagnetic fields based on the distance from power lines;
- that this link was not found in epidemiological studies that estimated exposure using modelling processes or magnetic field measurements, these studies having limited statistical power;
- that no biological mechanism has been identified that could explain the epidemiological link;

the CES recommends:

- giving priority to pooled analyses, particularly for studies based on direct measurements of magnetic fields;
- encouraging epidemiological research into the effects of exposure to low-frequency electromagnetic fields taking account of possible co-exposure (such as pollutants from road traffic, for example);

Considering the scientific uncertainty that continues to surround the relationship between exposure to low-frequency magnetic fields and an increased risk of childhood leukaemia;

the CES recommends:

- encouraging the use of animal models<sup>7</sup> to study acute lymphoblastic leukaemia, primarily by developing murine models of childhood leukaemia that can be used in studies on low-frequency electromagnetic fields;

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<sup>6</sup> Transexpo is an international epidemiological study set up to assess the association between residential exposure to low-frequency electromagnetic fields and the incidence of childhood leukaemia. It involves studying a sample of children living in buildings with a medium-voltage/low-voltage transformer. The main interest of the study is that it selects subjects living in the same building, sick or healthy, and assesses their exposure based on the location of their place of residence, without specifically requiring their participation. In this way, the study avoids bias in control selection or participation.

<sup>7</sup> An alteration to the structure of one or more genes can cause a predisposition to developing a given disease. For this reason, some animals are genetically modified to be predisposed to developing a given disease. In this way, they can be used to analyse the influence of environmental factors in the induction of the disease.

- studying the possible role of other factors of proven toxicity (genotoxic or co-carcinogenic agents, etc.) in order to understand through experimentation the relationship between low-frequency magnetic fields and the occurrence of childhood leukaemia.

### **Meningiomas**

Considering the heterogeneous results concerning a link between exposure to low-frequency electromagnetic fields and the occurrence of meningiomas, the CES recommends continuing epidemiological studies, particularly in workers.

### **Ocular melanoma**

Considering:

- that only one major study has found a link between occupational exposure to low frequencies and the occurrence of ocular melanoma;
- that this study failed to take account of certain confounding factors and implemented an imprecise method of data collection;
- that this disease is rare (500 cases/year in France);

the CES recommends conducting an international study and/or a pooled study to confirm or refute this result.

### **Amyotrophic lateral sclerosis (ALS)**

Considering:

- the identification by a small number of epidemiological studies of an association between ALS and exposure to low-frequency electromagnetic fields in workers;
- the lack of data on the chronic exposure of workers to low-frequency electromagnetic fields;
- the identification of a number of biological effects (oxidative stress) at exposure levels of around one millitesla, possibly found in some workers;
- that these biological effects mainly concern oxidative stress and that an existing ALS murine model involves an enzyme for oxidative balance (superoxide dismutase mutation);

the CES recommends:

- giving priority to continued research into ALS, primarily with murine models specific to this disease;
- pursuing systematic and continuous registration of cases of ALS in order to encourage research through a population register placing the emphasis on occupational history. This would be similar to the Irish registry of motor neurone diseases, including ALS, as well as primitive lateral sclerosis and Kennedy's disease;
- continuing epidemiological studies in the workplace;
- assessing the relative proportion of risk for workers arising from either exposure to low-frequency electromagnetic fields or from the electric shocks that they may potentially have suffered.

## **Dementia and Alzheimer's disease**

Considering:

- the non-homogeneous results concerning the appearance of Alzheimer's disease;
- the association observed in two studies between occupational exposure to low frequencies and the appearance of dementia;
- that this association was more significant in workers who had suffered electric shocks;
- that certain cognitive disorders were highlighted in animals exposed to low-frequency electromagnetic fields;

the CES recommends:

- studying types of dementia other than Alzheimer's disease (frontotemporal dementia, Lewy body dementia, vascular dementia, etc.);
- assessing the relative proportion of risk for workers arising from either exposure to low-frequency electromagnetic fields or from the electric shocks that they may potentially have suffered.

## **Study of brain function**

Considering a number of studies that have highlighted:

- alterations in memory capacity as well as in levels of anxiety and emotion in animals, following exposure to low-frequency fields;
- alterations in brain plasticity and neurogenesis following exposure to low-frequency fields;
- disruptions in event-related potentials (EEG signals of very low intensity) in response to exposure to low-frequency fields in humans or animals;

the CES recommends:

- continuing research in these fields in order to confirm or refute these results;
- finding out more about the biological mechanisms potentially involved;
- assessing the possible pathological consequences of these effects on children and adults.

## **4. AGENCY CONCLUSIONS AND RECOMMENDATIONS**

This expert appraisal brings together the current knowledge available on exposure to low-frequency electromagnetic fields and their possible biological and health effects. In order to assess the level of evidence for the health effects reported in the literature, this opinion followed and adapted the methodological principles outlined in the ANSES report on exposure to radiofrequencies and child health (ANSES, 2016), concerning the identification of articles from the scientific literature, the analysis of publications, as well as the determination of evidence.

Concerning knowledge of exposure, ANSES sought to compensate for the lack of available information by drawing upon studies conducted primarily in the workplace and by undertaking original work to improve characterisation of the electromagnetic environment of individuals in the home.

However, the electromagnetic environment is changing, for example with the development of renewable energies and the decentralisation of electricity production to be closer to consumers. This has modified the spatial distribution of electromagnetic field sources. The changes in population exposure to the low-frequency electromagnetic fields that could be brought about by these new developments have not been documented to date.

ANSES endorses all the conclusions and recommendations of its Expert Committee on "Physical agents, new technologies and development areas". Below, it clarifies and supplements the recommendations on adapting the regulatory framework in terms of urban planning and exposure limits, managing exposure in the workplace and improving knowledge of the link between exposure to low-frequency electromagnetic fields and some diseases.

#### ■ **Strengthen and adapt legislation on exposure limits**

The limits for public exposure to electromagnetic fields suggested in European Council Recommendation 1999/519/EC of 12 July 1999 are not, by definition, binding. The Ministerial Order of 17 May 2001 setting out the technical terms and conditions to be satisfied in electricity distribution specifies exposure limits only for electromagnetic fields close to high-voltage power lines. This means that levels of population exposure to low-frequency electromagnetic fields are not subject to any regulations in France, other than in areas close to electricity transmission and distribution lines. In consequence, ANSES recommends extending the current regulatory framework for electricity transmission lines to all situations in which the general population is exposed.

#### ■ **Strengthen urban planning regulations**

In 2010, ANSES observed consistency in the results of epidemiological studies showing a statistical association between the occurrence of childhood leukaemia and residential exposure to low-frequency magnetic fields where average levels over 24 hours exceeded 0.2  $\mu\text{T}$  or 0.4  $\mu\text{T}$ , depending on the study. The results of this expert appraisal still concur with this conclusion.

The instruction of 15 April 2013 concerning urban planning close to electricity transmission lines advised establishment managers and urban planning authorities against building new sensitive facilities in areas exposed to a magnetic field greater than 1  $\mu\text{T}$ .

A study conducted by INSERM for ANSES quantified the proportion of the French population, and more specifically the proportion of children, who are exposed to this level of field, owing to the proximity of their homes or schools to high- or very-high voltage power lines. Depending on the exposure scenario adopted, the results show that around 0.35% (or 0.56% respectively) of children under 15 are exposed in their homes to a magnetic field of more than 0.4  $\mu\text{T}$  (or 0.2  $\mu\text{T}$  respectively). Around 0.18% (or 0.29%) of children of primary age attend a school exposed to a magnetic field of more than 0.4  $\mu\text{T}$  (or 0.2  $\mu\text{T}$ ).

As a result, the Agency is reaffirming its recommendations set out in 2010 to adopt a precautionary approach, to avoid any increase in the number of vulnerable people exposed around very high-voltage power lines and to limit exposure. To this end, the Agency recommends including the instruction of 15 April 2013 in regulations.

#### ■ **Manage occupational exposure**

A study conducted by the French National Research and Safety Institute (INRS) and the Occupational Health and Pension Insurance Funds (CARSAT) showed that some workers could be exposed to fields of very high levels, potentially exceeding the exposure limits set out in decree No. 2016-1074 of 3 August 2016 transposing European Directive 2013/35/EU of the European Parliament and of the Council of 26 June 2013 on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (electromagnetic fields).

ANSES underlines the importance:

- of enforcing these regulatory provisions regarding occupational exposure to electromagnetic fields, established by decree No. 2016-1074 of 3 August 2016. In order to assess the risks associated with electromagnetic fields, a number of specific tools are available for characterising occupational exposure. One such tool is OSERAY<sup>8</sup>;
- of reducing situations of overexposure, for example by adapting workstations.

In addition, the Agency recommends that manufacturers of industrial machines emitting low-frequency electromagnetic fields (at least those in the seven categories of machine with the highest levels of exposure, as identified by the INRS), measure the exposure associated with rated conditions of machine operation and use, and include these data in the technical specifications.

On this same subject, it recommends that the public authorities examine the relevance of the European directives applicable to these machines in order to complete them, as needed, to take account of these aspects and to include them in the process leading to CE marking.

Moreover, given that when pregnant women are exposed to a magnetic field of an intensity corresponding to the occupational exposure limits, the induced current density in the foetus may, in some scenarios, exceed the European exposure limits recommended for the general public, ANSES recommends:

- sending out this information to employers, and occupational physicians;
- that employers, preventionists, occupational physicians and occupational health services take steps to inform women of the regulatory provisions allowing them to adapt their working conditions when they are pregnant, in order to limit foetal exposure to low-frequency electromagnetic fields.

Lastly, the results of this expert appraisal show that biological effects (oxidative stress, genotoxic stress, effects on cellular physiology) occur at levels of exposure around the action values set out in decree No. 2016-1074 of 3 August 2016. Moreover, some epidemiological studies highlight a link between occupational exposure to low-frequency electromagnetic fields and the occurrence of certain health effects (neurodegenerative diseases and tumours of the central nervous system). ANSES therefore recommends assessing the pertinence of the scientific knowledge underpinning exposure limits.

#### ■ **Continue research into the possible risk of diseases associated with exposure to low-frequency magnetic fields**

Given the continuing uncertainty surrounding the link between exposure to magnetic fields and childhood leukaemia, ANSES recommends continuing research:

- into the populations that are most at risk, for example, by supporting the funding and implementation of the Transexpo study into homes located close to transformers;
- by improving assessments of exposure in epidemiological studies, for example by combining field measurements with modelling.

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<sup>8</sup> OSERAY is an application designed to help employers assess the risks arising from electromagnetic radiation. <http://www.inrs.fr/media.html?refINRS=outil61>.

In the workplace, considering the uncertainty surrounding recent data suggesting an association between exposure to low frequencies and the appearance of brain tumours or neurodegenerative diseases such as Alzheimer's disease or amyotrophic lateral sclerosis, a causal link cannot be established.

ANSES therefore recommends encouraging research into occupational epidemiology to study these health effects.

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#### **KEYWORDS**

Champs électromagnétiques, basses fréquences, leucémies, exposition, électricité, enfants, leucémie infantile, sclérose latérale amyotrophique

*Electromagnetic Fields, Extremely Low Frequencies, Leukaemia, Exposure, Electricity, Children, Childhood leukaemia, Amyotrophic lateral sclerosis*