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PARLIAMENTARY OFFICE FOR THE EVALUATION OF SCIENTIFIC AND TECHNOLOGICAL CHOICES

REPORT

On

"The health and environmental effects of electromagnetic fields produced by high and extra high voltage lines"

by Mr. Daniel RAOUL, Senator

Filed with the Bureau of the National Assembly

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Filed with the Bureau of the Senate

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First Vice-Chairman of the OPECST

CONTENTS

INTRODUCTION

Ladies and Gentlemen,

New technological projects, whatever they may be, have become subjects for debate in today's societies.

This is deplored by some, who blame obscurantism or ignorant interference in questions that are by nature complex and often difficult to master from every angle.

However, your *rapporteur* is convinced that this major evolution on the part of Western societies is the fruit of their ongoing democratization. Yesterday's hierarchical society - whether a social, ecclesiastical, entrepreneurial, political or scientific hierarchy - has today been replaced by a society in which all players, all citizens and all associations desire to participate in the decision-making process. Every government initiative must be debated and enjoy a certain level of consensus in order to be implemented. While this is certainly a constraint, it is also a strength.

While previously scientific progress was considered of superior value and therefore remained unquestioned, today some wonder whether science is progressing at a greater speed than society and or in an undesired direction. The calling into question of science's value can be perceived, experienced or intended as a questioning of the very idea of progress. In any event, this questioning certainly represents a call for greater governance, control and participation. It represents an important issue for our technological societies.

This new situation both feeds on and sustains two new concerns: environmental protection and health protection. As with democratization, these concerns are the source of not only new imperatives, but also new opportunities.

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This report commissioned by the Parliamentary Office for the Evaluation of Scientific and Technological Choices (OPECST) on the possible health and environmental effects of extremely low frequency electromagnetic fields emitted by high and extra high voltage lines falls within this context.

This subject of inquiry is fundamentally different from that of mobile telephony and relay antennas that have already been the subject of two

OPECST reports[1], the term "electromagnetic field" capable of causing some confusion. However, neither the frequency bands nor the sources are the same. Your *rapporteur* will return to this subject later in the report, but it was necessary to make this distinction from the beginning.

Likewise, this report does not consider all sources of extremely low frequency electromagnetic fields, but only high and extra high voltage lines, although your *rapporteur* will seek to shed some light on this issue for a better understanding of the stakes involved.

On the other hand, this report is not wholly independent in origin of the large scale energy infrastructure programmes already underway. However, your *rapporteur* wanted to treat this issue as separately and distinctly as possible so as to benefit from all scientific knowledge in considering the questions raised.

In this respect, it is important to point out that this report was not motivated by the publication of new scientific studies, but rather by the growing concerns of those living near the installations and of the French population as a whole, as illustrated by recent public debates and sociological studies.

In this same spirit and despite the significant delay engendered, your *rapporteur* desired to await the publication of the report by the French Agency for Environmental and Occupational Health Safety (AFSSET) on the health effects of extremely low frequency electromagnetic fields. Indeed, AFSSET had been commissioned in June 2008 to prepare a summary of the national and international studies available to date, to specify the population's exposure, and to make recommendations; in addition, the "Grenelle 1 Act" called for a report to be presented to the French Parliament. This document was made public on 6 April 2010.

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By commissioning a report from the OPECST, the Senate Economic Affairs Commission relaunched a debate that had been open for over thirty years: Do high voltage lines pose a health risk?

Indeed, doubts have persisted ever since 1979 and the first publication by Nancy Wertheimer. The gravity of the accusation has remained serious, seeing that this initial study demonstrated a link between the triggering of leukaemias among children and the proximity of high voltage lines.

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[1] Alain Gest, *Les incidences éventuelles sur la santé de la téléphonie mobile* (*"The Possible Health Impacts of Mobile Telephony"*), Nov. 2009, National Assembly ref: 2005 (13th legislative term), Senate ref: 84 (2009-2010).
Jean-Louis Lorrain, Daniel Raoul, *L'incidence éventuelle de la téléphonie mobile sur la santé* (*"The Possible Health Impact of Mobile Telephony"*), Nov. 2002, National Assembly ref: 346 (12th legislative term), Senate ref: 52 (2002-2003).

Where can be said today? What is the state of current scientific knowledge? Must the authorities take measures to protect the population?

In addition to this question, a second issue has developed, starting in the United States, surrounding the impact of these same lines on animal husbandry. Although less sensitive in nature, this subject also merits clarification in the light of relevant scientific publications that have appeared over the past many years.

To answer these questions, your *rapporteur* would first like to place them within their context, by, on the one hand, specifying what electric and magnetic fields are and what is known concerning the population's exposure to these fields and, on the other hand, by considering France's own network of high and extra high voltage lines.

Next, this report will deal with the possible health effects of these fields by considering three specific concerns currently being debated: juvenile leukaemias, neurodegenerative diseases and electromagnetic hypersensitivity (EHS).

Finally, it will answer questions concerning these fields' impact on wild animal life and on animal husbandry.

I. EXPOSURE TO EXTREMELY LOW FREQUENCY ELECTRIC AND MAGNETIC FIELDS

To understand and measure the potential impact of the fields emitted by high and extra high voltage lines, this report will first explain what these fields are and take stock of the relative importance of the various emission sources and of the population's and individuals' exposure to these fields.

Your *rapporteur* will close this first part of the report with recommendations to improve the available data.

A. ELECTRIC AND MAGNETIC FIELDS: A FEW DETAILS

1. Electric, magnetic and electromagnetic fields

A field is a physical phenomenon by which energy is exchanged and forces are exerted on and effect objects at a distance. It is characterized by its intensity and direction. The term "field" commonly refers to the area in which this phenomenon occurs. An object falls either within or outside the field.

Apart from electromagnetism, the most well known field is undoubtedly the attraction between celestial bodies – for instance, between the Earth and the Sun or between the Earth and the Moon - or on the surface of the Earth itself: the force of gravity, first discovered by Newton, by which objects are pulled down towards the ground.

Electric and magnetic fields are first and foremost natural phenomena. They are a prerequisite for life. AFSSET experts point out that: "On Earth, these fields are much more intense than the gravitational field, for it is these fields that ensure the intercohesion of atoms, which allows for the construction of molecules and, generally speaking, of matter, including that which makes up our bodies. Therefore, it is these fields that prevent each of our molecules from falling to the ground due to the gravitational field".

Electric and magnetic fields are intimately linked for the intermediate and radio frequencies. One can therefore talk of "electromagnetic fields". **However, it is essential to point out that this is not the case for extremely low frequency fields. It is therefore inappropriate to speak of electromagnetic fields. These two fields must be dealt with separately.**

In addition, and as your *rapporteur* will explain in detail, only the magnetic field is seen as posing possible health risks.

Electric fields are produced by differences in electric potential. The higher the voltage, the more intense the resulting field. Electric fields can occur even in the absence of any electric current flow.

Electric fields are associated with the presence of positive or negative charges. **The intensity of an electric field is measured in volts per metre (V/m).** All live electric wires produce an electric field. This field exists even in the absence of any current flow. For any given distance, the higher the voltage, the more intense the field.

Electric field intensity decreases rapidly, proportional to the inverse of the square of the distance between the emission source and the measurement point ($1/d^2$).

A metallic conductor constitutes effective protection and, to a lesser extent, all other types of obstacles.

For this reason, the electric field of a buried power line is hardly discernable.

However, **magnetic fields only occur in the presence of a flowing current**. These fields are produced by moving electric charges. The stronger the current, the more intense the magnetic field. The intensity of a magnetic field is measured in amperes per metre (A/m); however, in research and in technical applications, it is more common to use a different scale: **magnetic flux density or magnetic induction**. This is measured in tesla (T) or, more commonly, **microtesla (µT)**.

Magnetic field intensity also decreases rapidly in proportion to the square of the distance and sometimes even more rapidly depending on source geometry (for instance, the cube of the distance ($1/d^3$).

So, **in the presence of an electric current, the intensity of the magnetic field will vary according to electric consumption, while the intensity of the electric field will remain constant**.

Therefore, an electric field exists with or without a magnetic field; however, if a magnetic field exists, it is always accompanied by an electric field.

At this point, it is useful to remember a few physical scales and their units of measurement:

Physical scale	**Unit of measurement**
Voltage	volt (V)
Electric current	ampere (A)
Electric power	watt (W)
Electric field	volts per metre (kV/m)
Magnetic induction	tesla (T)
Frequency	hertz (Hz)

Likewise, it is necessary to review the various scale prefixes that can subsequently be used and that, for greater simplicity, vary amongst themselves by three decimal points in either direction (a one-thousand-fold increase or decrease in scale). For example, an exposure to a few millitesla is some 10,000 times greater than an exposure to a few tenths of a microtesla:

Giga	1,000,000,000 (10^9)
Mega	1,000,000 (10^6)
Kilo	1,000 (10^3)
Unit	1
Milli	0.001 (10^{-3})
Micro	0.000,001 (10^{-6})
Nano	0.000,000,001 (10^{-9})
Pico	0.000,000,000,001 (10^{-12})

2. Static and alternating fields of high and low frequencies: the electromagnetic spectrum

An electromagnetic field is characterized by its frequency or the wavelength of its emission.

Frequency is the number of oscillations or cycles per second.

Wavelength is equal to the distance between a point on one wave and the same point on the next wave.

The higher the frequency, the shorter the wavelength, and vice versa.

There exist **static magnetic fields** that remain constant over time. This is the case with magnets. The geomagnetic field is also a static field, created by movements of the Earth's core. Its force is some 50µT in France. A static field, whose frequency is therefore nil, can nevertheless be intense.

To illustrate this phenomenon, AFSSET prepared a diagram placing various sources according to their intensity and allowing for comparisons to be made between, in particular, the magnetic fields of the human body and artificial magnetic fields:

Field intensity (in tesla)	1	10^{-5}	10^{-7}	10^{-8}	10^{-9}	10^{-11}	10^{-13}	10^{-15}
Activity	MRI	Earth	Environmental noise	Car at 50 m	Adult heartbeats	Foetus heartbeats	Adult brain	Foetus brain

In addition, there exist alternating fields characterized according to their frequency.

Extremely low frequency fields are those with a frequency of up to 300 Hz (for example, an electric current). An **alternating current will create a field that varies over time**, with the current changing direction at regular intervals; for instance, **50 cycles per second (50 Hz) for the electric current in European countries**.

Medium frequency fields (300 Hz to 10 MHz) are created by some electrical appliances (for example, computer screens and anti-theft devices).

Radiofrequencies vary from 10 MHz to 300 GHz (hertz and ultrahertz range) and are used by radios, televisions, radar, mobile telephones and microwaves. The intensity of these fields is also measured in watts per square metre (W/m²), or power density.

Beyond radio frequencies lie **ionizing radiations**. Electromagnetic waves are carried by energy particles known as "quanta". The higher the frequency, the greater the amount of energy carried. The energy can be sufficiently great to break intra- and intermolecular connections. This is notably the case with regard to cosmic rays, X-rays and gamma rays emitted by radioactive substances. These are referred to as "ionizing radiations". Other forms of radiation with insufficient energy and without this capacity are known as "non-ionizing radiations".

To aid comprehension, all of these radiations can be presented in a synthetic manner within the framework of the electromagnetic spectrum:

Radiation	Frequency	Range	Application examples
Non-ionizing	0Hz	Static fields	Magnets, MRI
	3-300Hz	Extremely low frequencies (ELF)	Electric network and electrical appliances
	300 Hz to 30 kHz	Intermediate frequencies	Video screens, induction heating
	30 kHz to 300 GHz	Radio frequencies	Radio broadcoasting, television broadcasting, mobile telephones, microwave ovens, radars, satellite-based communications
	300 THz to 385 THz	Infrared	Anti-theft devices, remote controls
	385 THz to 750 THz	Visible	The Sun, lazers
	750 THz to 3 PHz	Ultraviolet	The Sun, light therapy
Ionizing	3 PHz to 30 PHz	X-rays	Radiology
	Greater than 30 PHz	Gamma rays	Nuclear physics
k=kilo=10^3, M =mega=10^6, G=giga =10^9, T=tera =10^{12}, P=peta =10^{15} Source: Fondation Santé et Radiofréquences ("Health and Radio Frequencies Foundation")			

B. ARTIFICIAL SOURCES OF EXPOSURE TO EXTREMELY LOW FREQUENCY MAGNETIC FIELDS

To measure the magnitude of fields emitted by transmission lines, one can compare them to other sources of magnetic fields to which the population is exposed. The most common sources are primarily electrical appliances, professional electrical devices and electric transport.

1. Household appliances and professional devices

People are exposed to magnetic fields within households.

This exposure is the result of household electric wiring and the use of electrical appliances.

The household magnetic field created by a home's electric wiring is around 0.2 µT, according to AFSSET, based on data provided by the World Health Organization (WHO).

The field emitted by household appliances, however, varies greatly according to the type and model of the appliance.

AFSSET carried out a series of measurements through Supélec (a *grande école* of engineering). Below is an overview of the results at a distance of 30 cm:

Device	**Magnetic field (µT)**	**Electric field (V/m)**
Alarm clock radio A	0.08	16
Electric kettle A	0.06	11
Toaster	0.21	10
Dishwasher	0.21	9
Alarm clock radio B	0.14	30
Espresso machine	0.7	8
Microwave oven A	3.6	13
Stove oven	0.2	6
Microwave oven B	7	4
Induction cooker	0.2	32
Hairdryer	0.05	28
Personal computer power feed	0.02	18
Electric kettle B	0.05	18
LCD TV (15 inch)	0.01	75

In general, at a distance of 1 metre, the field is lost in the ambient noise. Most of these sources are intermittent; meaning, they are not always on and in use.

These figures, which were calculated using the same methodology and devices in the same laboratory, complement and confirm the various measurements carried out by foreign bodies that AFSSET was able to collect.

These foreign measurements, carried out between 1986 and 2009, illustrate the extreme variability of this type of data. Nevertheless, they provide a good idea of the expected exposure within a household where electrical appliances are used on a systematic and daily basis:

Device	Magnetic field (μT)
Toaster	0.006 to 0.7
Dishwasher	0.6 to 0.3
Coffee machine	0.08 to 0.15
Hotplate	0.1 to 0.35
Refrigerator	0.01 to 0.4
Stereo system	0.19
Cathode ray display - TV	0.04 to 1
Iron	0.12 to 0.3
Drill	2 to 3.5
Washing machine	0.15 to 3
Electric saw	1 to 25
Dryer	0.08 to 0.3
Razor at 3 cm	15 to 1,500
Hairdryer at 6 cm	6 to 2,000
Electric blanket at 3 cm	0.3 to 5
Bedside lamp	2
Electric alarm	0.1 to 1
Incandescent light bulb	2
Vacuum	2 to 20
Electric underfloor heating	8 to 12
Domestic electricity meter	0.6 to 3.5
Halogen lamp	0.17
Electric radiator	0.15 to 5
Fan	0.03 to 4

Evaluating the exposure to these types of sources is complicated by their potentially mixed nature, intended for both professional and domestic use.

AFSSET also collated the results of studies carried out between 1984 and 2009, in order to furnish magnetic field measurements for typical devices:

Device	Magnetic field (µT)
Photocopier	1 to 1.2
Fax machine	0.4
Computer screen	0.7

Likewise, AFSSET cites a 2007 Canadian study (Frenette and Barre) on the exposure of 64 hairdressers to magnetic fields emitted by hairdryers in 33 salons in the Montreal region. The authors demonstrated the potentially high exposure for this particular profession and the impact of an a priori harmless device. They concluded that it is necessary to attempt to limit this exposure, in particular for pregnant women.

2. Electric transport

Electric railways appear to be important sources of exposure for both professionals and private individuals.

The Expers study on the exposure of the population demonstrated, in particular, that the use of electric transport was a notable cause for variations in exposure between adults and children.

SNCF (the French National Railway Corporation) furnished AFSSET with relatively precise data and, in addition, was questioned by your *rapporteur*.

In a TGV (high-speed rail) driving cab, the field is 12.5 µT and can reach 37.5 µT in a double TGV driving cab at full speed. In the other engine types, the fields are comparatively weaker, varying from 1.25 to 6.25 µT. This amounts to a form of occupational exposure suffered by the driver. Although significant in magnitude, it remains well below current standards.

Passengers are exposed to a field of around 7 µT onboard the TGV Atlantique and around 2.5 µT onboard the Méditerranée TGV Duplex (the latter magnitude being lower as a result of the second train's aluminium structure).

According to an American studied carried out in 1993 in view of a possible exportation of the TGV, the field was estimated at 0.7 µT in proximity to the rails and 0.59 µT in the station.

3. High and extra high voltage transmission lines

A line is considered high voltage starting at 50,000 V. 400 kV is the maximum voltage for lines in France. Abroad - in particular, for very long distance transport - lines exist with a voltage of 1 million and more volts.

It is not the line's "nominal" voltage that creates the magnetic field, but rather its amperage; in other words, the magnitude of the current effectively flowing through the line. Even if a high voltage line is meant to carry a great quantity of electricity, the amount of electricity varies depending on its position within the network, the time of year and the time of day.

The charge is stable coming out of a continuously producing power plant, such as a nuclear plant. However, the charge will fluctuate significantly originating from a discontinuous source such as a hydroelectric dam, wind turbines or a gas-burning power station called upon to deal with a peak in consumption.

A line can also be used only occasionally, such as the Cusset-Vénissieux line outside Lyon, which serves as a backup line only around 30 days out of the year.

Located on the outskirts of a greater urban area, the line's electric charge will vary according to consumption: during the course of the day and week and from season to season.

The measurements carried out in situ are therefore extremely telling; the graphs illustrate the decrease in the charge during the night and the evening peak of consumption. They also illustrate possible charge transfers, or changing consumption over the year according to luminosity and temperature, for example.

But the transmission line is also subject to certain technical and operational constraints that depend on the outside temperature and the necessity to minimize electricity losses during transmission, essentially by the heat diffused.

Once this general framework has been drawn up, it is advisable to determine the order of magnitude of the electric and magnetic fields emitted by the high and extra high voltage lines.

Examples of electric and magnetic fields at 50 Hz for overhead power lines (source: RTE, France's electricity transmission network):

	Electric fields (V/m)			Magnetic fields (µT)		
	Under the line	At 30 m	At 100 m	Under the line	At 30 m	At 100 m
400 kV	5,000	2,000	200	30	12	1.2
225 kV	3,000	400	40	20	3	0.3
90 kV	1,000	100	10	10	1	0.1
20 kV	250	10	-	6	0.2	-
230 V	9	0.3	-	0.4	-	-

Magnetic fields are weaker for buried lines (source: RTE):

	Ribbon cables			Trefoil cables		
	Directly below	At 5 m	At 20 m	Directly below	At 5 m	At 20 m
225 kV	20 µT	4	0.3	6	1	0.1
63 kV	15 µT	3	0.2	3	0.4	-

Transformers meant to lower or raise the voltage constitute a second source of exposure for the population linked to electricity transmission. In proximity to a transformer, the field varies from around 20 to 30 µT.

C. RESEARCHING MAGNETIC FIELD EXPOSURE

These various magnetic field emission data, measured at a certain distance from emitting devices, only provide a vague idea of the population's overall exposure and the exposure of individuals to these types of fields.

However, carrying out such an estimation or measurement proves very complex, though essential if one is to attempt to measure the possible effects of such exposure.

1. The various methods of measuring exposure

Several methods can be used to measure exposure to magnetic fields.

Until recently, indirect measurements were almost exclusively utilized.

The well known and classic example is making use of the wiring or cabling code - in other words, the classification of lodgings according to their

distance from a power line and the cable diameter of this line – which was used in the 1979 study by Wertheimer and Leeper.

This simple approach was again recently used by Draper in his 2005 study (distance at the time of birth of an individual's home to a high voltage line).

The distance to the line serves as an estimation of exposure. While this measurement is meant to sum up exposure, it takes into account neither the line's charge and charge variations, nor exposure within the household, nor, of course, past exposure.

For the most part, studies carried out prior to 1979 measured more precisely the exposure of individuals. In particular, researchers developed quasi-direct measurements of exposure at fixed locations: the bedroom, the school and representatives of the "living environment", over long periods, during the day or during the year. These measurements allow for more precise data and an approximation of the exposure of individuals.

More recent studies have attempted to determine the exposure of individuals by asking participants to wear a portable dosemeter. These devices provide instantaneous measurements at three-second intervals, but they obviously do not provide a history of exposure, nor, for the time being, measurements over time.

2. Three foreign studies of population exposure

A consultation of the international scientific bibliography uncovers three studies carried out in the United Kingdom (1999), Germany (2001) and Taiwan (2007) on the population's overall exposure to extremely low frequency magnetic fields. All three studies are considered in the AFSSET report.

In the United Kingdom, the study covered 6,670 households. 2.3% presented an exposure of over 0.2 µT and 0.4% an exposure of over 0.4 µT, with only 20% of these households located near high voltage lines (within 400 m).

In Germany, the study looked at 1,835 households. In 1.4% of these households, the median was greater than 0.2 µT and in 0.2% greater than 0.4 µT; electricity distribution often seemed to be the cause of this excessive exposure.

The Taiwanese study examined 2,214 households in direct link with the presence of children under the age of 7 at home. Average exposure stood at around 0.12 µT. An average exposure of greater than 0.4 µT was discovered in 5.4% of the cases studied.

3. Recent French studies on the exposure of individuals

In France, two recent studies allow for a more precise idea of the exposure of individuals to 50 Hz magnetic fields.

a) The Champlan study

During the winters of 2007 and 2008, AFSSET carried out through Supélec a series of measurements targeting the 50 Hz magnetic field within the municipality of Champlan. This study fell within a wider study, coordinated by the French Environment and Energy Management Agency (ADEME), that considered all forms of pollution affecting the municipality.

The municipality of Champlan is, in fact, crossed by several high voltage and railway lines. The objective was therefore to measure the impact of these lines, while at the same time separating them from domestic sources of exposure.

18 volunteers were selected, 7 of whom for their proximity to high voltage lines. Their exposure was measured over a 24-hour period. The frequency of the measurements and the distinction between the fundamental frequency and the harmonics, as well as the interview the following day with Pr Azoulay from Supélec allowed for the identification of all emission sources with the recorded measurement.

This produced day-long profiles in which each activity manifested itself: proximity to high voltage lines, use of an appliance, train traffic, passing through a walk through scanner, and even for those living near high voltage lines: changes in exposure over time according to the charge of the line over the course of the day and the location within the house (upstairs, ground floor, garden, etc.).

In most cases, exposure was low. In 12 cases, average exposure over 24 hours fell below 0.2 µT and in a single case, exposure was greater than 1 µT. However, multiple peaks in exposure were observed, most often explained by the use of a microwave or various other household appliances, or by walking through the anti-theft scanner at a supermarket.

This study was obviously limited in scope. Nevertheless, it opened up interesting avenues:

- The characterization and possible quantification of various sources.

- The possibility of defining exposure profiles allowing for a more precise appreciation of the effective exposure of certain population categories.

b) The Expers study

The Expers study was carried out by a second Supélec laboratory within the framework of a thesis supervised by Pr Gilles Fleury.

The study followed a 2004 request by the Conseil Supérieur d'Hygiène Public de France or CSHPF ("French Council on Public Health") for a scientific evaluation of the French population's exposure to extremely low frequency magnetic fields.

This study was almost entirely funded by RTE (700 of the 720 thousand euros, the remaining funds provided by the Ministry of Health).

The objective was to measure exposure over 24 hours and to characterize it for a sample group of 1,000 children (aged between 0 and 14 years) and 1,000 adults.

The recruiting of volunteers proved to be very difficult. Over 95,000 telephone numbers were dialed: 47% of the calls were answered, but only 3% agreed in principle to take part in the study. On average, 70 minutes were necessary to convince the volunteers to participate in the programme, as compared to only 3 minutes on average for the agency that carried out the operation. The crux was finding child participants. The researchers finally had to settle for the simultaneous volunteering of a parent and a child from the same family (523 redundancies out of 2,000 participants), which also engendered an over-representation on the part of women within the sample group (64%). Nevertheless, children under six years of age were greatly under-represented compared to the French population as a whole; this constituted a real shortfall, as your *rapporteur* will later demonstrate. A total of 2,032 data series were validated and analyzed.

The initial results illustrated the lower exposure of children compared to adults.

But proportionally speaking, more children were exposed on average to over 0.4 µT. Only two children were exposed based on the geometric mean, 30 children if one takes into account the arithmetic mean of 3.1%.

Among these children, in 20 cases, exposure was due to the presence of a single alarm clock radio and, in 4 additional cases, by the presence of both an alarm clock radio and an RTE, ERDF (subsidiary of Electricité de France) or SNCF source. In one case, the child lived and attended school near an SNCF line. In four cases, the source was an electrical appliance. In one case, the source was a single ERDF line (under 50 kV).

The number and proportion of adults exposed on average to over 0.4 µT were lower: 0 adults for the geometric mean and 11 for the arithmetic mean. In 9 cases, alarm clock radios were the cause. In two other cases, electrical appliances were the source.

Because these results gave too great importance to the presence of alarm clock radios placed next to the bed during the night - the measuement devices being frequently placed on the bedside table – an **analysis of exposure during the waking hours** was also carried out.

During the waking hours, only 11 children presented an average exposure of over 0.4 µT (arithmetic mean), for the most part due to the presence of electrical appliances and, once again, alarm clock radios (2 cases). For the adults: in three cases, rail transport was the cause of exposure, in four cases electrical appliances were to blame, and in two cases the participants' profession was the source.

For the sample group, the proximity to overhead transmission lines or overhead railway power lines appeared to be a factor of over-exposure.

The first study to examine the individual exposure of a population on a national scale, the Expers study shed invaluable light on this subject.

However, the study suffered from significant biases with regard to its recruiting of participants and provided only a small amount of data on the exposure of young children in proximity to transmission lines.

4. Exposure to the fields emitted by high and extra high voltage electric lines in France

A study on the exposure of the French population to magnetic fields emitted by high and extra high voltage lines was carried out in 2004 in the Côte-d'Or department by Electricité de France (EDF). The study examined 237 residences categorized according to their proximity to 400 kV, 225 kV and 63 kV lines. Average exposure for these households was 0.005 µT (Clinard et al.).

Based on this study, **RTE estimates that 375,000 people in France (0.6% of the population) are exposed to a magnetic field of over 0.4 µT**.

However, AFSSET believes that this study is too small and difficult to generalize from, given the nonrepresentative nature of the chosen residences.

For its part, AFSSET points to a 2003 Belgian study indicating an exposure rate for children of over 0,4 µT within a range of 0.26 to 0.63%, a result coherent with the RTE data.

D. YOUR RAPPORTEUR'S RECOMMENDATIONS

Based on these initial results, your *rapporteur* has drawn a few conclusions.

- For extremely low frequencies, **one cannot talk of electromagnetic fields; rather, one must distinguish between electric fields and magnetic fields**.

- **The magnitude of a magnetic field is determined by the power of the transmission line, its amperage, and not its nominal voltage**

(expressed in volts). It is nil in the absence of an electrical transmission and continuously varies according to the charge.

- High and extra high voltage lines are far from being the only emission sources of extremely low frequency magnetic fields. Other sources can play an important or, at the very least, significant role in the exposure of a given individual. This point must be kept in mind, **especially when considering the chronic effects of weak exposures of around 0.4 µT**.

- While the exposure of the overall population and especially the exposure of individuals to extremely low frequency magnetic fields is certainly better known, it remains in reality little understood.

The average overall exposures that are calculated provide only a limited amount of information due to the measurement methods employed.

The exposure rates of individuals measured over short periods of time are, for the time being, too limited in number to, for instance, provide exposure typologies according to specific profiles.

Furthermore, within the framework of studying the potential, long-term effects of exposure to these fields, it is today impossible to characterize the type of exposure to be measured that could have a causal effect: peak accumulations? Continuous minimal levels? Averages?

Consequently, **your *rapporteur* believes that new studies must be carried out** in order to further our understanding of exposure, based on measurements rather than calculated reconstitutions:

- At the overall population level, by seeking to reliably determine the average exposure level and, for instance, according to housing type and location.

- At the individual level, to better determine the exposure of very young children and, more generally, of individual typologies.

These measurements would also provide citizens with a better understanding of the consequences of living near magnetic field sources, whether power lines or railway lines.

II. THE NETWORK OF HIGH AND EXTRA HIGH VOLTAGE LINES IN FRANCE

To shed light on the scientific debate on the possible health and environmental effects of extremely low frequency electric and magnetic fields, it is desirable to:

- Succinctly present the role of the electric transmission system and its future development.

- Specify what can be gained by burying the lines, given the reservations aroused by overhead power line projects, to mitigate the magnetic field.

- Finally, to consider methods liable of engendering a wider consensus on infrastructure projects for electricity distribution.

A. THE ROLE AND DEVELOPMENT OF THE SYSTEM

A network of high and extra high voltage lines does not exist for its own sake, ex nihilo. It has as its mission the transmission and distribution of electricity from production zones (usually centralized sources) to consumption zones (usually distinct and distant: large cities and regions of little power production). **Therefore, it is the fruit of a history and vision of development of our society.**

The power system in France, as abroad, has developed in response to **a growing demand for electricity**. In addition, it helps to secure the country's power supply. Finally, it must continue its transformation to accompany France's economic and social projects, the evolutions of production and consumption zones, and new demands on the part of society.

1. France's power transmission system

In France, there are some **80,000 km of high and extra high voltage lines**. This constitutes **Europe's most extensive high voltage system**.

Lines of 63 and 90 kV are considered high voltage and lines of 150, 225 and 400 kV extra high voltage.

These lines are connected to the distribution network via 2,350 power transforming stations that distribute the current to the 20,000-volt ERDF network and the 156 local distribution companies (LDCs).

Rte
Réseau de transport d'électricité

The 400-kV and 225-kV power transmission network

	400kV	225kV
Poste 400kV	●	
1-circuit line	———	———
line w/ 2 or more circuits	———	———
France-England interconnection (270 kV, direct current)	----------	

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a) A national history

The high voltage power system was **very early on identified in our country as a "public service", thereby justifying state intervention**[1].

In 1922, the setting up of high voltage lines was regulated by a law covering their installation and setting prerogatives for companies in the public's interest.

In June 1936, the Front Populaire created a new post, that of Under-Secretary of Electricity and Solid Fuels, to which Paul Ramadier was named; its objective was to launch a programme of national interconnections. In 1938, Édouard Daladier confirmed this initiative by launching a five-year investment programme.

Somewhat surprisingly, the system's development was not checked by the German occupation and the Second World War. In 1945, France enjoyed the most extensive high voltage system in the world. **From 1923 to 1946, the country's extra high voltage system grew from 899 km to 12,403 km.**

On 8 April 1946, France nationalized its production and transmission companies. **93 transmission companies** were affected. This allowed, in particular, for **the setting of standards: the adoption of 225 kV, then 400 kV and 50 HZ**, decisions that still structure today's system.

The development of the 400 kV system began in the 1960s, this voltage having become a European standard for crossborder interconnections.

b) The system's management

Due to **the opening of the European electricity market to competition**, notably established by two directives of 1996 and 2003, the legislature modified the French organization.

In February 2000, it specified the content of EDF's public service missions and organized the independent management of the transmission network, its director being directly nominated by the minister in charge of energy. On **1 July 2000, the Réseau de Transport d'Electricité or RTE (France's power transmission network) was created**.

In 2004, the legislature organized the transformation of EDF into a public limited company, with 30% of its capital available to non-state shareholders. **RTE also became a public limited company and subsidiary of EDF on 1 September 2005.** The particularity of RTE is that **100% of the company's shares must be held by the state, EDF or other state-owned companies**.

RTE is the manager of the French power system. Its oversees the system's operation, maintenance and development. It guarantees the safety of

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[1] Source: RTE Web site.

the electric power system and the supply of electricity. Within the framework of the market, it guarantees all users impartial treatment based on public rates.

2. The function of distribution

a) The overall problem

The electricity distribution network naturally seeks to meet consumer need, but it must confront **two insurmountable difficulties**:

• **The first is that the localization of electricity production is governed by an irreconcilably different set of variables than that governing the localization of electricity demand.** This problem is naturally most evident in the case of a **nuclear power plant**, though it is hardly less apparent for **an off-shore wind generating station or future large photovoltaic power stations**. In these cases, the electricity is not produced where it is consumed. Rather, it must be transferred.

• **The second difficulty is that electricity cannot be stored.** The electricity transmitted must always correspond to the electricity consumed, if one is to avoid a break in the system, commonly known as a "blackout", or having to institute partial power cuts, which is known as "load shedding".

For these two reasons, **a power system is organized according to the so-called "N-1 Rule"; in other words, the system must be able, at any moment and anywhere, to deal with the failure of a transmission or production element** by transferring the transmission charge onto another line or calling upon another power source, while at the same time guaranteeing the transmission of electricity to where it is needed.

To meet this challenge, two solutions are possible:

- Increase the number of production sources near the consumption zone, so as to meet peaks in consumption or to deal with a failure; however, this solution is expensive.

- Develop the network so as to allow for, via interconnections at the regional, national or European level, the optimization of electricity production and transmission. This solution is especially interesting in the case of winter peaks in consumption. The peaks are staggered over time from the north to the south of Europe, depending on habits and customs, thereby allowing for the compensation of momentary production shortages by exporting/importing current from one country to another.

These problems were the subject of an OPECST hearing, open to the press, on 16 December 2009.

b) Three examples: Brittany, Provence-Alpes-Côte d'Azur and Alsace-Lorraine

The two French regions of Brittany and Provence-Alpes-Côte d'Azur (PACA) are two electrical peninsulas with weak production and/or a weakened power system.

Brittany only produces 8% of the electricity that it consumes, even though its demand for electricity is growing at a faster rate than the national average due to its dynamism. As a result, measures to strengthen the region's network and to save energy have been implemented; in particular, the EcoWatt initiative, which has managed to gather together some 9,000 people whom it seeks to alert by SMS in the event of a consumption peak, so that they reduce their electricity consumption at home.

The PACA region also finds itself in a difficult situation. It imports some 50% of its electricity. Above all, the large urban areas (Aix, Marseille, Toulon, Cannes and Nice) are all served by a single, 400-kV line. For this reason, the slightest incident can rapidly have grave consequences, such as a fire in July 2009 that forced a shutdown of the line, or a lightning strike during the winter of 2008. In both cases, a load shedding was implemented, affecting over a million households.

The cancellation of the project for a 400-kV Boutre-Broc Carros line, in 2006, left the region without any short-term solution.

An initial series of measures consisted of raising the voltage between Toulon and Nice and carrying out important work on several power transforming stations, for a total cost of €80 million.

A second series of measures, approved in December 2008, consisted of three separate projects: reducing the region's electricity consumption by 15%, developing renewable energies (from 10% to 20% of production by 2020), and, finally, creating a safety net comprised of three new underground 225-kV lines (Manosque-Draguignan, Fréjus-St-Cassien and St-Cassien-Cannes), which should secure the system until 2025.

In the Alsace-Lorraine region, the power system was strengthened to meet demand. The 225-kV line linking Metz to Strasbourge via Sarrebourg was transformed into a 400-kV line. This project was completed in 2008, for a total cost of €140 million; its goal was to secure the electricity supply of Strasbourg and Sarrebout, both of which depended on the same line, and to carry out complimentary connections: the Saint-Avold power station (900 MW, operated by the SNET company), in terms of production, on the one hand, and the TGV East line in terms of consumption, on the other. Moreover, the increase in voltage would allow for energy savings by limiting transmission losses.

3. Necessary development

a) The overall problem

While the project for a Cotentin-Maine line meets the need to secure the electricity supply for western France (in particular, Brittany) and allows for the linking up of the future Flamanville European Pressurized Reactor (EPR), this singular situation must not overshadow a larger set of issues. **The power system will necessarily evolve and, in all probability, develop to accompany the new energy policy recommended by the Grenelle Environment Round Table: connecting renewable energy sources to the network.**

Within this framework, France has adopted the goal within the Grenelle Environment Round Table of **raising its aeolian power production 20 fold (to 19,000 MW, including 6,000 MW produced offshore), and its solar power production 40 fold (to 5,400 MW) by 2020**.

As an example, in Germany, 850 km of new 380-kV lines will be installed to meet the development of its aeolian power production.

These objectives necessitate that we begin immediately to reflect upon the transmission to consumption zones of the electricity to be produced in the large power stations and, therefore, upon the installation of high voltage lines.

It also amounts to **a challenge for the network's organization, for these power sources are intermittent**.

RTE estimates that **by 2020, €1 billion in investments will be needed to integrate only wind power to the network**.

b) Two examples: Nord-Pas-de-Calais for wind power and PACA for solar power

In **the Nord-Pas-de-Calais**, 77% of the region is well-suited to the installation of wind turbines and numerous ZDEs (wind turbine development zones) are being established by the prefects for **a projected production of 400 to 800 MW**, raising the question of their connections to the power system. Given the planned power levels, these zones should be directly linked to the 400-kV network, which should engender **the creation of two power transforming stations and an underground, 30-km line to link them up**.

These evolutions must be prepared within the framework of the regional renewable energy plans.

An example is provided by **PACA**. There, ADEME carried out a study to evaluate and map the **solar power potential** of the region and to measure the electric power system's capacity for its integration. This study was the subject of an extensive dialogue.

For the entire region, the solar power potential was estimated at **4,196 MW**, 74% of which could be handled by the present system. But the situation varies greatly from one department to the next. In the Bouches-du-Rhône, the Vaucluse and the Var, less than 10% of the potential power could not, for the time being, be transmitted. However, this same figure rises to 28% for the Alpes-Maritimes, 50% for the Alpes-de-Haute-Provence and 88% for the Hautes-Alpes.

A diagnosis of this kind illustrates the significant evolutions implied by the development of renewable energies and will therefore serve as the basis of a pragmatic consideration of the network from this angle. For the time being, technical connection proposals have yet to be formulated.

B. IS BURYING A SOLUTION?

Faced with the difficulties of getting projects approved for new lines - for landscape, health or environmental reasons or simply due to a lack of dialogue or common projects - the burying of high voltage lines is often presented as the panacea. A buried line encounters less resistance than an overhead line; as it cannot be seen, the perceived risk is mitigated.

In reality, the burying of an overhead line obeys technical and financial criteria. It is covered by the public service contract between RTE and the French state and it does not do away with the magnetic field.

Your *rapporteur* will here specify and update certain points already touched upon a few years back by our colleague, Christian Kert, Deputy, in his report on the perspectives of burying lines offered by new technologies[1].

1. The technical and financial prerequisites

a) The technical possibilities

Cables have been significantly improved over the past few years.

An underground power line is made up of at least three cables. Each cable consists of a conducting core wrapped in several layers of metallic or synthetic insulation.

These cables are heavy and rigid. They have a limited length, which necessitates relatively complex junctions.

The installation must allow the cables to be protected from external stresses and to control the thermal environment to ensure the evacuation of losses and to ensure the protection of third parties against short circuits.

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[1] *Christian Kert, The contribution of new technologies to the underground siting of high and very high voltage electric cables*, 2001, National Assembly n° 3415 (11th legistlative term), Senate n° 94 (2001-2002).

At an extra high voltage, beyond a certain distance, the connection must be carried out under direct current with significant transformation losses.

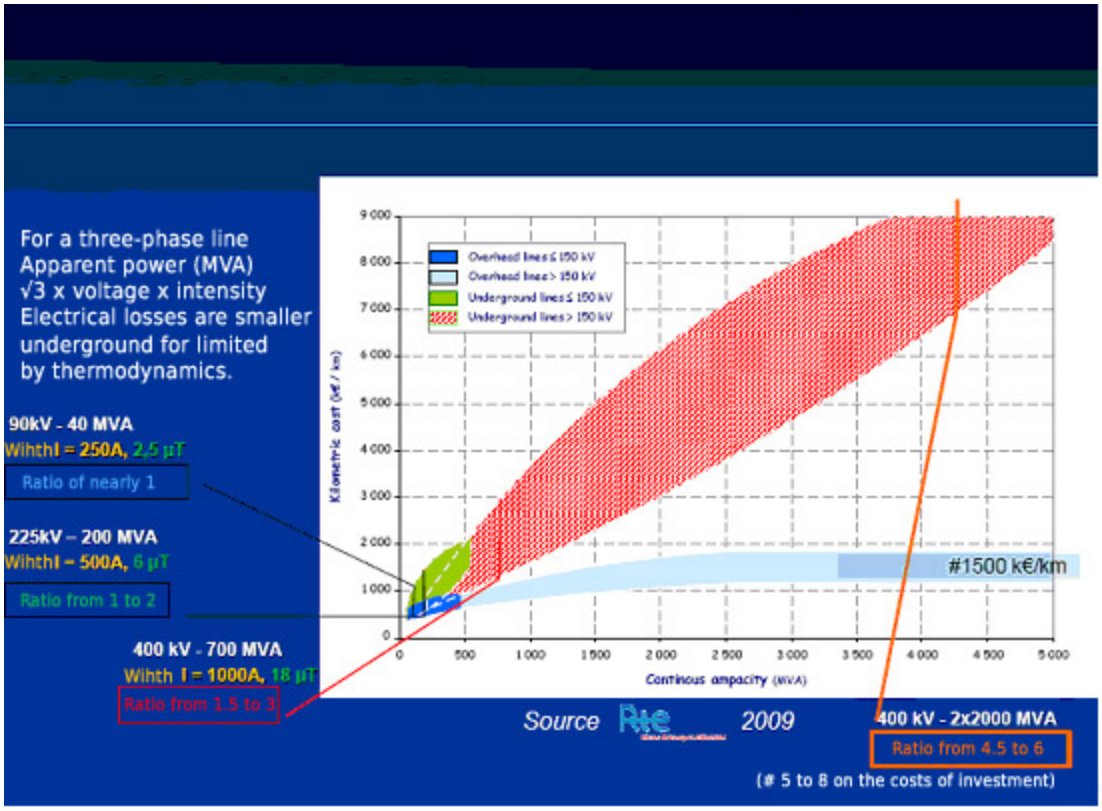
b) The financial equation

A greater obstacle than the techniques themselves is their financing to the rapid development of underground extra high voltage lines.

The cost of burying a line can be broken down into two parts. The first corresponds to the civil engineering cost and depends on the extent of the work to be carried out and, therefore, on the type of terrain and the type of line (ribbon or trefoil cable). The second part of the cost depends on the power transmitted, rather than on the line's nominal voltage.

This burying cost must be considered over time. It can be moderated by the mitigation of electricity losses during transmission.

The following diagram summarizes the financial equation (sources: RTE and Sycabel[1]):



Up until 90 kV, the ratio between burying and overhead lines is around 1 to 1.5, depending on the situation.

Beyond this voltage, costs rise rapidly. Burying can only be an option for compelling needs: in large urban areas, for underwater interconnections or for very specific landscaping reasons.

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[1] *French professional trade union of manufacturers of electric and communication cables and wires.*

One must also consider the fact that **farmers generally disapprove of burying lines**. **Underground lines engender much greater constraints for crops than do overhead lines**, whose impact is limited to the presence of pylons.

Finally, **burying lines presents no benefit to the flora or fauna**.

2. The accelerating elimination of overhead power-line networks

a) The overall situation

In France, there are **4,000 km of underground high-and-extra-high-voltage lines**, for the most part in the large cities.

Concerning **extra high voltage** (over 220 kV), RTE manages **Europe's largest underground system (nearly 1,000 km)**, with France only falling **behind Japan and the United States**.

Lines are buried in order to meet regulatory and contractual obligations and also depend on the appropriateness of the procedure.

Burying lines can be obligatory for certain protected sites: listed sites, national parks and nature reserves.

It also corresponds to a commitment included in the public service contract between RTE and the French state:

- At least 30% of all installations to be built or renewed with a voltage of between 63 and 90 kV must be buried.

- The overhead power line network must not be extended; two options are therefore possible: remove or bury the lines.

- The preferential recourse to underground connections, in 400 kV in exceptional situations, in 225 kV in urban areas with over 50,000 residents, and in high voltage in areas of grouped housing and in all "environmental priority zones".

Since 2005, the rate of burying high voltage lines has remained above 30%, with a 60% burial rate in 2008.

Since 1997, the overall length of the overhead power-line network has not increased. Indeed, it has even shrunk from 80,000 km to around 78,500 km, equivalent to its 1994 level.

Since 1950, the underground network has grown from 500 km to 4,000 km, with a strong increase since 1989 (5% per year).

b) New lines, old lines: different treatments

An example of application is the burying, in the Toulouse area, of the new high voltage (63 kV) electrical feed for the SOFICAR factory, European leader for the manufacture of carbon fibres for the aeronautics, automobile and

sporting goods industries. This will be carried out underground for nearly 5 km, at a cost of €4.5 million.

With regard to a pre-existing high voltage line, another recent example is the burying of the 63-kV Cusset-Vénissieux line for a distance of three kilometres, to allow for Greater Lyon's further growth, based on an agreement between the concerned parties.

However, for 225-kV lines, the procedure is different for technical and financial reasons. **The burying of pre-existing lines does not fall within the framework of those investments covered by the network's utilization fee.**

In Cenon, in the Greater Bordeaux area, an agreement for a neighbourhood's urban renewal was signed by ANRU (the National Agency for Urban Renewal) within the framework of the national programme. It allowed for **the burying of 1.5 km of lines** and the elimination of some twenty pylons corresponding to three lines. The operation cost **€6.2 million**, 25% of which was paid for by ANRU, 23% by the municipality, 15% by the greater urban area, 17% by the European Union and 20% by RTE. This serves as an interesting example of a partnership-based approach that allowed for the burying of a pre-existing line.

In the case of a new line between Nanterre and Nourottes in the Parisian suburbs, it was decided to **bury 21 km of line** (the longest underground line in France), for a **cost of €40 million**. This decision was made following 7 years of consultation, which allowed for a minimization of the new line's impact, with, for the most part, the line following traffic lanes.

3. The impact on the electric and magnetic fields

The burying of a line eliminates the electric field due to the technical configuration of the cables and the type of installation.

However, this is not the case with regard to the magnetic field, which persists, even though it is toned down and more concentrated in space.

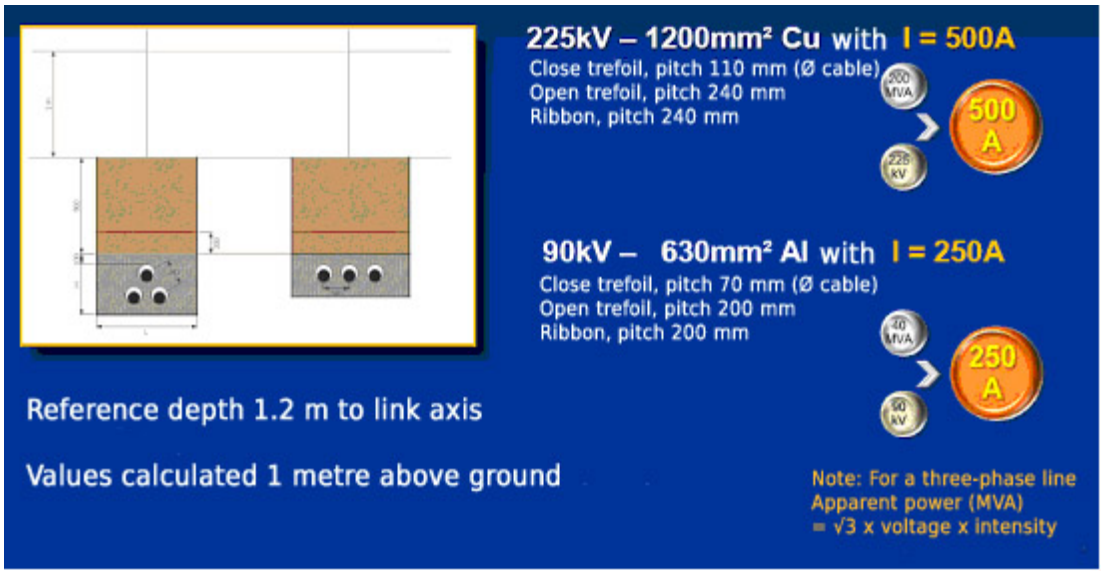
a) Classic installation configurations

The magnitude in reduction of the magnetic field depends on the installation configuration.

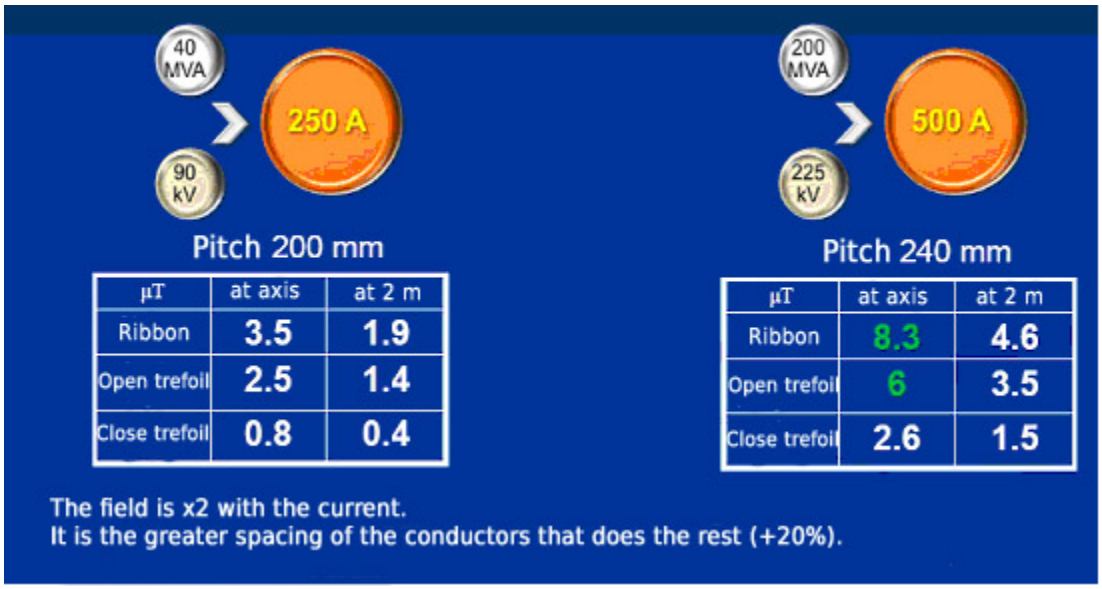
We know that low voltage distribution cables can be twisted (two live wires and one neutral), thereby eliminating the magnetic field.

However, technology does not allow us to do the same thing for high and extra high voltages. But rather than installing the cables parallel to one another as a flat "ribbon", as is done with overhead power lines, it is possible to install them as a trefoil (in other words, in clumped groups of three) and to concentrate the field.

However, the junctions between the cables must take the form of ribbons. Also, one must take into account thermal problems and maintenance and repair needs.

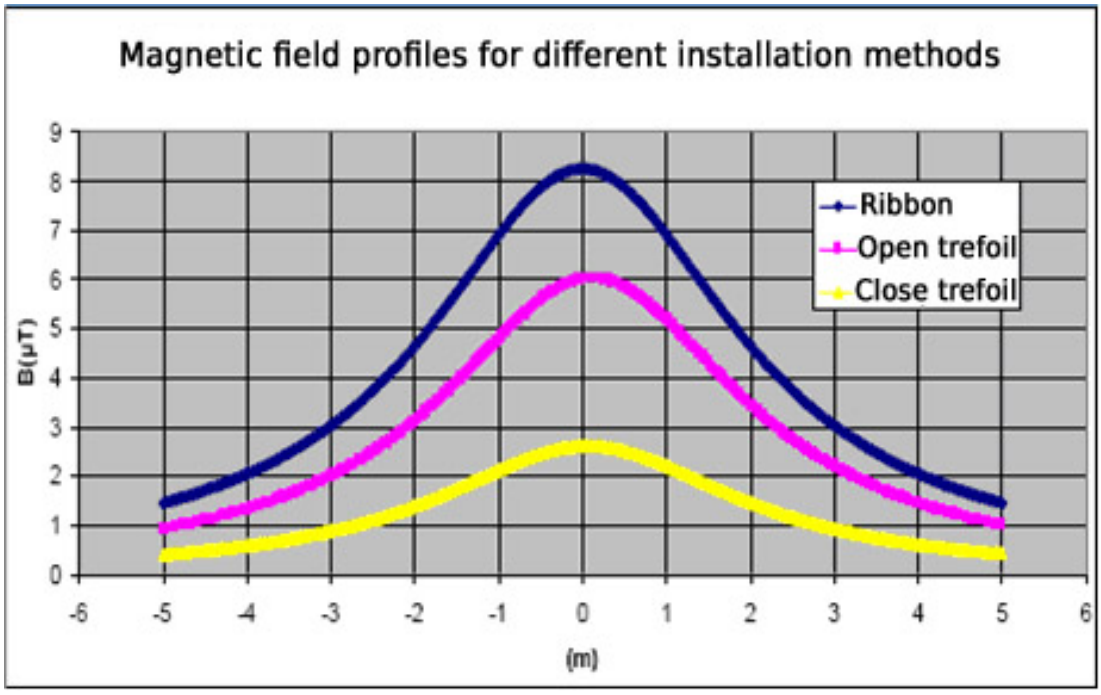


The field produced varies depending on the strength of the current and the configuration of the installation (gaps between the cables):



Source: Sycabel

This geometric effect is more easily illustrated visually, via the following example of a 225-kV line with a current of 500 A:



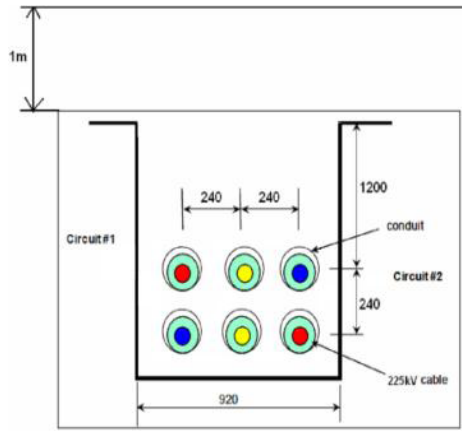
Source: Sycabel

The field can also be moderated by the depth of the installation. Passing from a depth of 1.2 to 2 metres reduces the magnetic field by around 50%, though it increases the costs of installation.

b) Complex installation configurations to minimize the field

In addition, complex installation configurations can be considered in order to minimize the magnetic field.

For instance, **two split ribbon cables** can be installed. This entails using two conductor ribbon cables at 250-A instead of one 500-A ribbon cable. This allows for a reduction of the field of around 10 fold:



Depth 1.2 m	At axis	At 2 m
Variation, 2 ribbons at 250A	0.9	0.4
Standard, 1 ribbon at 500A	8.3	4.6

Another option is the installation of **one or two passive compensation circuits** above and below the line. This configuration has only

a moderate impact if trefoil cables are installed (6% and 13% reduction, respectively). However, it has a much greater impact when associated with ribbon cables (26% and 49%).

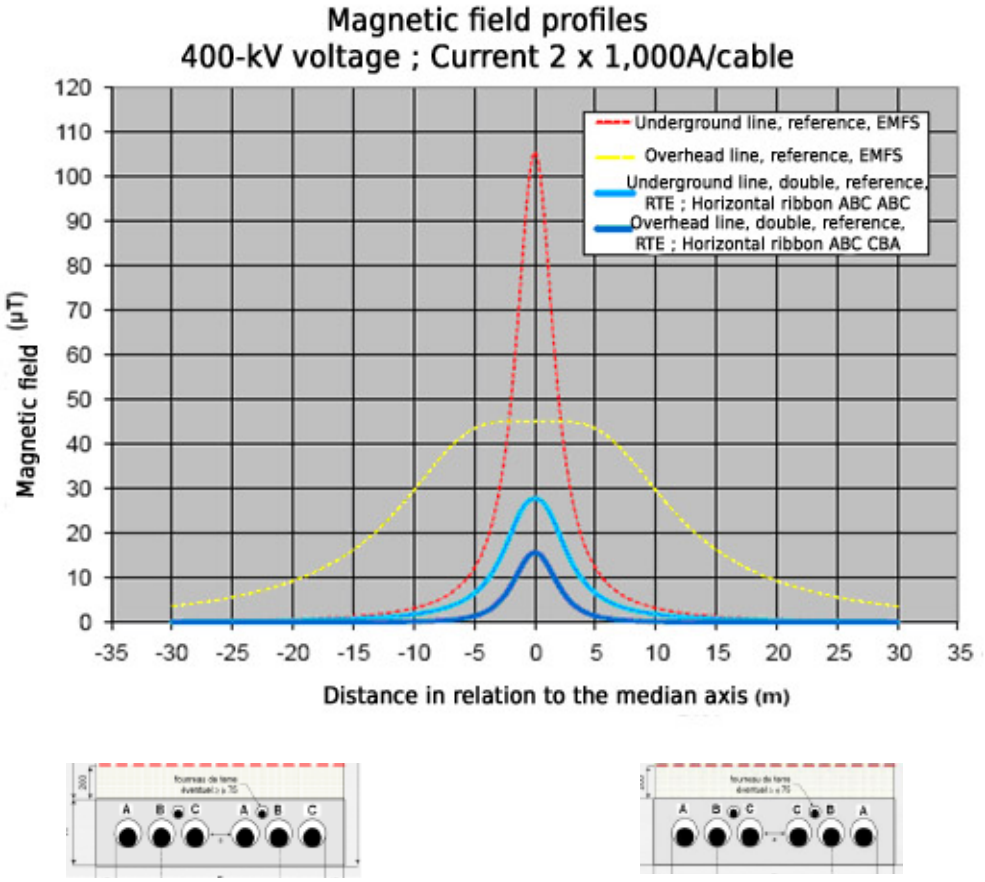
This technique is especially suited to junction chambers, where the cables are necessarily installed as ribbons and where their spacing can increase the field by a factor of 2 to 3. This is an important point, for a junction chamber must be installed every kilometre for a 90-kV line, but every 500 metres for a 225-kV line.

These more complex configurations increase **the costs of line installation and use and worsen power losses by way of the "Joule effect"**.

c) The difference between overhead and underground lines

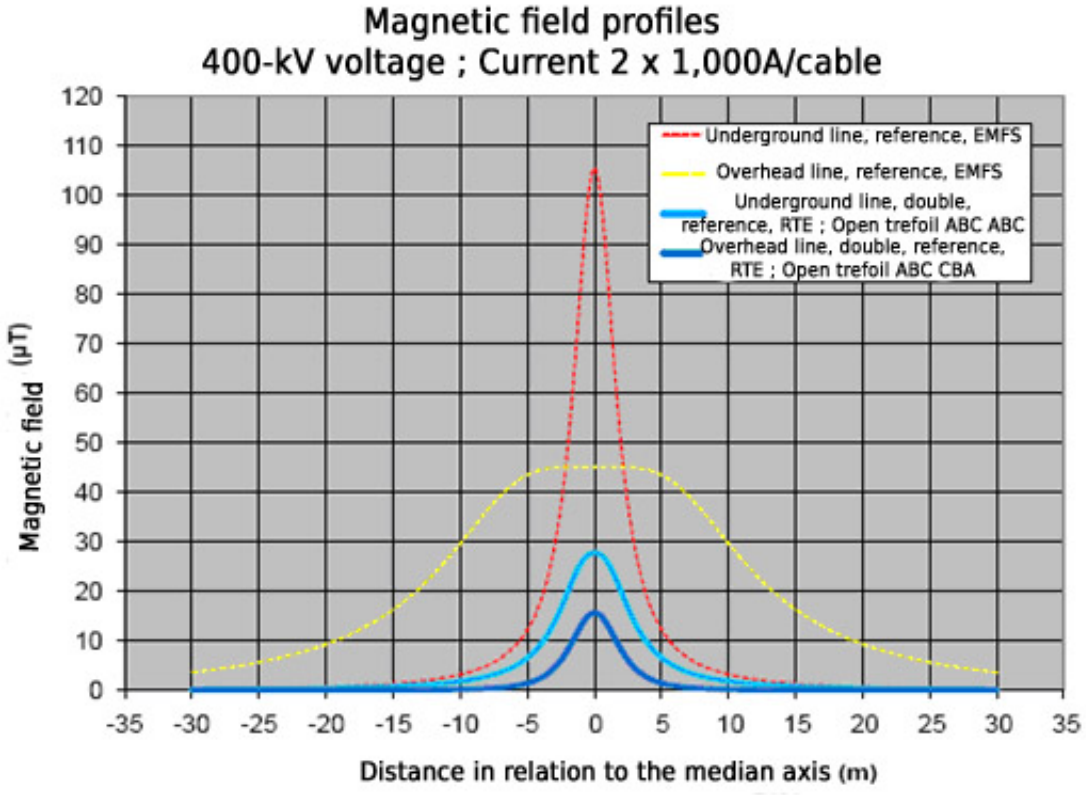
The burying of lines results in a general mitigation of the field, its concentration within a limited area and its rapid reduction.

One can first and foremost **compare the installation of ribbon cables to the installation of an overhead power line**. In the following diagram, the field values marked in red correspond to a line installed according to British standards, a scenario that is impossible in France (in other words, a 400-kV line laid 30 cm below ground):

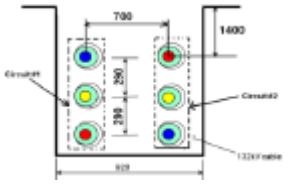


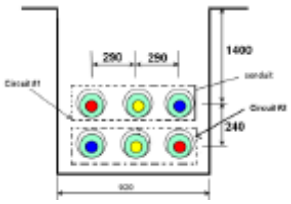
Source: Sycabel

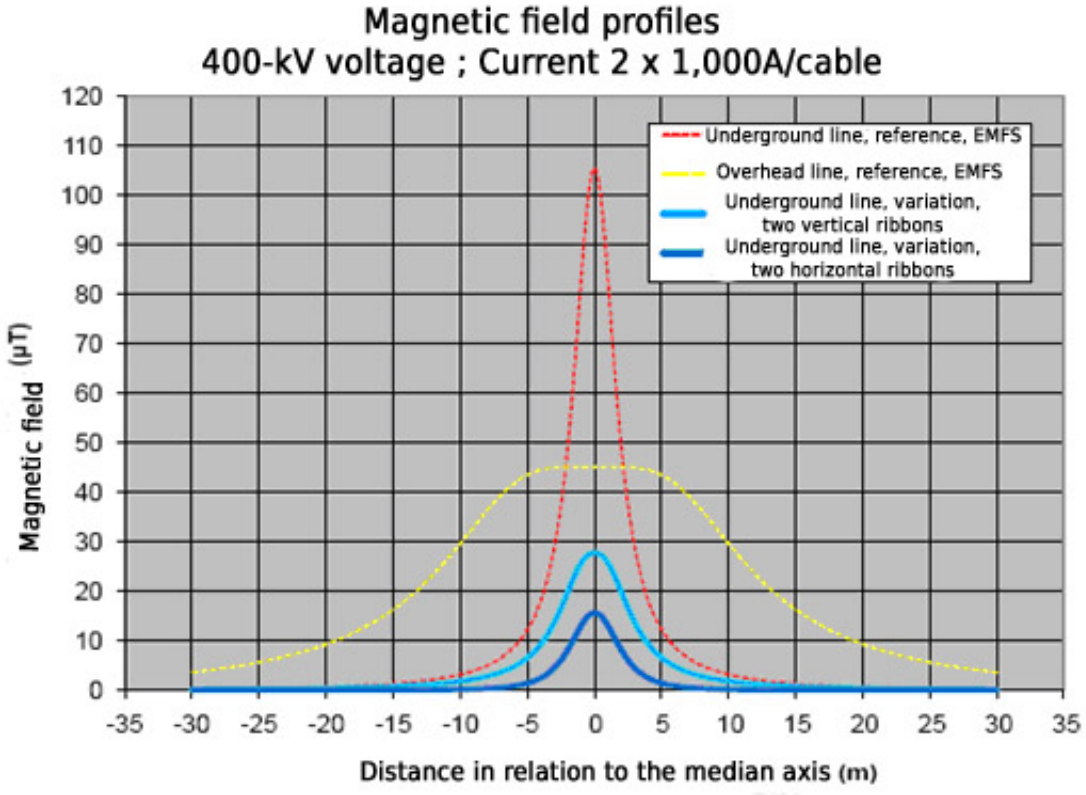
A **trefoil installation** allows for an even greater mitigation of the emitted field, with the trefoil's various conductors having less of an impact:



The burying of **split ribbon cables** is even more effective, reducing the field even further. Once again, the configuration of the cables within the ribbon is logically of great importance:







Source: Sycabel

4. The conclusions and recommendations of your *rapporteur*

The burying of overhead power lines has greatly progressed over the past few years, within the framework of the public service contract between the French state and RTE.

Burying lines allows for a real reduction of the magnetic field, especially if one utilizes installation configurations designed for this purpose.

While burying can be chosen for aesthetic and/or political reasons, **this solution should normally remain a technical-economic decision based on the procedure's cost-effectiveness**.

The costs and constraints are far from being negligible for both the line's manager and concerned farmers.

In municipalities, concerns about security/safety, aesthetics and field mitigation **disfavour the installation of overhead power lines.**

Your *rapporteur* believes that **particular attention must be paid to pre-existing, extra-high-voltage lines**. In certain cases, building permits have been accorded beneath such lines, which is hardly acceptable in France in the 21st century. While safety standards normally guarantee that no serious

accident can occur, the risks are nevertheless evident. The situation in Champlan is particularly striking.

Your *rapporteur* therefore proposes that the following be **included in the next public service contract between the French state and RTE**:

- The carrying out of a **national inventory of zones in which homes are located beneath or immediately next to extra high voltage lines**.

- The implementation of **financial measures - cofunded by the municipalities and an appropriate user's fee - to allow for the progressive elimination of these lines**.

- This contract must be accompanied with **an objective laid out in precise figures**, in addition to the current goals.

C. MAKE LINES ONCE AGAIN A PUBLIC GOOD

In 1922, the French legislature deemed that it was in the public's interest to implement a certain number of measures to facilitate the installation of lines by power transmission companies. **In 1936, this mission was recognized as a "public service". Ever since 1946**, electricity transmission has been a **nationalized activity run by completely state-owned companies**.

This legal system, which departs from common law and modern economic standards, illustrates the fact that **power lines are not private property belonging to private operators, but rather a public good belonging to the national community to ensure an essential service**. Indeed, electricity is not just a good like any other; it is essential to the proper functioning of our society.

Its mode of production and its transmission do not obey private interests at odds with other private interests (for instance, those of local residents). The mode of electricity production, the energies used and the centralization of production **are not the result of decisions made by private operators, but rather democratic decisions made by elected officials**. The same is true regarding electricity transmission.

Electricity production and transmission are therefore determined by a common decision-making process expressed by representative bodies. **While not necessarily consensual, the final decision is determined by the will of the majority, which lends it its entire legitimacy.**

The building of a new nuclear power station - and, therefore, of extra high voltage lines to link the station to the power network - or the construction of other power stations running on renewable energies falls within the remit of the public authorities, who express **a collective decision for a common project**.

Your *rapporteur* believes that the current method of dialogue concerning high and extra high voltage lines **focuses too much attention on the opposition between the operator, RTE, and other players**. Though **the lines' nature as a public good has been somewhat lost**, it merits restoration by improving dialogue and increasing participation on the part of private citizens.

1. Improving dialogue

a) Concerned local residents, but a debate on the general interest

The installation, renovation or modification of overhead power lines creates a demand for information on the part of elected officials and local residents. This demand for information is accompanied by a show of concern, which often entails - at least for new lines - the organization of an opposition to the installation.

There are numerous causes for these reservations, worries or oppositions, the most common being:

- The ugliness of the overhead line.
- Human health risks.
- Animal health risks.
- Financial losses linked to a decrease in property value or agricultural output.

Negative reactions on the part of local residents can often be explained by the NIMBY ("not in my backyard") syndrome. This reaction is legitimate, as Ms Christine Lombard, RTE consultant for northeastern France, recently pointed out in the RTE newsletter: "An important particularity of our profession is that we build our infrastructure on other peoples' property". Consequently, it is only natural that the construction of installations engenders reservations and opposition.

However, this does not sum up the reactions of local residents. Your *rapporteur* has observed, following a visit to the Mayenne department and after interviewing several social science researchers, that citizens show responsibility. The debate concerns more the definition accorded the general interest than an opposition between the general interest and private interests.

However, the general interest is not some transcendental concept, but rather the result of democratic deliberation. Citizens, by carrying the debate, consider the various general interests possible, which can be expressed via a few schematic alternatives:

- The growing provision of electricity or controlling demand.
- The centralized production and decentralized distribution or the decentralized production of energy.

- The creation of a structure for the general interest in relation to questions raised concerning public health.

- Differences between development projects carried out within a single area or between several areas of the same region or country (for instance, industrialization and urbanization versus tourism and environmental protection).

Furthermore, one should keep in mind the local history of this type of questioning. Such a history is particularly evident in the Manche department, as several persons interviewed by your *rapporteur* pointed out. The Manche is already "packed", with the Cogéma plant in La Hague, two nuclear units in Flamanville and a 400-kV line. A new EPR reactor and a high voltage line are therefore not to be installed within a "virgin" area. Previous decisions play an important role in the debate.

In parallel to the concerns expressed by local residents and the resulting debate, one must not ignore **the role played by opponents to nuclear energy**. This is particularly clear with regard to the Cotentin-Maine line meant to link the future Flamanville EPR to the national power system. Several opponents met with by your *rapporteur* clearly explained that their attitude vis-à-vis high voltage lines was a consequence of their commitment against nuclear energy and its relaunch in France as symbolized by the building of an EPR. Having been unable to prevent the project's launch, they still attempt to obstruct its construction and connection to the electrical power network. They are undoubtedly unwavering in their opposition.

b) Repositioning local elected officials in the centre of the system

With regard to these concerns or oppositions, elected officials more often act as relays for their fellow citizens - which is entirely their mission - than as initiators or sponsors of the collective project.

This situation is to be explained by **insufficient information and the lack of participation in defining an infrastructure whose very meaning is derived from the socio-economic development of a region**.

During a field visit, your *rapporteur* was struck by the insufficient information available to mayors on the health and environmental consequences of power lines.

And yet, organs for planning and dialogue already exist.

(1) Existing measures: national and regional plans

The Act of 10 February 2000 relative to the modernization and development of the public electricity service made provision for the elaboration, at the national level, of a "development plan for the public power transmission system that is subject to, after a maximum interval of two years, the approval of the minister in charge of energy following an assessment by the CRE ('Regulatory Commission on Energy')".

RTE prepared the first plan for the 2003-2013 period, in accordance with the state-defined terms and conditions. This plan was drawn up from regional reports resulting from local dialogues carried out within each region and gathering together elected officials, state authorities, electric power system representatives (producers and network managers), regional socio-economic authorities, and representative associations.

Its role is notably to identify "zones of electric fragility" according to constraints that already exist or are liable to appear in the short or medium term within the public transmission system. The plan presents an assessment that could serve as a basis for the network's future development projects.

These measures are undoubtedly overly administrative or long-term in nature to attract any real commitment on the part of grass-roots elected officials. In any case, it would seem useful to complete them.

(2) Maintaining an informal dialogue

The RTE newsletter recently related the visit by a departmental association of mayors to a power transforming station in the Haute-Loire department. Clearly, such initiatives should be made general practice. An **invitation of this type once every term – in other words, once every six years – would seem to be a good practice**. Information and dialogue are, in the long run, essential for a state-owned company with public shareholders, whose infrastructure necessarily belongs to citizens. **Pursuing a dialogue, even in the absence of any project – and, therefore, any important issue - under discussion,** is a solution to be favoured, for otherwise RTE could give the impression of entering into such dialogues only within the framework of accompaniment plans and, therefore, the granting of subsidies.

(3) Strengthening the dialogue around the regions' future

The installation or renovation of a high or extra high voltage line is the fruit of a region's development and the installation of industrial companies or large infrastructures. It constitutes the essential and last stage.

Very often, even if the term or duration of an evolution is not always known, **work carried out on the network can be anticipated five to ten years in advance**.

A simple case would be an increase in the power of a line or the renovation of an older line. In the Auvergne region, one can cite the situation of the towns of Le Puy, Ysingeaux and Saint-Etienne, which are currently served by a 225-kV line dating from 1941. Rendering the power network safe and secure, the development of these towns, and integrating renewable energy sources into the network should engender within five years the installation of a second 225-kV line, in addition to renovation work on the pre-existing line.

Projects for the network's evolution must therefore be much more consensual.

To this end, your *rapporteur* proposes the establishment of institutional measures for dialogue to prepare for the future.

A 10-year energy assessment for a given region appears to be an excellent tool.

The study carried out in **the Haute-Durance area** seems to testify to the validity of this procedure based on an energy assessment for the year 2020. Within this zone, the assessment pointed to a probable increase in consumption of around 70 to 80 MW, although current consumption is only 190 MW. Consequently, choices must be made between developing further energy sources and controlling consumption, as well as in development zones (for instance, a project for opening up a rail line to Italy). This procedure has given rise to a consensus on the necessity to transform a 150-kV line and a 63-kV line into two 225-kV lines and to build a power transforming station. This dialogue has been extended to partner associations and socio-economic partners.

A second tool that could be used in parallel to the energy assessment procedure would be **organizing a meeting of elected departmental officials, with, at its centre, the prefect, the president of the departmental council and the RTE**. The prefect and state authorities must also play a full role in considering the region's evolution. In this manner, each party can become aware of the changes needed to compensate for or overcome possible weaknesses in the network and to communicate to RTE the new needs and necessary actions vis-à-vis the population.

These measures will be usefully linked to the considerations necessary for the development and integration of renewable energies.

(4) Mayors, instigators of field-measurement requests

One source of concern for the population is the question of magnetic fields. This anxiety can become irrational, for these fields are usually not perceived by the human body. As pointed out by Mr Hervé Laffaye, Assistant General Manager of RTE: "Magnetic fields must be given concrete form".

One of the most effective measures that your *rapporteur* tested with regard to radio frequencies was **carrying out magnetic field measurements and simulations in situ prior to and following the installation**.

The agreement signed on 17 December 2008 between RTE and the AMF ("Association of French Mayors") holds, in particular, that the manager make available to mayors a practical and independent system for meeting requests to carry out magnetic field measurements in "living environments" located near high and extra high voltage lines.

This system is **very positive**, but your *rapporteur* would like for the convention to be **completed with a simulation system**.

Indeed, **the field emitted by a single line can vary greatly over the course of a day or year**. For this reason, **a measurement taken at a single**

point in time provides but a limited amount of useful information. **However, such a measurement if fully pertinent when it confirms the simulation and relativizes the exposure due to lines as compared to other sources.**

c) More and better information

To improve dialogue, it is most certainly necessary to provide more information to not only the elected officials, but all citizens.

(1) Creating a state-run Web site dedicated to high and extra high voltage lines

In its 2010 report, AFSSET recommends "planning on creating a Web site for the general public on the subject of extremely low frequency fields; the site could allow visitors to, in particular, compare field measurements to power line location and would encourage the access of French citizens to the most important documents of international expertise".

This recommendation is rather surprising, for such a site already exists: that of RTE and its local variations. The Web site provides all useful information on the subject and citizens enjoy access to almost all relevant elements.

What is problematic is that the site is managed by neither the Ministry of Health, nor the Ministry of the Environment, nor the Ministry of Energy. Once again, the operator appears as the sole provider of information and expertise, engendering doubt and a suspicion of partiality among some people.

State authorities must become recommitted to informing the public. RTE's commitments in the matter do not in any way mitigate the French government's obligations to provide impartial, up-to-date and reliable information.

(2) Greater information destined for associations

Undoubtedly because RTE builds aerial installations whose only occupation of ground are its pylons and power transforming stations, **the company has not appreciated the full extent of the demand for information engendered by the construction of the larger installations**.

In Mayenne, the associations met with by your *rapporteur* felt that the dialogue, the information provided and the manner in which this information was communicated were more wide-spread and of better quality for the construction of the LGV (high-speed rail) line.

As your *rapporteur* will explain in greater detail in the section relative to environmental impacts, RTE would benefit from the development of scientific partnerships in order to increase and spread knowledge and understanding.

For these large infrastructures, citizens now expect that **an assessment be carried out prior to construction/installation, so as to be able to evaluate the impact a posteriori**. Although it need not be as comprehensive as for an LGV-type infrastructure, an initial assessment of plant life would, for instance, be coherent with a request for a scientific inventory once the line has been built. The nature of the ground or soil lying beneath a line is undoubtedly not entirely neutral in the manifestation or non-manifestation of electricity-induced problems among farm-raised animals.

More generally speaking, it can be said that RTE has not yet adopted a sufficiently **inclusive and participative approach**. The professional associations with whom RTE negotiates the installation of a line seem to be familiar with the dossier, but this is not necessarily the case of the other concerned parties, who consequently denounce a "culture of secrets" and "haughty" contacts.

2. Encouraging citizen participation

In addition to information and partnerships, or links with elected officials and associations or trade unions, it would be a good idea to experiment with a greater participation on the part of citizens.

RTE has already begun this direct, participative dialogue by launching a blog: http://www.audeladeslignes.com/, which allows for the spread and discussing of information.

It would undoubtedly be possible **to go further**.

Mr Yannick Barthe, sociologist at the Sociology of Innovation Centre of MINES ParisTech, has demonstrated the fact that one cannot only analyze public reactions via the filter of a fear of technology.

a) The fear of technology: an insufficient explanation

Your *rapporteur* will here rely on the work by Mr Daniel Boy: *Pourquoi avons-nous peur de la technologie ?* ("*Why are we afraid of technology?*"), published by the FNSP Press (SciencesPo) in 2007.

Three points can be underlined: the modification of the traditional hierarchy between the learned and the ignorant, and the parable of the fear of the railway; the questioning of the rationality of risk perception; and, finally, the contestation of the "Paracelsus paradigm".

The traditional approach to the question is based on the idea of an ignorant public, whose ignorance leads it to have irrational fears of the unknown. The "knowledgeable" must therefore be allowed to exercise their rational superiority to make the decision to implement an advance in technology, the benefits of which will be evident to everyone in the longer term.

This stance is supported by the parable of the fear of the railway and the negative impact this fear would have had on the development of the towns of Orléans (the Les-Aubrais railway station) and Tours (Saint-Pierre-Des-Corps). This thesis is also supported by certain parliamentary debates (of 13 June 1836 and 28 April 1838), during which the astronomer and Senator François Arago would have denounced the dangers posed by railways.

These references are, in fact, anecdotal evocations that are at best simplified, if not actually falsified; indeed, this parable was first made use of in the 1970s by the advocates of certain technological evolutions, notably nuclear energy.

More generally speaking, this **classic superiority is based on the "paradox of risk perception"**: in other words, one is more afraid of an unknown yet low risk than by a known yet possibly greater risk (driving, smoking, etc.).

But this approach was questioned by the American school of risk perception analysis, founded in the tradition of Chauncey Starr, author of the article *Social Benefit Versus Technological Risk - What is Our Society Willing to Pay for Safety?* (*Science*, 1969). In this article, Starr notably asks the fundamental question: "How safe is safe enough?".

This school, the principal living representative of which is Paul Slovic (*The Perception of Risk*, London, Earthscan, 2000), is based on research carried out in the 1960s on subjective probabilities. Slovic would apply this research to the question of natural catastrophes and, above all, starting in the 1970s, to the question of industrial risk perception following his reading of Chauncey Starr and in reaction to the political debates relative to pesticides, nuclear energy and industrial pollution. Moreover, it was these protests that eventually drove the American Congress to fund important research programmes on the subject.

Paul Slovic would in this manner define a "psychometric paradigm" made up three elements:

- The perceived balances between risks and benefits.

- The psychological factors of risk perception.

- **The evaluation gap between laymen and experts.**

It is the last element that interests us here.

The studies principally show that laymen have a rather good understanding of objective, recurrent risks or "realized risks" (the morbidity rate: x number of deaths each year) and that the evaluation differences between laymen and experts are of little significance.

However, **the difference in risk evaluation is great for those risks provoking practically no observed death, yet liable, in the event of a catastrophe, to cause a great number of deaths ("unrealized risks"; a nuclear accident, for instance), even though the experts judge these risks**

to be low. But **for the most recent risks of this type, it becomes difficult to distinguish between the rationality of experts and that of laymen**.

There is therefore **a "real risk" and a "perceived risk", both of which are rational and which do not separate experts from laymen**.

The third aspect is **the questioning of the Paracelsus paradigm**.

This paradigm, which dates from the 16th century, states that it is "the dose that makes the poison"; in other words, no substance is harmful by nature, but all substances can be noxious if ingested in sufficient quantity.

This paradigm constitutes a major foundation of the scientific and administrative reasoning behind risk management.

A risk of absolute 0 does not exist – indeed, it would be unverifiable – but one must define a standard below which there is no danger, even after repeated or continuous exposures. There is therefore an administrative definition incorporating a scientific base of 0 and the absence of any poison.

However, **this idea of a dose limit is increasingly contested by the public, whose "intuitive toxicology"** (Paul Slovic) is based on an "all or nothing" perception of risk.

Studies carried out by the psychologist Paul Rozin (1998) showed that the perception of food health risks was largely expressed by the "laws of contagion": there is a definitive transfer of cleanliness and of dirtiness between two elements - the one healthy, the other unhealthy - provoking a complete contamination (example of the cockroach).

There is also a wider questioning centered around the refusal of exposure standards and rate limits, of weak doses, and of dispersed pollutions.

For certain authors, such as Ulrich Beck in *Risk Society: Towards a New Modernity* (first English translation: 1992), exposure rate limits in fact legitimize environmental pollution.

These debates can be found notably with regard to the labelling threshold of those products liable to contain GMOs.

Scientifically speaking, a distinction is made between "deterministic effects" (for example, those linked to ionizing radiation beyond a certain dose), definite, measureable effects, and so-called "stochastic effects", below this same dose limit, which are indeterminate (in other words, not necessarily inexistent, but incapable of being measured and the reality of which cannot even be proved).

In the end, Daniel Boy demonstrates that **it is this different rationality that can assert itself in the management of risks**, whether they be chemical or technological in nature. **It renders difficult, if not impossible, an understanding of an absence of 0 risk**, while scientifically evaluated risks

are modelled in the form of probabilities expressed in 10^{-x} and are avoided by redundant security systems (the nuclear industry).

b) Developing participative approaches

The studies carried out by Yannick Barthe open new avenues to avoid this potential impasse.

These risks are linked to an uncertainty made up of a range of indications or evidence. This situation can sometimes prove intractable, for providing scientific proof of a non-causality can be very complicated. Furthermore, one is often confronted with social groups that do not share the same standards of proof; in other words, that which is liable to convince some will not convince others, due to phenomena of presumed guilt or innocence vis-à-vis certain players.

That being the case, one of the best methods of managing this type of risk is attempting to involve the public. The public produces knowledge and understanding via its observations.

Within the framework of high voltage lines, it can be observed that **such measures already exist in part with ornithologists, hunters and beekeepers**.

Indeed, via the CNA ("National Avifauna Commission") - which your *rapporteur* will describe in greater detail in the third part of this report - EDF, RTE and ERDF set up a collaborative organ for the bottom-up transmission and sharing of information, as well as the production of knowledge. Dead birds are reported below power lines or at the foot of pylons; the latter become potential birdhouses and lines can be equipped with devices for scaring off birds following a common analysis.

The agreement between RTE and the Fédération Nationale des Chasseurs ("National Federation of Hunters") is part of a similar approach, with the possibility of using the area below power lines to cynegetic ends and developing a partnership.

In the same spirit, draft agreements between RTE and the beekeepers of the Île-de-France region offer some interesting prospects.

These experiments could be broadened, in particular to encompass farmers and local residents.

For example, along the future Cotentin-Maine line, farmers are requesting the setting up of "control farms", for they formulate diverse complaints - for the time being, difficult to authenticate scientifically – relative to the drying up of the soil and electrical problems.

Via measures of this type, carried out by the farmers themselves, appreciable progress could certainly be made by considering them as producers of information that must then be processed in a collaborative manner.

The widespread participation of local residents is undoubtedly more difficult to conceive; nevertheless, it must not be excluded.

A high or extra high voltage line is a highly visible and intrusive infrastructure, even if its actual footprint is not very considerable, for such an infrastructure is essentially aerial in most cases.

It undoubtedly has **as great an impact on the landscape as do listed heritage sites** that lead to the setting up of a CLI ("local information commission") or a CLIS ("local information and monitoring commission").

Without going so far as to set up a CLIS for high and extra high voltage lines, your *rapporteur* believes that it is necessary to imagine means to **involve the public in the life of the line**. The dialogue with the population must not necessarily come to an end when all authorizations have been accorded and the installation has been put into operation.

One must think up the means of **informing the population of pruning, repair and maintenance work, of partnerships** with associations, and of concrete achievements.

Means to **gather together a return of information or observations** could also be of interest.

Finally, **this concertation process must be designed within a more general framework of defining a collective development project that is decided on and shared with the region's elected officials**.

3. Guaranteeing the independence of expertise and research

One of the great difficulties of pursuing a dialogue on large technological installations is the questioning of expertise, which is both discredited and made sacred. Faced with this difficulty, the independence of the scientific procedure should be strengthened.

a) The discrediting and sanctification of expertise

Mr Jean-François Béraud, Secretary-General of the CNDP ("National Commission on Public Discussion"), emphasized, during the public hearing of 29 January 2009, that contracting authorities and experts have lost much of their credibility. Their explanations based on the scientific literature are not believed by the public. Experts are often suspected of having a hidden connection to the contracting authority. In addition, the fact that certain experts seem to be trapped within their certitudes diminishes their capacity to convince the public, the latter feeling that it is being told what it must think.

According to Mr Béraud, "When the expert's position is too definitive, the public's reaction is to say: 'In fact, we're not being told everything'. And when the expert shares his doubts, the public thinks that 'Since he doesn't know everything, then one can't be entirely sure that there isn't any risk'".

At the same time, the expertise is sanctified. For scientific or technological sets of issues in which expertise potentially holds an essential role, many would like to accord it an inappropriate role: proposing decisions that have been scientifically validated and are therefore indisputable. The expert would be he who founds political choices on reason.

For complex and uncertain subjects, the expert can play the pernicious role of a suppressor of uncertainty by over-simplifying ongoing studies and proposing a single political solution. He would drain science of its healthy doubt and politics of its democratic debate.

On the other hand, but with the same arbitrariness and over-simplification, the expert can intentionally maintain doubt and uncertainty so as to block certain decisions. Nothing would be sufficiently safe and certain to be able to act. The environment would not be healthy enough, one would always have to take further precautions, etc.

Furthermore, expertise does not obey any strict criteria. Courts can summon up "experts" who, in reality, are not considered as such. NGOs or consultancies can take advantage of expertise that does not obey the scientifically recognized criterion of peer review.

This offer of expertise manifests itself in response to public demand, but is also the result of the state's incapacity to propose a more visible and credible expertise.

b) Encouraging greater independence

In his previous report on mobile telephony and radio frequencies, your *rapporteur* put forward the idea of a "health-radio frequencies foundation". At the time, he observed the discrediting of experts who were criticized for working, for having worked or even for being in the future able to work for the operators. Their signing a research contract with a private company basically amounted to their being "branded" by a portion of the public opinion. Your *rapporteur* also noted insufficient public funding.

In certain respects, your *rapporteur* is tempted to paint the same picture with regard to extremely low frequency magnetic fields, where the same processes are at work, though less acutely. Those who contest the international consensus denounce a servile expertise.

More objectively, your *rapporteur* has observed that **the French state has lost too much interest**, due to the public service contract passed with RTE, which notably makes it the company's mission to inform citizens and finance research. **Today, RTE is the main and sometimes nearly the only funder of research** carried out in our country on these subjects.

This situation is rather **to the credit of RTE**, which maintains an enduring tertiary expertise and finances theses. These research contracts are established in a transparent manner and must result in a publication in a

scientific review, with a reading committee. This represents one prerequisite for funding, to avoid only positive results being submitted to the publication.

RTE is also the only source of expertise for certain topics. For instance, no other company is authorized to carry out measurements.

This situation is not to be explained uniquely by the contract linking RTE with the state. Unquestionably, **the weak funding and small number of research projects is due to the fact that the scientific community does not consider the subject of "magnetic fields / health and environment" promising** as a notable source of scientific knowledge at the world level. Much has already been published and the international consensus implies the absence of any link. **Considering the difficulty of successfully publishing negative results and the essential nature of this evaluation criterion for today's researchers, there is little incentive** to enter into this field of study.

Yet, the question is an important socio-economic subject and **everything makes it seem as though RTE, the public service operator, is the only body to benefit from the funding of such research**.

It is not easy to solve these problems. However, your *rapporteur* would here like to propose a few avenues worth exploring:

- RTE should no longer provide either direct funding or funding via a body directly dependent upon the research company.

- With regard to health, it could fall within the remit of AFSSET to launch invitations to tender for research on the potential health impact of magnetic fields, with the agency ensuring its financing notably via a contribution by RTE, but also by the state and other research or economic players, such as electric cable manufacturers. A steering committee could be put in charge of monitoring the projects.

- With regard to **animal husbandry**, research should be financed by **a restructured and enlarged GPSE ("Permanent Group for Electrical Safety") in which the French state would have reassumed its full role** (see Part III).

- With regard to **wild flora and fauna**, the **CNA ("National Avifauna Committee")** could be enlarged or a separate ad hoc body set up (see Part III).

III. THE POTENTIAL HEALTH IMPACTS

Your *rapporteur* will present in this part of the report the general results of the international assessments of the impacts of extremely low frequency electric and magnetic fields (ELF-EMFs), before discussing the possible causal links between these fields and electromagnetic hypersensitivity (EHS), juvenile leukaemias, and neurodegenerative diseases such as Alzheimer's.

A. THE GENERAL RESULTS OF INTERNATIONAL ASSESSMENTS

Over the past 30 years, since the publication by Nancy Wertheimer, a great many studies have been carried out on the health effects of electromagnetic fields: cancers, reproductive abnormalities, cardiovascular and neurodegenerative diseases, disorders such as somnipathies, headaches, etc.

1. The various international reports

The knowledge base has been regularly updated, in particular:

- **At the world level**, by the International Agency for Research on Cancer (IARC), in 2002, and the World Health Organization (WHO), in 2007, via monographs on the health effects of electric and magnetic fields of extremely low frequency.

- **At the European level**, in January 2009, by the Scientific Committee on Emerging and Newly Identified Health Risks (SCENIHR) for the European Commission which was in the process of updating its reports.

- **At the national level**, by AFSSET in 2010 and the CSHPF ("French Council on Public Health") in 2004.

This list is nonexhaustive, for many other collective assessments have been carried out abroad by national bodies.

These collective assessments reflect an international scientific consensus on the subject. This consensus does not correspond to any unanimity on the part of researchers, nor does it mean that it cannot be questioned by new studies; however, it does represent the most serious and admissible basis for assessing a potential health risk and justifying a political decision.

2. The short-term effects and protective standards

The only harmful effects that have been directly established are linked to high exposures of very great intensity.

The current standards, set by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) and the European Commission (recommendation 1999/519/CE), **are sufficient** for the population's protection. This opinion is supported by the international consensus.

These standards set the **exposure limit at 100 µT for the public at an instantaneous value of 50 Hz** (or 83.3 µT at 60 Hz).

Moreover, in 2007, the WHO called upon all states to apply these standards.

AFSSET confirms that: "The short-term effects of extremely low frequency fields are known and well-documented, and the limit values of exposure allow for the population's protection".

Furthermore, after having observed certain notable regulation differences - such as in **the Netherlands, which adopted a mean limit of 0.4 µT near new, "sensitive" constructions** (housing, schools and day nurseries), or in Switzerland, where the limit is set at 1 µT for sensitive locations such as housing, hospitals, schools, offices and playgrounds - the AFFSET report judges that: "Their diversity illustrates the complexity of the approach, as well as **the absence of scientific data sufficiently well-founded to establish a common policy based on science**, rather than on arbitrary decisions".

3. The long-term effects

a) The international consensus

The long-term effects are:

- Either improbable, for the scientific studies do not provide sufficient elements or have brushed them aside.

- Or the subject of debate, for they have not been causally established.

At the world level, in 2002, IARC estimated that there was insufficient scientific proof to associate a carcinogenic effect with fields, excepting extremely low frequency magnetic fields, as your *rapporteur* will go into further detail below.

In 2007, the WHO indicated: "We studied a certain number of other diseases [excepting acute juvenile leukaemias – author's note] in search of a possible connection to exposure to ELF magnetic fields. The diseases studied include childhood and adulthood cancers, depression, suicide, reproductive dysfunctions, growth disorders, immunological modifications and neurological diseases. The scientific data in favour of such a link [...] are much more tenuous [...] and, in certain cases (for example, with regard to cardiovascular diseases and breast cancer), they sufficiently demonstrate that ELF magnetic fields do not cause these diseases".

At the European level, in 2009, the SCENIHR report came to the same conclusion; after confirming the data gathered in 2007, the report argued in favour of maintaining current standards (in other words, uniquely based on effects linked to acute exposure).

At the national level, in 2004 and again in 2005, the CSHPF concluded that, excluding juvenile leukaemia, no link has been established between the exposure of children to ELF-EMFs and a risk of a cerebral tumour or any other type of solid tumour and that no link has been established between the environmental or occupational exposure of adults to ELF-EMSs and an increased risk of cancer, no matter the type.

In 2010, AFSSET supported the ICNIRP's position not to modify its proposed regulations concerning exposure limit values and not to take into account possible long-term effects that have not been sufficiently established. AFSSET stated that: "No connection has been established between extremely low frequency magnetic fields and pathologies other than cancers [juvenile leukaemias – editor's note]; however, these fields' hypothetical implication in neurodegenerative pathologies (Alzheimer's and amyotrophic lateral sclerosis) cannot be ruled out".

b) The questioning of the collective expertise

However, this opinion is not unanimous. Certain scientists do not share these conclusions and believe in the existence of negative effects produced by processes not recognized by the international community and therefore remaining to be confirmed.

Pr Dominique Belpomme is a French scientist worth citing in this category. He has notably evoked the "corona ion hypothesis", put forward by Pr Denis Henshaw of Bristol. According to this theory, extra high voltage lines of greater than 110 kV produce ions and ionize pollutants. Another hypothesis directly advanced by Pr Belpomme concerns the disorientation of cells due to electromagnetic fields, thereby causing cancerous mutations (Belpomme, Hardell, 2007 et 2008, *Environmental Research*).

c) The proposal for an indirect monitoring

As demonstrated by a study carried out by CRIIREM[1], an NGO located in western France, a multitude of symptoms and feelings of sickness are often evoked by residents living near extra high voltage lines.

Except with regard to certain pathologies that your *rapporteur* will touch upon further below, international scientific data do not allow for medical monitoring to be directed in any one specific direction.

Consequently, the direct yet wide-ranging medical monitoring of local residents would risk creating more problems than answers.

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[1] *Comité de recherche et d'information indépendant sur les rayonnements électromagnétiques ("Independent Research and Information Committee for Electromagnetic Radiation").*

Indeed, an examination accompanied with blood tests or other measures rapidly becomes unwieldy and stressful, if repeated over time. Furthermore, it is difficult to justify and explain if it lacks direction.

(1) The failed monitoring effort in Coutiches

It is here necessary that your *rapporteur* touch upon the events that occurred in Coutiches, in northern France, during the 1990s.

In this city near Douai, a programme was set up, at the request of local resident associations, for the medical monitoring of volunteer residents living immediately next to a recently built 400-kV line. The programme followed around one hundred people maximum and, for the most part, was carried out in waves of two measurements per year. All monitoring came to an end in 2002.

Initial examinations noted a certain iron deficiency for the concerned population.

This clinical result was the subject of a scientific article in the *European Journal of Internal Medicine* (2000, Éric Hachulla et al.), entitled: *Pseudo-iron deficiency in a French population living near high-voltage transmission lines: a dilemma for clinicians*. The author formulated the hypothesis of a connection to ELF-EMFs of greater than 0.2 µT. **However, he concluded that: "These spurious results plead for a larger study to confirm our observations".**

Following its publication, this article naturally became the subject of a debate that, in fact, confirmed the unconvincing nature of the obtained results. The examinations were potentially incomplete. The sample group was too narrow, allowing for possible false positives or negatives, and certain specialists felt that no real differences existed between the sample group and the overall population.

Nevertheless, in the grey literature available on the World Wide Web, Coutiches is referenced by those convinced of the harmful health effects of magnetic fields and high voltage lines and who accuse EDF of having intentionally wrecked the population's medical monitoring. For its part, EDF insists that the monitoring programme came to end due to a lack of volunteers and because this approach lost its meaning.

A reading of Pr Hachulla's publication suffices to reestablish the sole objective element of this controversy: the insufficiently convincing nature of the results.

Moreover and in light of foreign studies and the work carried out by the INVS ("National Institute of Health Monitoring") on this subject, it would seem evident that the monitoring of a very small sample of the population has no epidemiological value and can even have very counter-productive effects from a scientific standpoint.

The INVS was notably led to emphasize that within the framework of a similar monitoring effort carried out around a uranium production facility in Fernald, Ohio (United States), the two advantages were: firstly, the population's universal medical coverage provided by the producer (France and the United States not sharing the same type of social security coverage). Secondly, the fact that this medical coverage also served as a form of psychological compensation for the induced anxiety. An individual benefit undoubtedly exists, but at the population level, such a measure can appear as an alibi and even have a negative effect.

(2) An attempt at indirect monitoring: a study on treatment consumption

Considering these difficulties, but also the interest of medical monitoring for science and for dealing seriously with the anxiety of local residents, **your *rapporteur* would like for a feasibility study to be carried out on a study of treatment consumption** (for instance, in the Manche department, for a sample similar or identical to that used in the CRIIREM study; in other words, comparing residents living near the existing line to future residents near the planned line).

In an indirect study such as this, the data would be collected without the direct participation of the patients. This would lend a certain objectivity to the study.

The data would be collected from social security bodies or agencies within the framework of a research agreement.

The data to be collected would be: medical consultations, drug consumption, sick leave, radiological and biological treatments, hospitalizations (including surgical treatments), medical transport and physiotherapy treatments.

Such a study could firstly allow researchers to note any abnormal consumption by comparing an exposed population to a control population. Secondly, it could lead to a more targeted inquiry.

Therefore, a study of this type could constitute **a scientific response suited and proportionate to the population's anxiety**, in a context in which various uncertainties remain.

*

The international scientific consensus therefore implies that fields do not have any health effects other than those identified for very high exposure rates and for which protective standards already exist. With regard to long-term effects, experts believe that there is too little evidence to support and validate the hypothesis that fields cause diseases.

Today, only three groups of pathologies are subjects of debate: electromagnetic hypersensitivity, juvenile leukaemias and certain neurodegenerative diseases.

It is on these three groups that your *rapporteur* will focus his attention.

B. HIGH VOLTAGE LINES AND ELECTROMAGNETIC HYPERSENSITIVITY (EHS)

Electromagnetic hypersensitivity has, above all, been linked to radio frequencies and mobile telephony. However, it is also associated with this frequency band and poses the same problems.

1. Assessing the situation

AFSSET, which has already studied this subject in relation to radio frequencies, proposes a definition of EHS that could serve as a reference.

EHS is characterized by the fact that the person suffering from various symptoms attributes them to electromagnetic fields.

AFSSET, relying upon the WHO, proposes the following symptom categories:

- Dermatological symptoms: rashes, tingling and burning sensations.

- Neurasthenic and vegetative symptoms: fatigue, lassitude, difficulty concentrating, dizziness, nausea, palpitations and digestive disorders.

- Additional symptoms: headaches and locomotor, cardiorespiratory, hearing; allergic and vasomotor disorders.

However, up until now, it has not been possible to establish model patient profiles, the syndrome remaining too heterogeneous.

Your *rapporteur* notes that, contrary to an all too common preconception and according to recent studies, EHS is not associated with any psychiatric personality disorders; rather, these patients suffer from anxiety vis-à-vis their environment and professional life (Osterberg, 2007; Rubin, 2005), similar to persons suffering from idiopathic environmental intolerance.

The prevalence of EHS is very difficult to determine. SCENIHR estimates it at **between 5% of the population** in Switzerland (Schreier, 2006) **and 1.5%** in Sweden (Hillert, 2002).

No double-blind study has established any link or demonstrated that the patients truly suffered from EHS. **No data has connected this syndrome to ELF-EMFs.**

This conclusion, which reflects the international consensus, is contested in France by Pr Dominique Belpomme and the Association for Research and Treatments Against Cancer (ARTAC).

The professor's studies are based on a sample group of 315 patients suffering from what he calls "EMF intolerance syndrome", which he has

begun to describe. Pr Belpomme distinguishes an initial phase that is slow and progressive and during which the above-described symptoms manifest themselves, for the most part. There then follows an "established stage" characterized by insomnia, chronic fatigue and a tendency towards depression. Pr Belpomme has then observed effects on the patients' social integration: for instance, social problems among children, as well as possible predispositions to a neurological degeneration.

He distinguishes EMF intolerance syndrome from hypersensitivity, which would be symptomatic of a very acute sensitivity to magnetic fields due to either a genetic predisposition or external events linked to the environment, such as heavy metal intoxication, or even the presence of significant dental amalgams.

With regard to these initial observations, he is currently seeking objective testing instruments for diagnosis and screening: cerebral Doppler ultrasounds, bioassays (elevated rates of certain proteins, vitamin D deficiency) and electromagnetic tests.

2. Recommendations

Your *rapporteur* believes that **science must make further progress** in this field. To this end, he has two recommendations:

- **Take patients seriously.**

- Seek to **characterize the patients' symptoms** and attempt to prescribe for them an appropriate treatment within the framework of a **national coverage system**.

a) Patients must be taken seriously

The suffering of patients claiming to be subject to EHS can be extreme. This **suffering must be respected and covered.**

Certain sufferers reach a point of complete desocialization following multiple moves, job losses, family problems and health problems, to such an extent that EHS undoubtedly becomes – whether it be recognized as such or not – the veritable and objective cause of other medical and social problems that would be extremely difficult to treat without tackling the patients' EHS itself.

In his report on mobile telephony and relay antennas presented to the OPECST in 2009, our colleague, Deputy Alain Gest, put forward the proposal that France follow in the footsteps of Sweden and begin to recognize associations representing patients claiming to suffer from EHS, so as to seriously treat the sufferers of this phenomenon.

However, this initiative is confronted by the difficulty of precisely identifying EHS sufferers, for EHS is, for the time being, the result of an "auto-declaration", rather than the fruit of any diagnostic study of symptoms

classically characterizing a pathology and carried out following a series of examinations.

b) A national coverage system

One of the most promising avenues of research and patient coverage would probably constitute seeking to characterize the symptoms of EHS in a much better manner than is currently the case and thereby **propose a treatment inspired by those developed for the idiopathic environmental intolerance (IEI) syndrome**. IEI was first described in 1987 by Cullen, who referred to it as "multiple chemical sensitivity" (MCS), in relation to exposure to environmental chemical substances.

Pr Dominique Choudat of the Cochin hospital has formulated the hypothesis that EHS is a variant of IEI. According to this hypothesis, EHS would be an acquired pathology characterized by recurrent symptoms concerning numerous areas of the body, which arise following a known exposure to EMFs of very different types, but at exposure levels well below those causing harmful effects in the general population. However, no physiological abnormality has been demonstrated that could explain these symptoms.

Indeed, the symptomatology of EHS does not appear to be specific to this syndrome and remains extremely varied.

It has been demonstrated that a person confronted with a dangerous or unhealthy situation, or having experienced a shock, can keep in his/her memory the circumstances surrounding the event and afterwards avoid them by unconscious conditioned reflexes that manifest themselves through similar symptoms. These symptoms can either dissipate over time or, on the contrary, become worse, leading to serious handicaps. A cognitive, behavioural therapy is therefore appropriate, while at the same time pursuing a wide-ranging diagnosis, for these disorders can be interlinked with others.

A research project has therefore been presented, the objective of which would be to evaluate the pertinence of this hypothesis and the effectiveness of individualized medical coverage for patients suffering from EHS within the framework of a specialized consultation with doctors at professional and environmental pathology consultation centres and in accordance with a standardized protocol.

The idea would be to equip patients over a given period of time (for example, one week) with an instrument for measuring individual exposure; this would be associated with a localization and description of the patients' activities, so as to establish a connection, if any, between the measurements carried out, the patients' activities and the observed symptoms.

Based on these data, the clinician would then decide if a total, partial or negative correlation exists.

Despite the consensus of the international literature, it is not impossible that some patients exhibit a real sensitivity.

Taking into account the scientific data, the most frequent cases should prove to be partial or negative correlations. Consequently, further objectification should be pursued via cognitive and behavioural therapy, while maintaining a wider diagnostic approach to treat the whole patient.

Besides the fact that this project is liable to **significantly improve the lives of patients**, it offers the possibility of **setting up a national network of 23 professional referral centres**.

By integrating this network into a pre-existing structure, **occupational and urban physicians will naturally refer their patients to these centres**.

The patients themselves could directly consult the referral centres.

Provided with the means of spreading information among health professionals, these centres would also be able to provide precise, reliable medical information.

This project has been submitted to the French Ministry of Health. The project received the full support of your *rapporteur*, as explained in a letter addressed directly to Ms Roselyne Bachelot on 20 January 2010[1].

C. ELECTRIC AND MAGNETIC FIELDS AND JUVENILE LEUKAEMIAS

The possibility of a link existing between extremely low frequency magnetic fields and juvenile leukaemias is a central question for this report.

Since 1979, this issue is at the origin of all questioning relative to the health effects of high and extra high voltage lines and remains an essential issue due to the classification of ELF magnetic fields as possible carcinogens by the WHO.

So, what can currently be said on this topic?

1. The Wertheimer study of 1979 and its implications

This questioning began in the United States, where the issue became particularly controversial. Your *rapporteur* will here rely on an article by Olivier Postel-Vinay published in the magazine *La Recherche* in December of 2000 (no. 337).

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[1] *A positive reply was provided a few days following the presentation of the present report before the OPECST.*

a) The Wertheimer study of 1979

From a scientific standpoint, the question of a possible link between ELF-EMFs and a heightened risk of juvenile leukaemia was first raised by Nancy Wertheimer in her study published in 1979 in the *American Journal of Epidemiology*. Nancy Wertheimer, a psychologist affiliated with the University of Colorado, studied at her own expense and with the help of her physician friend, Ed Leeper, the occurrences of this disease in the Denver, Colorado region in which she lived. In fact, she had been assigned to carry out a study among families with a child afflicted with cancer and had observed a possible link between the families' location of residence, electricity distribution and the frequency of juvenile leukaemia.

The study concerned 344 children who died from cancer before the age of 19 and 344 other cases of cancer-free children. The children's houses were divided into two categories depending on deduced exposure (proximity to transmission lines and cable diameter). The incidence of cancer was 1.6 to 2.2 times greater in the more exposed category.

This study suffers from various limits and biases that have since been detailed, the three main ones being:

- The fields were not measured, but instead roughly estimated.

- The study was not blind: the authors knew which houses had been occupied by the sick children.

- Other factors liable to cause leukaemias were not taken into account (low household income, tobacco smoke, diet, uterine and infantile life, other forms of pollution, etc.).

Nevertheless, the novelty of the findings, the statistical link, and the significance and sensitivity of the subject all allowed this study to cause a considerable stir, which called for new studies to confirm or invalidate the results.

b) The polemic caused by Paul Brodeur

However, the question eventually escaped from the scientific realm, to be taken up by an American polemist, the journalist Paul Brodeur, who at the time was writing for *The New Yorker* magazine. His approach to the subject would influence the debate.

Brodeur published a series of books that planted the idea, in the minds of the public and media, of the existence of a hidden truth and a conspiracy endangering the public health.

The first book, entitled *The Zapping of America: Microwaves, Their Deadly Risk and the Coverup*, was published in 1977 and therefore predated the study by Nancy Wertheimer.

His second book, entitled *Currents of Death*, published in 1989, was a compilation of the various articles that had appeared in *The New Yorker*

following the polemic caused by his first book and the study by Nancy Wertheimer.

His third book was published in 1993: *The Great Power-Line Cover-Up: How the Utilities and the Government Are Trying to Hide the Cancer Hazard Posed by Electromagnetic Fields*.

2. The post-Wertheimer meta-analyses

The polemic aside, numerous scientific studies were carried out following that of Nancy Wertheimer.

Your *rapporteur* will not present in this report a complete inventory of such studies (which, in any case, can be found in the various collective assessments cited as references), but will instead limit his discussion to two decisive meta-analyses that succeeded in convincing the International Agency for Research on Cancer (IARC) of the WHO.

The study by Ahlbom et al. (British Journal of Cancer, 2000) is a meta-analysis that examined the data of nine previous studies. These controlled case studies used either actual measured fields or calculated fields, over a duration of from 24 to 48 hours.

The results indicated that, for a mean exposure level of below 0.4 µT and for a population of 3,203 children suffering from leukaemia and 10,338 healthy children, the increase in risk was almost nil.

However, for 44 sick children and 62 healthy children exposed to **a field equal to or greater than 0.4 µT, the risk increased by 2 fold**.

In brief, 99.2% of the children studied were exposed to less than 0.4 µT and did not suffer from any increased risk. 0.8% of the children, who were more heavily exposed, suffered from a greater than average risk to develop leukaemia.

The study by Greenland et al. (*Epidemiology*, 2000) included 15 studies and used a threshold of **0.3 µT, above which a risk factor of 1.7 was found**.

An important point underlined by the report prepared by the CSHPF in 2004 is that **these studies neither evoke the existence of a dose-risk connection** (neither in terms of exposure intensity, nor in terms of exposure duration)**, nor shed any light on an exposure threshold or period of exposure particularly indicative of a heightened risk**.

3. 2002: the IARC places ELF-EMFs in "Group 2B"

In 2002, the IARC published a monograph on the cancer risk evaluation of static and extremely low frequency electric and magnetic fields. ELF-EMFs were classified as Group 2B.

a) The IARC monographs

One of the missions of the IARC is to prepare monographs on the possible carcinogenicity for humans of environmental agents or factors: chemicals, complex mixtures, occupational exposures, physical and biological agents, and behavioural factors.

These monographs are a source of scientific information for the public authorities to prevent exposure to potential carcinogens.

They are prepared by groups of international experts who carry out a review of the scientific literature and evaluate the degree of risk.

Since 1971, over 900 agents have been evaluated, 400 of which have been classified as carcinogenic or potentially carcinogenic.

b) The IARC classification

The IARC's classification of agents comprises **five categories:**

Group 1: Agents that are carcinogenic for humans.

Group 2A: Agents that are probably carcinogenic for humans.

Group 2B: Agents that are possibly carcinogenic for humans.

Group 3: Agents not classifiable as to their carcinogenicity for humans**.**

Group 4: Agents that are probably not carcinogenic for humans.

Your *rapporteur* has included the complete results of this classification as an annex to this report so that readers can analyze for themselves the relative risk of each group.

To clarify this classification system, it should be pointed out that the discovery of **a new pathology linked to an environmental factor is only validated after several stages of corroborating results:**

- A **clinical observation**: practitioners observe an increased occurrence of the disease, notably among particularly exposed populations (professionals) or targeted populations (by age, sex, etc.).

- An **epidemiological observation**, with the demonstration of a risk and a dose-effect link, this observation being confirmed by several studies.

- A **mechanism** confirmed by reproducible **in vivo** studies on animals, as well as by reproducible **in vitro** studies.

The listing of an agent in Group 1 (in other words, as a certain carcinogen) most often corresponds to the accumulation of epidemiological proof, in vivo and in vitro.

The classification in Group 2A (probable carcinogens for humans) most often corresponds to only two elements of proof.

The classification in Group 2B (a simple possibility) usually corresponds to but one element of proof.

Finally, listing an agent in Groups 3 or 4 corresponds either to an absence of data or to data tending to invalidate the agent's carcinogenicity.

c) The 2002 monograph

In 2002, the IARC published a monograph relative to static magnetic and electric fields and extremely low frequency fields.

Its conclusions were as follows:

"There is **limited evidence** in humans for the carcinogenicity **of extremely low-frequency magnetic fields in relation to childhood leukaemia.**

There is **inadequate evidence** in humans for the carcinogenicity of extremely low-frequency magnetic fields in relation **to all other cancers**.

There is **inadequate evidence in humans for the carcinogenicity of static electric or magnetic fields and extremely low-frequency electric fields.**

There is inadequate evidence in experimental animals for the carcinogenicity of extremely low-frequency magnetic fields.

No data relevant to the carcinogenicity of static electric or magnetic fields and extremely low-frequency electric fields in experimental animals were available."

As a result, the **IARC listed ELF-EMFs in Group 2B, but the remaining fields studied in Group 3.**

d) Extremely low frequency magnetic fields classified in Group 2B

This classification was **based on the results of only the two epidemiological studies** carried out by Ahlbom and Greenland that are expressly cited and considered "closely consistent". Without them, the IARC would probably not have placed these fields in 2B. According to testimony gathered by your *rapporteur*, it was these studies that finally swayed the experts' decision.

However, **this classification was not established unreservedly**. While the IARC believes it improbable that the results of these studies were a matter of chance, it indicates that they may have been influenced by biases:

- Biases of selection, notably due to the fact that the controlled case studies relied on household measurements and therefore suffered from a low response rate on the part of the chosen participants.

- The studies based on calculated fields in northern Europe did not suffer from this bais, but rather from the limited number of exposed subjects.

- The inadequacies of the measurements of child exposure.

In addition, the IARC did not rule out the possibility that these various biases could have accumulated and determined the results. Indeed, it emphasized that: "If the observed relationship were causal, the exposure-associated risk could also be greater than what is reported".

4. The post-IARC studies

The IARC's decision constituted a stage as significant as the 1979 study.

It sparked numerous reactions and led to **the implementation of all recent collective assessments requested by the various governments**. **All confirmed the IARC's results as their limits.**

a) The epidemiology

For France, the most recent is **the AFSSET report of 2010, which concludes: "Therefore, nothing allows us to question, in any manner, the conclusions of the IARC on the possible association between extremely low frequency fields and juvenile leukaemia"**.

The report cites, in particular, two studies: that of Shüz et al. (2007) that confirmed Ahlbom's results, but studied the nocturnal exposure of children, and that of Kheifets et al. (2009) that confirmed those data relative to electric fields.

A third **study published in 2005 by Gerald Draper** demonstrated a correlation between these leukaemias and the subjects' proximity to extra high voltage lines; this study made very considerable waves.

It looked at 29,081 children who had developed cancer, with 9,700 of these children suffering from leukaemia. These children were aged from 0 to 14 years and were born in England and Wales between 1962 and 1995.

Their exposure to electromagnetic fields was measured based on the distance of their household at the time of birth with the nearest extra high voltage line.

The study concluded that those children "living" less than 200 m from a line faced a 1.69 times greater risk to develop leukaemia and those "residing" between 200 and 600 m faced a 1.23 times greater risk than those children "residing" more than 600 m from such a line.

Gérald Draper's study found no correlation with any other type of cancer.

Furthermore, the authors concluded that these results suffered from considerable statistical uncertainty and that the observed link could be due to chance or confusions.

The main criticism dealt with the very considerable approximation of exposure.

Some even see in this study grounds for supporting the nascent hypothesis of the harmlessness of such lines, for, considering an exposure approximation of this magnitude and a correlation beyond the zone in which the field was perceptible, it would seem likely that other factors were to blame for the observed leukaemias. Others feel that the Draper study could point to a viral hypothesis of leukaemias, as has been formulated for other large installations or construction sites.

Nevertheless, Gérald Draper is an epidemiologist respected by his peers and his results are coherent with those of previous studies and of the IARC.

Your *rapporteur* believes that this study, in fact, raises more questions than it answers. It is not more convincing than previous studies, nor does it rule out the possibility of a link existing between leukaemias and high voltage lines. Rather, it maintains doubt on the subject.

Since 2002, epidemiology has not managed to provide any additional proof specifying the risk evaluated by the IARC.

b) In vivo and in vitro

Faced with the doubt and the causal weakness of the epidemiological studies, **one must turn to laboratory studies to attempt to acquire a level of certainty via the demonstration of a mechanism**.

Unfortunately, few elements are available; in its 2009 report, SCENIHR examined in particular the following studies.

In recent years (2005, 2008), the publications by Fedrowitz and Löscher dealing with rats are the most often cited. However, their power to convince is limited by their non-replication and by the fact that they only obtained an impact of co-carcinogenicity with a specific race of rats: Fisher 344s. These animals were exposed to a field of 100 µT during 26 weeks, which is infinitely greater than the 0.3 to 0.4 µT encountered in epidemiological studies. Finally, these studies did not consider leukaemia, but rather breast cancer.

Another study (Erdal, 2007) is also not statistically significant and exposed rats to fields of 1 mT, which is once again much greater than that used in epidemiology.

In vitro, the same sort of difficulties are encountered. Studies carried out on the co-carcinogenicity of extremely low frequency magnetic fields provide some positive results due to the impact observed on certain cells (Cho 2007, Koyama 2008, Markkanen 2008), but often based on acute exposures: 5 mT in one case, 0.1 mT in another.

In 2010, therefore, our understanding is hardly any better than it was in 2002, as summed up by AFSSET: "With regard to possible long-term effects, there exists a **strong convergence between the various international assessments**, which remains constant over time. **A statistical link between**

exposure to ELF-EMFs and juvenile leukaemias has been observed by various epidemiological studies. These studies demonstrate a good coherence amongst themselves. The observed link is **statistically significant for a residential exposure [...] of greater than 0.3 or 0.4 µT, depending on the study**. **However, to this day, those studies that have been carried out to determine a biological mechanism of this effect have been inconclusive [...] This sustained incapacity to identify a mechanism of biological action constitutes a challenge** to our understanding the questions raised by the results of the epidemiological studies."

5. What is known regarding the causes of juvenile leukaemias?

Lacking direct answers regarding the possibility of a causal link between juvenile leukaemias and high voltage lines, what is known of the causes of this disease itself?

Your *rapporteur* will here rely on information provided by Ms Jacqueline Clavel, director of Unit 754 of INSERM (France's "National Institute of Health and Medical Research"), which manages the national registry of juvenile cancers and is currently carrying out the GEOCAP study for the geolocation of juvenile cancers according to environmental factors.

1,700 new child tumour cases are reported each year in France, for an annual incidence rate of 156 cases per million:

Types	Number
Leukaemias	487
Central nervous system tumours	394
Lymphomas	201
Sympathetic nervous system tumours	143
Soft-tissue sarcomas	105
Kidney tumours	96
Bone tumours	81
Germinal and gonad tumours	65
Melanomas and carcinomas	52
Retinoblastomas	49
Liver tumours	14
Others	4

Source: J. Clavel, Inserm, 2009.

For leukaemias, the annual incidence rate is around 44 per million.

For acute leukaemias with a possible link to magnetic fields (acute lymphoblastic leukaemia, or ALL, and acute myeloid leukaemia, or AML), the annual incidence rate is 40 per million.

Between 1990 and 2004, there were 6,640 cases of acute leukaemia in France.

Based on these international data, **the CSHPF estimated in 2004 that** - supposing that an exposure of 0.3 µT or greater represents a risk factor of juvenile leukaemia and that this level of exposure concerns 2% of children under the age of 15 - **2 to 12 cases could be attributed each year in France to electromagnetic fields, no matter the origin** (high voltage lines or the domestic environment), for an average of 53 cases over 10 years.

If one then supposes that a quarter of this population is subjected to over 0.4 µT due to the proximity of their households to transmission lines (see the "Côte d'Or study" carried out by EDF in 2004), this over-exposure would be liable to account for **0.5 to 3 cases per year**.

20% of sick children are not saved, or **potentially 0 to 1 death per year for this reason**.

This evaluation allows us to measure the magnitude of the risk. Nevertheless, it is rather crude, for subject to numerous uncertainties: evaluation of the exposed population and the population exposed due to power lines.

In the great majority of cases, these leukaemias manifest themselves between the ages of 1 and 6 years, peaking at around 3 years.

An increased incidence of these diseases has not been observed, but rather a concentration during the peak period, as was able to be demonstrated by comparing the evolution of incidence rates between Western and Eastern Europe.

Nor have significant differences in incidence been observed among the various European countries. However, differences are more significant among ethnic groups, according to studies carried out in the United States and New Zealand.

These variations or non-variations of incidence leave a number of questions unanswered:

- Are they real or linked to biases (such as the quality of the diagnosis and counting) or to "rival" diseases?

- If these variations are real, can they be explained by differences in lifestyle? Socio-economic conditions? Epidemics?

In parallel to these general questions and data, we know that leukaemias are multifactorial diseases, whose various mechanisms are poorly understood.

Nevertheless, the following risk factors have been established:

- High doses of ionizing radiations.
- Anti-cancer chemotherapies.
- Genetic predispositions (to cancer or not).
- Down's syndrome.

Furthermore, several hypotheses have been formulated around risk factors:

- Specific viral infections that could make leukaemia a rare response to a frequent and common infection (Kinlen, 1988), notably following the intermixing of populations linked, for instance, to the construction of a large installation.

- The "hygienist hypothesis" (Greaves, 1988), by which leukaemias would be a response to an immunity isolation and an insufficient exposure to diseases at a young age, with breast feeding and collective child-care being good means of reducing the risk of occurrence.

- Ionizing radiations at low doses (radon) or non-ionizing radiations, whether ELF-EMFs or radio frequencies.

- Chemical exposures to pesticides (parental or domestic, such as the use of insecticides by the mother during pregnancy), to air pollution, to road traffic or nearby service stations, and to passive smoking (by the mother during pregnancy or by the father prior to conception).

- Finally, it could amount to epigenetic mechanisms.

None of these hypotheses is, from a research perspective, favoured over the others. The possible link between ELF-EMFs and leukaemias is not any stronger.

This is precisely the objective and spirit of the GEOCAP study, which seeks to study the prevalence of various exposures: ELF-EMFs, road traffic, residential radon, nuclear sites, "Seveso" industrial sites, and service stations.

6. Conclusions and Recommendations

a) The facts

Information gathered by your *rapporteur* reveals the following elements:

- Between 1990 and 2004, 6,640 children were afflicted with acute leukaemias in France (between 450 and 500 cases per year). According to experts and taking into account the population's exposure, if there were a causality between the ELF-EMFs emitted by high and extra high voltage lines and leukaemias, this relationship would undoubtedly explain no more than around 0.5 to 3 cases per year (2 to 12 cases for all ELF-EMFs).

- The children concerned are, for the most part, from 0 to 6 years of age.

- Since 1979, epidemiological studies have demonstrated the existence of an increased risk of juvenile leukaemia for exposures greater than 0.3 µT.

- This epidemiological piece of data led to the competent international organization, the IARC, to classify extremely low frequency magnetic fields in Group 2B (possible carcinogens), rather than in Group 2A (probable carcinogens).

- No study since 1979 has demonstrated any mechanism of action on the part of these ELF-EMFs contributing to the development of juvenile

leukaemias. No in vivo or in vitro piece of data supports the existence of any causal link.

- High and extra high voltage lines are not the only factor of child exposure.

- These transmission lines are but one possible environmental factor alongside several others to explain the development of leukaemia.

So much for the facts.

b) The opinion of your rapporteur*: do not leave things as they are*

Your *rapporteur* believes that while the current scientific data allow us to dismiss (with a high level of probability) a link between the various cancers and the ELF-EMFs emitted by high and extra high voltage lines, **no scientific piece of data allows us to state with certainty that these same fields do not play a role in the development of leukaemias**.

The classification carried out by the IARC must logically reassure those populations living near power lines with regard to all cancers; however, it must just as **logically incite them to ask questions regarding these lines' possible impact on children aged from 0 to 6 years**.

Your *rapporteur* believes that the risk is low. He even firmly believes that there is probably no risk, but no scientific results exist to dismiss the risk entirely.

Therefore, he believes that **the question should not remain as is** and that the dossier should not continue along the same "business as usual" path.

Indeed, **even if only five children were concerned each year** (as the experts state would be the case in the event of a confirmed causality), **the suffering of these five children would suffice for us to take action**.

Families living near power lines and elected officials must have at their disposal certainties or, at the very least, a greater probability of causality or non-causality than they do today.

Indeed, the evolution of the electric transmission system is a necessity for our country and corresponds to collective objectives approved by the national government in pursuance of sustainable development. Its implementation must be carried out in the most consensual manner possible, within the framework of a shared project. From this perspective, it is important to attempt to shed light on health-related questions.

c) What must be done?

Confronted with this situation, what must be done?

(1) Relaunching research

The first obvious and urgent recommendation is to carry out the necessary research, with **the objective of inciting a revision of the IARC classification in one direction or the other**.

Your *rapporteur* believes that **the Ministry of Health must rapidly take charge of this relaunching, dividing the research among the three avenues possible:** identifying a strong statistical link via epidemiology, discovering a mechanism of action via in vivo and in vitro studies, and seeking the causes of juvenile leukaemias.

- Identifying a strong statistical link via epidemiology.

The existing studies are the subject of numerous criticisms targeting essentially three central aspects: the method of estimating exposure, the (often significant) confidence interval, and the justification of the 0.3 or 0.4 µT threshold.

In its 2007 monograph, **the WHO gave "high priority" to up-dating the existing grouped studies on juvenile leukaemia with the help of new data**.

However, epidemiological studies are confronted with certain limits, notably the impossibility of reconstituting the exposure history of children. Faced with the exaggerated expectations aroused by INSERM's GEOCAP study, Ms Jacqueline Clavel was obliged to specify the extent of the study in a letter (dated 17 February 2010) addressed to the departmental councillors of the Manche department and which was eventually passed on to your *rapporteur*.

In this letter, she indicated the limitations of her study with regard to the specific question of a possible link between ELF-EMFs emitted by high and extra high voltage lines and acute juvenile leukaemias:

- Only the children's most recent home address is available (neither the previous addresses, nor the addresses prior to or at the time of birth are available); consequently, although specific, these measurements are historically limited.

- The study included too few subjects living near power lines to provide a reliable statistical answer. Of the 15,000 control subjects of the initial recruitment phase, 342 children (2.3%) lived within 200 metres of a transmission line of 63 to 400 kV and 110 children (0.7%) within 50 metres. Only 9 children lived within 50 metres of a 400-kV line and 24 children within 50 metres of a 225-kV line.

- This study will therefore not provide a definitive answer to the question raised by foreign publications regarding the possibility of an increased risk of juvenile leukaemia near transmission lines.

- However, it will in the medium term allow for a much better understanding of the question, via an improved understanding of the exposed population and the possible co-factors of risk.

To overcome its statistical limitations, the GEOCAP study doubled its recruitment and its **results** have been delayed; they are **expected in late 2010**.

This study will be extended, for the leukaemia cases included in the national registry will continue to be geolocated, providing greater precision and allowing for a better understanding of the possible causalities.

In addition, the GEOCAP study could be **reinforced by an exposure validation study**. This validation of exposure could perhaps be extended to continuous or quasi-continuous domestic EMF sources, such as electric underfloor heating.

The pursuit of a reinforced GEOCAP study is therefore an initial, serious possibility for obtaining more precise data.

A second possibility would be to **replicate the Draper study in France and to compare the results to the GEOCAP study.** Indeed, by comparing exposure at the location of birth with the incidence of the disease, the British researcher worked in the opposite direction as the GEOCAP study, which compares the occurrence of leukaemia with at-home exposure at the time of diagnosis.

In France, such a study could make use of the child cancer registry and thus analyze data covering the past 20 years (1990-2010).

This would involve INSERM having access to this piece of data (address at the time of birth), which for the time being is protected.

Your *rapporteur* believes that this option should be seriously considered.

A third possibility would be for the Ministry of Health to request that a feasibility study be carried out, at the European level, of a cohort study to shed light on the question.

In a letter dated 22 February 2010 addressed to the Director General for Health and which was also passed on to your *rapporteur*, the INVS believes that such a study would not be scientifically valid for a limited geographical area, for it would include too few cases. It is therefore out of the question that the study be carried out on a single existing high voltage line, for this would engender a "spotlight effect": the few cases identified "by chance" (statistically speaking) would be liable to be taken for proof, while, in fact,

they would lack any statistical or scientific value. Such a study would even be dangerous: a positive result would cause unnecessary anxiety, while a negative result would provide false reassurance.

However, the INVS indicates the magnitude of the study that would be necessary to demonstrate any health effect.

The demonstration of **a doubling of the risk by a cohort study would involve the monitoring of 225,000 child-years, or, for instance, 22,500 children over 10 years**.

The demonstration of a risk multiplied by 1.5 would necessitate the monitoring of a much larger population, in the region of 765,300 person-years.

In a letter addressed to your *rapporteur*, Pr André Aurengo estimated that such a study would involve monitoring nearly 100,000 children for ten years (50,000 exposed children and 50,000 non-exposed children) over a long period of time in order to attempt to demonstrate a doubling of the risk with a sufficient level of statistical certainty. The concerned diseases are very rare: in the region of 4 cases per year for every 100,000 children, with some 470 new cases annually in France. In addition, average exposures to over 0.3 or 0.4 µT are also very rare (in the region of 2%) and among these cases, 0.4% are due to the existence of nearby power lines (with different causes of exposure to extremely low frequency electromagnetic fields in the other cases).

Ms Jacqueline Clavel believes that these juvenile leukaemias are too rare to imagine ever monitoring a population of children from birth with a satisfactory level of statistical power. She estimated that some one million children would need to be monitored.

An international study would be complex, difficult to implement and potentially contradictory with regard to its results, as demonstrated by the INTERPHONE project.

Therefore, in all likelihood, this hypothesis must be excluded.

- Finding a mechanism.

The second option, **recommended in priority by SCENIHR** - notably in its report of 6 July 2009 on the research priorities to help overcome knowledge gaps in the subject - is to demonstrate the mechanism of action of ELF-EMFs on leukaemias.

For this committee, if is unlikely that epidemiology would provide a clear answer to the question raised. It therefore recommends that attention be focused on in vivo and in vitro laboratory studies.

For SCENIHR, it is of the utmost importance to reconcile the laboratory data with the epidemiological data.

It suggests that these studies be based on experimental models that have already provided an answer for ELF-EMFs and that they seek to **demonstrate a dose-effect relationship for fields inferior to 100 µT**.

It believes that **results could be obtained within two to three years**.

The SCENIHR's recommendation is fully **coherent with that of the WHO in 2007, which recommended according "high priority" to the development of transgenic murine models of juvenile leukaemia**, as well as the evaluation of co-carcinogenic effects via **in vitro** animal studies.

In this regard, it should be pointed out that a French team managed in 2004 to create an animal model of type pre-B acute lymphoblastic leukaemia (ALL), which is the most frequent form among children (Bernard et al., 2005, *Experimental hematology*). To the best knowledge of your *rapporteur*, no experiment on exposure to extremely low frequency magnetic fields has been carried out.

- Understanding the causes of juvenile leukaemias.

Finally, considering the uncertainties surrounding the factors triggering the disease and the moment at which they have an effect (for instance, before or after birth), **it would be necessary to seek a better understanding of the hierarchy of risk factors**.

To this end, **the GEOCAP study seems well suited and should provide the first results at the end of 2010**. Perhaps the study will reveal greater environmental risk factors than that which is currently known to link juvenile leukaemias with high voltage lines? **While that would not directly answer the question that we are concerned with here, it would help rank the public health priorities.**

In addition, **medical studies on the disease itself should be deepened, so as to also prioritize the causes explaining the triggering of the disease** and the plausibility of a magnetic cause that currently does not seem to hold the attention of specialist clinicians.

With regard to research, your *rapporteur* first and foremost recommends:

- Financing in vivo or in vitro studies liable to shed light on or invalidate the possibility of a mechanism.

- Supporting INSERM's GEOCAP study by reinforcing its means and improving its precision.

- Studying the feasibility of replicating the Draper study in France, in the spirit of the GEOCAP study.

- Pursuing fundamental research on juvenile leukemia itself.

(2) The WHO recommends a benefit-risk approach

In its 2007 monograph, the WHO considered that **the elements of proof were sufficient to cause concern, but insufficient to establish any causality**.

For the WHO, if the causal link were established, **between 100 and 2,400 leukaemia cases worldwide per year would be explained by this factor, or between 0.2 and 4.9% of the total annual incidence of leukaemia cases, which were estimated at 49,000 worldwide in 2000**.

As a result, according to the WHO, **prudent strategies are warranted**.

This means that **the WHO does not recommend reducing the limit values set by current standards "until an arbitrary level in the name of the principle of precaution [for] such practices undermine the scientific foundations on which the limits are based and risk constituting a costly - yet not necessarily effective - approach of ensuring protection"**.

The WHO even believes that it **"is difficult to determine the health benefits that would be provided by reducing exposure. Therefore, the measures must cost very little"**.

(3) The British government applies the same principle

The British government provided a solution founded upon a cost-benefit approach in response to the Stakeholder Advisory Group on ELF-EMFs (SAGE), which sought to elaborate a precautionary approach on this subject and which presented its report in April of 2007, and to a transpartisan parliamentary study published in July 2007 on the same subject, both of which recommended - though each in its own manner - the implementation of corridors closed to construction around high and extra high voltage lines.

The Sage committee had recommended a freezing of residential, school or similar constructions within a corridor 60 metres on either side of power lines and avoiding the construction of new overhead lines within a similar distance. The transpartisan study extended the corridor to 200 m for the most powerful lines.

The British government rejected this recommendation, for it was incoherent with the cost-benefit approach advocated by the WHO. Indeed, its cost was estimated at between 1 and 2 billion pounds for the loss in property value alone.

It underlined that the government could not finance at a high cost the prevention of an uncertain health risk at the expense of other objectives such as, in the energy sector, fighting climate change. In its response of 16 October 2009, it emphasized: **"It should not be assumed that the consumer would be willing to pay, especially bearing in mind the uncertainties of the science"**.

Furthermore, it indicated that **the number of juvenile leukaemia cases in the United Kingdom was estimated at around 500 per year**. **If a causal link did indeed exist, it could account for some 4 or 5 cases, but only a third could be attributed to this specific cause** (ELF-EMFs in general, as opposed to those emitted only by electric power lines), although

certain studies have placed this figure as high as 25. **In parallel to these data, the British government pointed out that in 2006, 299 children under the age of 15 had died from diverse injuries or poisoning and that 149 had died during traffic accidents.**

(4) Should one go further? The AFSSET proposal

In its 2010 assessment, AFSSET believed it justified, as a precaution, to stop increasing the number of exposed sensitive people. It recommends creating a zone closed to new constructions that are open to the public (hospitals, schools, etc.) and that serve sensitive populations (pregnant women and children), with the zone being delimited at least 100 m on either side of extra high voltage lines; this zone would also be respected for the installation of new lines and could be reduced in the event of the lines being buried.

AFSSET recommends relying on the powers accorded to the prefects by the Act of 13 December 2000 and the Decree of 19 August 2004.

Your *rapporteur* finds valid the approach that seeks to escape the present situation by attempting, on the one hand, to find a scientific answer to the question of a possible causality between power lines and juvenile leukaemias and, on the other hand, to **avoid exposing more people**.

However, AFSSET's recommendation does not seem in accordance with the recommendations of the WHO to find very inexpensive solutions, considering the scientific uncertainty. Nor does it seem scientifically well founded. Finally, AFSSET's recommendation seems liable to engender more anxiety than reassurance.

AFSSET provides no evaluation of its recommendation and only relies on reducing exposure. However, **its recommendation would likely prove expensive, as in the United Kingdom**. What is more, one should keep in mind that the "Operational Committee on Health Monitoring and Emerging Risks" (COMOP 19) of the Grenelle Environment Round Table did not retain the proposal to create a 200-metre-wide corridor closed to construction.

The proposal is not scientifically well founded, for it is known that the distance to a line provides but a weak approximation of exposure. All lines do not share the same power and lines of the same voltage are not always used with the same intensity. Therefore, a limit of 100 m seems of limited effectiveness, though it would have a high cost.

The persons and buildings targeted are also too vaguely defined based on an average exposure of 0.3 or 0.4 µT over 24 hours.

Furthermore, high voltage lines would only explain a portion of juvenile leukaemias liable to be provoked by ELF-EMFs – if the causality were established. The Expers study notably demonstrated the influence of railway lines and domestic devices.

Your *rapporteur* also points out that a child from 0 to 6 years of age spends more time at home than in any collective institution. Would the AFSSET proposal be effective?

Finally, such a measure, if implemented as is, **would risk increasing the population's anxiety without providing any solution**, for it would engender a questioning of all buildings/facilities targeted by the measure but already built. **This anxiety would be unjustified, in view of the current science.**

(5) What risk-benefit approach for France? The recommendation of your *rapporteur*

Your *rapporteur* believes, as does AFSSET, that:

- We must alleviate the current uncertainty.

- We must seek to **not increase the number of people exposed, while awaiting new scientific data**.

To this end, your *rapporteur* believes that **the most appropriate attitude given the current state of scientific knowledge is for the government to accord itself 5 years to**:

- **Relaunch research** and have at its disposal targeted data on the very specific issue of a possible causal link between juvenile leukaemias and high voltage lines.

- At the end of 4 years, request that AFSSET update its scientific evaluation and, if necessary, provide a recommendation for protecting the population along with a socio-economic evaluation.

In 2015, the French government would thereby be able to make a better informed decision.

- By 2015, your *rapporteur* believes it pertinent to recommend - **in a prudent manner** and taking into account the scientific uncertainties - that parents and authorities (in particular, elected officials) **seek to avoid, whenever possible and at a reasonable cost, the exposure of children aged 0 to 6 years, as well as unborn children, to fields greater than 0.4 µT on average**.

Indeed, the population that must be targeted corresponds to unborn children, for this period could be favourable to the predisposition to leukaemias (though no certainty exists) and to children 0 to 6 years of age, who risk suffering from an acute leukaemia. But **only this population is concerned**.

While the exposure of these children should be minimized, occasional over-exposures can be tolerated, for nothing in the scientific literature states that an occasional over-exposure - within the limits of the current regulations - is harmful.

On this subject, your *rapporteur* thinks it reasonable **to draw inspiration from those measures undertaken in the Netherlands and described in a comparative legislation memorandum prepared by the French Senate** (complete memorandum included as an appendix).

Recommendation of 3 October 2005
by the Dutch Minister of the Environment

On 3 October 2005, the Minister of the Environment addressed a recommendation to the executive organs of the municipalities and provinces, as well as to the power transmission companies.

According to this document, during the elaboration of urban development plans, as well as during the determination of high voltage power line routes, **one should, to the greatest extent possible, avoid creating "new situations" by which children would remain for sustained periods of time in zones located near high voltage overhead lines for which the magnetic induction averaged out over one year exceeds 0.4 µT**.

To facilitate the task for the municipalities, the text introduces the idea of "**indicative zones**": corridors whose width varies according to the voltage of the line and in which it is recommended to avoid new constructions destined for so-called "sensitive" populations, notably schools, day nurseries and playgrounds.

The width of these corridors is established as follows, the line being located in the centre of the corridor:

Voltage	Corridor width
50 kV	2 x 40 metres
110 kV	2 x 50 metres
150 kV	2 x 80 metres
220 kV	2 x 150 metres
380 kV	2 x 200 metres

This recommendation does not apply to installations built prior to 3 October 2005, unless they are the subject of modifications. Several terms used in the recommendation are discussed in an appendix, which was updated in November 2008. For instance, the word "child" refers to any person under 15 years of age, while a "long-duration stay" means at least 14 to 18 hours per day, on average, the average being calculated over one year.

The recommendation is non-binding. Several municipalities have decided to not follow the recommendation during the construction of new collective facilities. In the resulting dispute, the tribunals underlined several times that the municipalities were not bound to respect the recommendation, though they were obligated to justify their decision.

The government could therefore recommend, in a non-binding manner, to formalize a "caution zone" with a maximum exposure of 0.4 µT.

It would recommend against building new installations or constructions destined for children of this age group and in which they would spend a sustained period of time (several hours per day, throughout the year: households, day nurseries, nursery schools and parks with playgrounds) and against installing any lines (no matter the type) in those areas in which the mean ELF-EMF **measured over 24 hours and annualized is greater than 0.4 µT**.

The same recommendations would apply to **power transforming stations**.

This attention paid to high voltage lines should be **extended to SNCF railway lines**.

The attention paid to magnetic fields should lead concerned parties to take care that, within such buildings, **the exposure linked to electric installations and devices does not exceed this recommended limit**.

Likewise, just as parents are recommended to avoid that their children use a mobile telephone too often, **it is today reasonable to advise parents to, as far as is possible, limit the exposure of their young children**.

To this end, **mayors and local authorities could usefully rely upon, on the one hand, the agreement signed between RTE and the AMF allowing for magnetic field measurements to be carried out**.

Citizens could ask their mayors to have such measurements carried out in a given neighbourhood or, in exceptional cases, directly ask RTE or EDF to carry out these measurements.

However, your *rapporteur* underlines the fact that **such a non-binding recommendation would only have meaning if, in parallel, the French government commits itself to taking the necessary measures to obtain within 5 years new scientific data**.

D. MAGNETIC FIELDS AND NEURODEGENERATIVE DISEASES

Neurodegenerative diseases constitute the third type of pathology engendering a scientific debate on the existence of a possible link with ELF-EMFs emitted by high and extra high voltage lines.

Recent publications support this hypothesis and are upheld by the international consensus of experts.

1. The hypothesis of a possible danger

a) The scientific data

The attention of your *rapporteur* was drawn to this question by the 2009 SCENIHR report.

(1) The epidemiology

A recent meta-analysis (Garcia et al., 2008) grouping together 9 case-control studies and 5 cohort studies demonstrated a significant association (1.6 to 2) between occupational exposure and the risk of triggering Alzheimer's. AFSSET, which cites this study, points out that the data taken into account is very heterogeneous and that their interpretation is therefore limited.

Swiss studies on railway employees in Switzerland (Rösli et al., 2007) and on people living near power lines (Huss et al., 2009) would tend to confirm this link.

Rösli carried out a study that looked at 20,141 railway employees from 1972 to 2002 (464,129 subjects/year). Based on measurements and models, he calculated the accumulated exposures and compared the most exposed groups (typically **train drivers**) to the least exposed railway workers (typically station agents). It must here be pointed out that Swiss railways use a 15 kV - 16 2/3 Hz alternating current.

Rösli found that drivers run a 1.96 times greater risk of dying of senile dementia than station agents and a 3.15 times greater risk of dying of Alzheimer's. He also demonstrated a dose-effect link by 10 µT segments with regard to senile dementia, Alzheimer's disease and amyotrophic lateral sclerosis or ALS (confidence interval of 95% = -6.8 to 11.7).

However, considering the confidence intervals, **the link is only truly strong with regard to Alzheimer's** and, according to the authors, only for the terminal stages of the disease.

Huss researched the potential relationship between **death linked to a neurodegenerative disease and the fact of residing next to an extra high voltage line (220 to 380 kV)**. The study looked at 4.5 million people between the years 2000 and 2005, based on an analysis of national data.

Huss found a risk of 1.24 (CI = 0.80 – 1.92) for those persons living less than 50 m from such a line at the time of their death, compared to those persons living 600 m or more away. But a dose-effect relationship was found according to the duration of nearby exposure: 5 years > 1.51; 10 years > 1.78; 15 years > 2. Similar results were obtained for senile dementia, but not for ALS or Parkinson's disease.

(2) In vivo and in vitro

In this regard, SCENIHR - mirrored by AFSSET - mentions two recent studies.

- The first study, in vivo, would seem to indicate no effect on ALS based on a mouse model (Poulletier de Gannes et al., 2008) for an exposure lasting 7 days to fields of 100 to 1,000 µT.

- The second study, in vitro, would seem to indicate a link with Alzheimer's (Del Giudice et al, 2007). It demonstrates the reaction of human glial cells to a field of 3,400 µT by increasing the production of a peptide involved in the development of the disease.

b) Field data for SNCF and the RATP

Taking into account the Swiss study, your *rapporteur* sought data available in France via the RATP and SNCF state railway services.

(1) The RATP

During their interview, the RATP authorities pointed out to your *rapporteur* that the Paris Metro operated on a direct current of 750 V, while the tramways and RER lines used a direct current of 1,500 V. For this reason, **the personnel are exposed to static magnetic fields.**

The RATP's epidemiological unit carried out **a cohort study on the causes of the mortality of 68,000 people having spent at least one year with the RATP, between 1 January 1980 and 31 December 1999**. The principal diseases examined were cancers and neurological diseases. 83% of the subjects studied were men having spent an average of 20 years at the company.

No increased risk was revealed in comparison with the general population, neither among the entire personnel, nor among train drivers and electromechanical engineers who represent the most exposed populations.

(2) SNCF

SNCF runs its trains on **a 25 kV - 50 Hz alternating current**.

At SNCF, no epidemiological study has been carried out. During his interview of the company's competent authorities, your *rapporteur* was not entirely convinced of their claim that this was uniquely a matter for the contingency fund, independent of the company.

The absence of data is regrettable, for the working conditions of the French railways are not exactly comparable to those of the Swiss railways, notably in terms of exposure: current type, engine type (TGV, for example), work organization, etc.

A study would allow to shed some useful light on the question.

2. Conclusions and Recommendations

(1) The disagreement between the WHO, SCENIHR and AFSSET

In 2007, the WHO considered that it was **important to study this association further and ranked it among its "high priorities"** of research. The organization indicated that this research called for "**extensive prospective cohort studies** including information on exposure to ELF magnetic fields, electric shocks and other risk factors". It also underlined - as AFSSET would also do, three years later - the necessity to use morbidity data (diseases), rather than mortality data (immediate causes of death).

For SCENIHR, the epidemiological data based on professional and residential exposure and some data provided by laboratory studies contribute to making the potential risk of a relationship between ELF-EMFs and Alzheimer's a serious hypothesis justifying new studies. The fact that Alzheimer's is a relatively common disease attracts all the more attention to this subject.

In its report of July 2009 relative to research priorities, SCENIHR believes that these studies must be both epidemiological and in vivo, with the use of pertinent animal models, for today "the evidence is inconclusive". Results can only be expected in the medium term.

SCENIHR has made this question its research priority relative to ELF-EMFs, placing it before juvenile leukaemias.

AFSSET has not carried out a ranking as such among the various risks and research priorities. It **simply recommends pursuing the research** on this subject due to the lack of current information and because **the hypothesis cannot be dismissed**. It believes that "**the data relative to this association remains unconvincing**". A contrario, as your *rapporteur* touched upon above, the agency formulated much stronger recommendations relative to juvenile leukaemias.

(2) Local monitoring rejected by the INVS

Asked to decide upon a request by the DGS (French "Directorate-General for Health") for the local monitoring of Alzheimer's near high voltage lines, the INVS submitted its rejection in early 2010.

In its rejection, which was passed on to your *rapporteur*, the INVS pointed out that **Alzheimer's disease was the subject of no monitoring programme at the national level** and that specialists had not requested the implementation of any screening. On the other hand, an early diagnosis is desirable.

However, the under-diagnosis of this disease has been estimated at around 50% due to the difficulty of identifying the initial symptoms, a reluctance on the part of the population, the priority given by attending physicians to other pathologies, and, finally, poor coordination between the social, health and legal fields.

An active diagnostic approach within a delimited zone would probably cause an artificial increase in the incidence of the disease due to its being generally under-diagnosed.

To avoid this monitoring bias and to demonstrate an excessive risk, it would be best to monitor an exposed population along with an unexposed population over a **very long period of time**. The INVS evokes monitoring subjects over their "entire lifetime".

For the INVS, "**these methodological constraints [...] appear to rule out the provision of any local solution** to the anxieties of those populations living near" a high or extra high voltage line.

(3) The recommendations of your *rapporteur*

Your *rapporteur* therefore observes that **a consensus exists on the part of experts regarding the absence of an established causal link** between neurodegenerative diseases and ELF-EMFs and the fact that this constitutes a **hypothesis requiring further examination**.

However, he also observes a **divergence concerning the analysis of this risk and the research priorities**.

He **invites the French government to**:

- **Not neglect this risk**, especially considering that the available epidemiological data deal more particularly with occupational exposures.

- **Support research** in the direction recommended by the national and international community of experts.

He earnestly requests that SNCF carry out an epidemiological study.

IV. THE POTENTIAL ENVIRONMENTAL IMPACTS

The second part of this OPECST report consists of an evaluation of the potential environmental impacts of extremely low frequency electric and magnetic fields emitted by high and extra high voltage lines.

The Office decided that this aspect of the report should not include the issue of lines' integration into the surrounding landscape, as this was the principal subject of an earlier report prepared by our colleague Christian Kert, Deputy, in 2001, dealing with the contributions of new technologies with regard to the burying of high and extra high power lines.

Your *rapporteur* will here deal with the impact of fields on flora and fauna, both wild and domestic.

A. THE WEAKNESS OF THE DATA ON WILD FLORA AND FAUNA

Very few studies seem to have been carried out to examine the direct effects of fields on flora and fauna; however, the scientific literature is more extensive concerning the measuring of lines' indirect impacts.

1. The near absence of scientific data on the potential direct effects of electric and magnetic fields

Despite the research carried out, your *rapporteur* was only able to find a very small number of studies dealing directly with the possible impacts of electric and magnetic fields on wild flora and fauna.

a) Birds

The most recent such study was a 2009 publication (Dell'Omo, *Comparative biochemistry and physiology*) dealing with **the common kestrel in Italy**. The author observed that these birds built their nets on pylons and, what is more, that the chicks were exposed over long periods of time to strong fields and during a very important period of their development (egg and pre-flight). An extensive comparative analysis was carried out on the birds' melatonin, leukocytes, growth curve and success rate at taking flight. No effect was found. However, this study is statistically limited in scope, for out of the 44 nests studied, only 28 were exposed to fields. It did, however, confirm a previous publication that examined the effect on common kestrels of exposure to 0.2 to 20.44 µT (Constantini et al., 2007).

In his bibliographical review, the author **summarized the various studies carried out on birds; their results are contradictory.**

Several American studies (Fernie et al., 1999, 2000, 2001 and 2005) have looked at the common kestrel of North America and demonstrated certain

effects varying according to age, sex and exposure duration, but in laboratory conditions that are rather different from natural conditions.

In the natural environment, the author located some research comparing the common wren, a passerine, with the tree swallow (Doherty & Grubb, 1998), which revealed a reduction in nest size for the first, but larger eggs and less reproductive success for the second. Another study (Hamman et al., 2007) revealed an increase in egg size among blue tits, but a reduction in egg size among great tits.

b) Fish

Your *rapporteur* learned of several American studies underlining the sensitivity of certain species of fish to weak electric fields. According to these studies, the American eel and the Atlantic salmon are capable of perceiving electric fields of 7 to 70 mV/m (McCleave et al., 1974). However, fields of 45 to 75 Hz and up to 20 V/m are said to have nearly no influence on young bream (Ibid. and Coate et al., 1970).

2. Studies of indirect observation

Indirect observation studies are more numerous. In these studies, researchers do not attempt to measure the impact of an electric or magnetic field on wild animals or plants; rather, they attempt to locate variations in compiled data with regard to abundance and behaviour.

These studies are convergent. They demonstrate that the dominant effect is a modification of the environment (for instance, via an "edge effect"). The installation of power lines usually has a favourable impact on the flora and fauna.

a) Flora

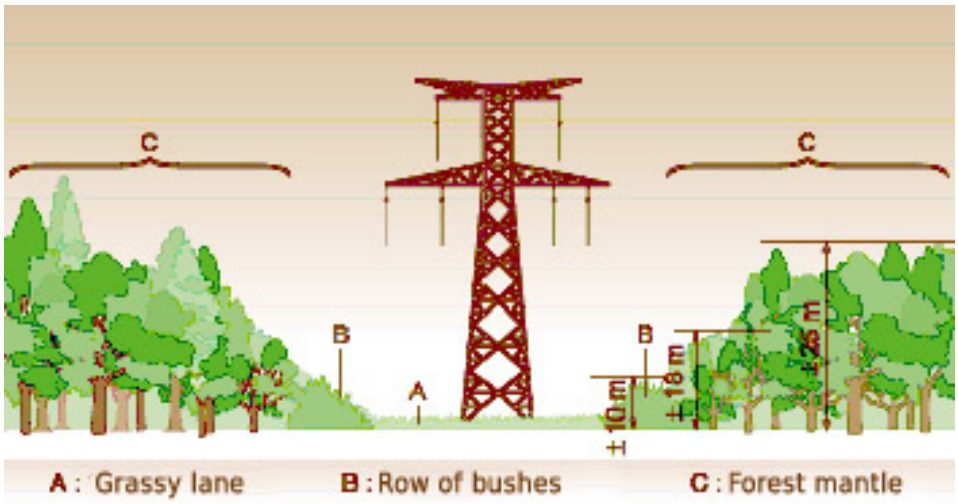
American studies carried out in the 1980s and notably dealing with 1,200 kV lines demonstrated the impact of the corona effect on trees that were allowed to grow immediately next to the lines. These trees were "self-pruned". Similar effects have also been observed in nature around 750 kV or 500 kV lines.

Today, these impacts are theoretical, for in the United States, as in France, the regular maintenance of forest corridors seeks to block any possibility of a short circuit occuring due to a tree coming into contact with a conductor. This phenomenon is the suspected cause of the great "Northeast Blackout of 2003", which deprived 50 million people of electricity in the northeastern United States. In France, RTE has committed itself - in its public service contract with the state - to restore service within five days. It is therefore necessary to limit the growth of trees and maintain easy access so as to avoid accidents and short circuits and to facilitate intervention.

More recently, the CBNBP ("National Botanical Conservatory of the Paris Basin"), a body dependent on the MNHN ("National Natural History Museum"), carried out a floral inventory along 170 km of 225-kV power lines in the eastern portion of the Ile-de-France region, within the framework of a partnership with RTE and the region.

This inventory was carried out along forest corridors. The study is of particular interest because in Ile-de-France, the forest comprised of beech, oak and hornbeam is "climax vegetation"; in other words, it represents the normal, final state following various ecological successions. But this climax vegetation is not the state presenting the greatest species richness. Open environments maintained by man via agricultural activities favour much greater species richness. In comparison to this phenomenon, the simultaneous abandonment of farmland and industrialization of agriculture undermines biodiversity. This tendency is strengthened by the region's scattered, haphazard development (urbanization, road networks) that can prevent species from accessing their living environments, engender reproductive isolation, increase inbreeding, decrease population size, and, in the end, increase the risks of extinction.

However, land occupied by RTE in forested areas entails the maintenance of an open environment so as to maintain a "safety zone" separating the trees from the power cables. RTE carries out regular maintenance work, such as a "rotary slashing" every three years and maintaining an access lane once a year. Schematically, these corridors are therefore comprised of a grassy lane running immediately below the line, bordered on either side by a row of bushes (no higher than 10 metres), which in turn are each bordered by a two-tiered forest mantle at 18 then 25 metres. The vegetation therefore obeys a triennial cycle.



Source: RTE

The results of this inventory are very significant. These corridors account for a third of the Ile-de-France region's biodiversity (500 species), including 70 "heritage species". 7 species are protected at the regional level and 1 at the national level, and 9 species are deciding factors for ZNIEFF

("Natural Zone of Ecological, Floral and Faunal Interest") classification. One species, the *Polygala chevelu*, had not been seen since 1960. The last sighting of this plant had been made in a municipality located near a power line.

Corridors maintained for power lines therefore appear to act as a sort of refuge for declining species and habitats. They engender an edge effect - favourable, for example, to the bloody cranesbill flower when dry.

They can also furnish **migration and distribution corridors** for these species, as has been demonstrated for gas pipeline routes, fully justifying their integration into a future "green belt".

Consequently, the CBNBP has formulated recommendations to encourage this refuge effect, notably by modifying the maintenance techniques: periodicity, the "exportation" of pruning/cutting by-products so as not to enrich the soil to the benefit of invasive species, paying special attention to sensitive zones, etc.

This study, limited in terms of the area covered, is particularly interesting, for nearly 8,200 km of RTE lines are located within forested environments. Additional conclusions remain to be drawn from this study. However, RTE's practices have already been modified to limit their impact on the landscape. Instead of carrying out clear cuttings every three or four years, RTE has progressively adopted the signing of 20-year forest management plans with the ONF (France's "National Forest Office").

b) Fauna

One must here distinguish between observations of mammals and those of birds.

(1) Mammals

Studies on mammals seem to be both rare and nonrecent.

Your *rapporteur* found the reference for a 1975 study (Goodwin) carried out in Idaho, in the United States, on the movement of caribou and elk in proximity to 500-kV lines. The study demonstrated that the animals were attracted to these open areas for feeding, but that they avoided them during the day during hunting season.

A study carried out at around the same time (Schreiber et al, 1976) in Tennessee looked at the abundance of small mammals in power line corridors through forests. The results varied according to forest type: broad-leaved or coniferous forests. But they confirmed, above all, the fact that the dominant impact was the opening up of the environment and the modification of the animals' shelter and food supply. These corridors also favour the presence of species absent from the adjoining forest.

Two experimental studies carried out along a 1,200-kV line (Rogers et al., 1980; Warren et al., 1981) provided similar results.

(2) Birds

The best known impact of power lines on birds is their **accidental mortality due to collision or electrocution**. This occurs when a bird lands on or takes flight from a pylon, touching the pylon and a conductor simultaneously.

This problem is significant for large migratory birds (for instance, white and black storks) and birds of prey (griffon, cinereous and Egyptian vultures, Bonelli's eagles, lammergeiers, etc.), in particular for threatened species with very small populations.

This question is dealt with by EDF, ERDF and RTE, in partnership with the LPO ("Bird Protection League") and the FNE ("France Nature Environment") and within the framework of the CNA ("National Avifauna Commission"), set up in 2002.

The solutions to be implemented are now well known. First and foremost, one must identify those zones that are sensitive to installations, in which bird mortality can be as high as around 300 victims/km/year. Once this "mapping" has been carried out, spiral markers (alternating red and white) should be placed on the line, to make it more visible to diurnal and crepuscular birds, respectively. Wind blowing through these spirals also has the advantage of producing a whistling sound perceptible to certain birds. This marking allows for a 65 to 95% reduction in mortality. The second measure is using raptor shapes as "scarecrows" to frighten away birds.

RTE estimates the cost of equipping 270 sections of line at €15 million.

Besides this impact unconnected to magnetic fields, your *rapporteur* notes that **pylons appear increasingly useful in facilitating the reproduction of valued species**.

In 2009, in cooperation with the LPO and by agreement in the Poitou Marsh Interregional Nature Reserve, birdhouses for common kestrels were installed. Likewise, nests built on pylons by storks (Loire Atlantique department) or ospreys (Loiret department) are monitored in partnership with the MNHN and LNE ("Loire Nature Environment").

In the Charente-Maritime department, since 1998 and the installation of the first nest for white storks on a pylon of the high voltage Saint-Agnant/Marennes line, such cases have increased. 10 years later, 23 nests on 18 pylons were observed, representing 10% of the department's nests. The reproductive success in such cases seems identical, although a risk of electrocution has been observed for young birds taking flight.

The lines therefore seem to be opportunistically used by wild animals; this has provided RTE and the FNC ("National Federation of Hunters") the

basis for a convention dealing with the benefits to fauna of pylon legs, installations overhanging fallow or neglected land, and forest corridors.

3. Conclusions and Recommendations

Your *rapporteur* can only regret the limited amount of scientific data available.

Hardly any data exist on the harmfulness of electric and magnetic fields to wild flora and fauna; **on the contrary, the observations would tend to show that power lines form refuge areas or corridors for certain species**.

Your *rapporteur* therefore recommends that **RTE widen and redirect its partnerships**. It is necessary to cooperate with institutions and associations located or operating near power installations, whether they be naturalists or hunters. Nevertheless, it would be desirable to pursue **a more scientific approach leading to the publication of studies in reading-committee reviews**.

To this end, it would be wise to establish a wider partnership with the competent scientific bodies involved in the study and protection of biodiversity: the MNHN, the national botanical conservatories in the regions, the INEE ("National Institute of Ecology and the Environment") of the CNRS, the ONCFS ("National Office for Hunting and Wild Fauna") and CEMAGREF ("Research Institute for Agricultural and Environmental Engineering").

These partnerships could be **formalized either within a CNA extended to include all wild fauna and incorporating all interested partners** or within an ad hoc body.

These scientific partnerships would notably allow us to answer **two scientific questions**:

- **Do fields impact the health** of wild plant and animal populations?

- **To what extent does a high or extra high voltage line disrupt its surrounding environment?**

The answers to these questions are important in order to deepen our knowledge of the effects of fields on living organisms and **to deal with the requests of local residents when a line crosses or is liable to cross a natural environment or protected zone**.

Replicating, specifying or widening the observations already made, these studies could consider:

- The impact of fields on populations of birds nesting on or near pylons, at the national level.

- The impact of power lines on wild mammals (weasels, rodents and ungulates).

- The impact of power lines on species of fish potentially sensitive to very weak electric fields.

- Carrying out floral inventories in other regions besides Ile-de-France.

B. WHAT IMPACT ON AGRICULTURE?

The second aspect of fields' environmental impact concerns their impact on domesticated flora and fauna.

A limited amount of data exists with regard to plants and beekeeping. However, a vast bibliography is avaiable for animal husbandry.

All observed effects are indirect effects provoked by fields.

1. Plants

The data gathered by your *rapporteur* are non-recent and American in origin.

Indeed, in the 1970s and '80s, studies were carried out – particularly across the Atlantic - to measure the impact of 1,200-kV lines.

These studies were carried out in laboratories. A joint research group including researchers from Westinghouse and the University of Pennsylvania carried out laboratory studies which looked at the impact of 60-Hz lines on plant growth. An initial series of tests was conducted on 85 plants exposed to over 50 kV/m. A second series was carried out in a greenhouse with a field of 30 kV/m. One should keep in mind that immediately below a 400-kV line in France, the electric field is 5 kV/m. These fields were therefore 6 to 10 times greater. Some damage was observed starting at 15 kV/m, but without any dose-effect relationship. Above all, the general results showed that the plants were impacted neither with regard to their germination, nor their growth, nor their productivity.

A 5% decrease in the germination rate was observed starting at 5 kV/m for sunflowers, but only in 4 of the 11 cases studied (Marino et al, 1983), therefore producing inconsistent results.

Field studies were also carried out in Indiana with 765-kV lines and in Tennessee with 500-kV lines, without producing any notable or convincing negative results.

In western Oregon, during five years, studies were carried out beneath 1,200-kV lines in the early 1980s; no notable effect was observed for fields of up to 12 kV/m.

In France, your *rapporteur* met with farmers union officials who are deeply concerned about the long-term impact on productivity of crops located near extra high voltage lines (225 kV and 400 kV), notably due to a drying out of the soil within a diameter of 400 to 500 m around pylons.

These field observations have yet to be corroborated by scientific studies.

2. Bees

Bees were **perhaps the first subject of a study on the impact of high voltage lines**, for a study carried out in 1973 (Wellenstein) observed the first negative effects.

Since then, American studies - carried out in the early 1980s in Oregon beneath 1,200-kV lines and in Illinois beneath 765-kV lines – showed that **electric lines could affect bee colonies**, even those placed within wooden hives. The studies also observed excessive propolization[1], a decrease in productivity, an increase in mortality, and difficulties to survive during the winter.

These phenomena were due to the fact that a wooden hive is an imperfect insulator, even if it contains absolutely no metal. For this reason, **induced currents** can exist, depending on the height of the hive, the humidity and the magnitude of the field. These currents are provoked by electric fields emitted by power lines **starting at 2 kV/m**, but usually arise at above 7 kV/m. Within the hives themselves, **currents of 0.02 to 0.04 mA are sufficient to repeatedly shock the bees** each time they come into contact with the charged zones; they also suffice to engender the above-mentioned problems.

The effective solution seems to be to earth the hive roof - especially in the case of a classic metal roof – and, more generally, to **distance the hives** from the lines.

However, these studies did not observe any effect on the bees' orientation or pollination capabilities, including immediately below a 1,200-kV line.

Later studies dealing with bees' magnetoception capabilities have recently shed light on this question.

Bees communicate amongst themselves via various methods, so as to indicate, in particular, the location of food. In addition to these communication methods, it seems that bees are provided with a mechanism rendering them naturally sensitive to magnetic fields (Hsu et al, 2007, *Plos One*).

The research seems to show that bees are capable of distinguishing minute variations (in the region of 26 nT) of the geomagnetic field, which is a

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[1] *Propolis is a material gathered by bees from certain plants. This botanical resin is used by bees as a sealant and as an antimicrobial to clean up the hive.*

static field. The tests carried out to evaluate their sensitivity to alternating fields show that this sensitivity decreases as the frequency increases. Relatively high at 10 Hz, it becomes weak for fields of less than 60 Hz and 430 µT (Kirschvink, 1997, *Journal of Experimental Biology*). This last study looked at a very small number of bees (10 to 15 per field type), but it would seem to suggest that **ambient electromagnetic noise is not liable to disturb bees**.

Finally, your *rapporteur* notes with interest **the prospective partnership between beekeepers and RTE**, the idea being to benefit from the ecological corridors formed by power lines. Such a partnership would be both interesting and necessary. **It would benefit from being reinforced by a scientific protocol.**

3. Animal husbandry

The question as to the impact of high and extra high voltage lines on farm-raised animals has been the subject of a great many studies, notably in the United States, Canada and Northern Europe.

These studies have allowed researchers to identify with a high level of certainty the problems posed by these lines, although unknown factors persist.

a) The international scientific data on the direct impact of electric and magnetic fields

Animal health – in particular, the health of cattle – has been the subject of numerous studies. These studies have been carried out for the most part in the United States and Canada, considering the existence of extra high voltage lines of up to 1.2 million volts, notably in the states or provinces of central North America, which are also the large agricultural areas of these two countries. Such studies have also been carried out in Northern Europe, particularly in Sweden.

Pr Brugère of the Maisons-Alfort Veterinary School presented the relevant bibliography for the past thirty years during the public hearing held on 29 January 2009.

No effect has been observed in the United States, including in those studies carried out for lines of over 1 million volts:

Authors (USA)	Line	Species	Method	Results
BUSBY K. et al, 1974	765 kV AC	Bov	Quest. for farmers	No effect
AMSTUTZ H.E. & MILLER D.B., 1980	765 kV AC	Bov, Ov, Pg, Cn, Cv	Monitoring during 2 years + retro over 10 years	No modification in health, behaviour or production
ROGERS L.E. et al, 1982	1,100 kV AC	Bov	Survey among crop and animal farmers	No modification in behaviour
MARTIN F.B. et al, 1986	400 kV DC	Bov	Monitoring of 516 animal farms below the line	No negative effect on milk production, reproduction or culling
MAHMOUD A.A. & ZIMMERMAN DR, 1984	345 kV AC	Pg	2 groups of 12 sows (exposed and control)	Gestation, number of living piglets, weight at birth, growth, and number alive at 21 days
STORMSHAK et al, 1992 LEE J.M. et al, 1993	500 kV AC	Ov	2 x 10 female lambs of 2 months; until 10 months	No effect on melatonin or age of puberty
STORMSHAK et al, 1993	500 kV AC	Ov	2 x 15 female lambs of 2 months; until 1 year	No change in concentration of melatonin among exposed
HEFENEIDER S.H. et al, 1994	500 kV AC	Ov	3 groups, parcels below line and control during 10 months	Exposure decreases IL- 1 (?)
HEFENEIDER S.H. et al, 2001	500 kV AC	Ov	3 groups, parcels below line and control during 27 months	Exposure does not modify IL-1 or IL-2. No health difference between exposed and control
ANGELL R.R. et al, 1990	500 kV DC	Bov	2 x 50 mothers + calves, parcels below lines and control during 29 months	No effect on fertility, calving dates, calves or mortality.
GANSKOPP D. et al, 1991	500 kV DC	Bov	2 x 50 mothers + calves, parcels below lines and control during 29 months	No effect on fertility, calving dates or calves. No use in taking measures due to this exposure

Source: Pr Brugère

The bibliographical review carried out for Sweden yields the same results:

Authors (Sweden)	Source	Study: type or object	Results
ALGERS B., EKESBO I., HENNICHS K., 1981	Skara 5	Cow fertility	Preliminary
HENNICHS K., 1982	Skara 7	Cow fertility below 400 kV > 15 days/year	No effect
ALGERS B. & HENNICHS K., 1983	Vet Res Comm	Review of literature on bio effects	Does not concern health
ALGERS B. & HENNICHS K., 1985	Vet Res Comm	2-year monitoring of farms below lines for fertility (2,050 inseminations) and culling	No effect
ALGERS B. & HENNICHS K., 1985	Prev Vet Med	Revisited study published in Vet Res Comm (inseminations)	No effect
ALGERS B. & HULTGREN J., 1986	Skara 15	Ovarian activity, behaviour, signs of oestrus, gestation, resting rhythms, foetal viability	
ALGERS B. & HULTGREN J., 1986	Svensk-Veterinartifning	Ovarian activity, nycthemeral activity, gestation, foetal viability	No effect
ALGERS B. & HULTGREN J., 1987	Prev Vet Med	Study comparing parcels below lines to parcels at a distance from lines	No effect
HULTGREN J., 1988	Skara 27	Voltages / parasitic currents	Behavioural, production and health effects
HULTGREN J., 1990	Vet Res Comm	Literature review. Parasitic currents are detected starting at 1 mA. Behavioural effects.	Behavioural effects
HULTGREN J., 1990	Vet Res Comm	Literature review. Parasitic currents can have physio effects starting at 4 mA	Physio effects

Source: Pr Bruyère

In Canada, an experimental farm was set up and studied from 1996 to 2007, demonstrating no effect of EMFs. In this cowshed, the bovids were subjected to electric fields of 10 kV and magnetic fields of 30 µT.

In 2007, the team responsible for the study and for the various publications concluded: "The absence of any abnormal clinical sign and the absolute value of the observed modifications allow us to exclude the existence of any danger to animal health" (Burchard et al, 2007).

Your *rapporteur* did not discover any scientific data contradicting these results.

b) The indirect effects: parasitic currents

While electromagnetic fields have no effect on animals, the same is not true of parasitic currents.

These are currents resulting from tension between points that normally should be at earth potential.

These unwanted currents have three main causes:

- The first is an earth-return current; this phenomenon does not concern France, but rather Canada and the United States, which have distribution systems that are different from ours.

- The second is magnetic or electric induction.

- The third is an electrical installation fault, either within the distribution network (via an insulation fault) or on the animal farm.

(1) Electric induction, magnetic induction

Indeed, when a conducting object insulated from the ground is subjected to an **electric field**, the electric charges migrate to its surface and split up in such a manner as to nullify the electric field within the object. An electric tension (voltage) is thereby induced on opposite faces of the conducting object. An electric current can then circulate if a person or animal touches it.

This could be the case, for example, of a metallic drinking trough insulated from the ground and located beneath a high voltage line.

To avoid this phenomenon of induced voltage, the conducting object should be earthed.

Electric induction is also demonstrated by the experiment of the fluorescent tube that lights up when held by a person standing beneath an extra high voltage line. This light is only visible in the dark. The light is produced by the electric field's ionization of the gas contained within the tube. But this phenomenon does not only occur near high voltage lines. For instance, it can also occur in proximity to the ignition system of a petrol engine.

One can also observe the phenomenon of **magnetic induction** induced by a magnetic field.

When a conducting object is placed within an alternating magnetic field, induced voltages develop inside the object. These voltages are proportionate to the magnetic flux harnessed by the object, in accordance to its exposed surface area. If this object constitutes a closed circuit, such as a metallic gate in a field, the voltages generate induced currents whose amplitude depends on the resistance of the circuit.

To mitigate this phenomenon of magnetic induction, the size of the conducting loops should be reduced, either by opening the loop via the insertion of insulating elements (an insulating post in the metallic gate), or by reducing its size via the creation of several smaller loops.

Both of these phenomena, magnetic induction and electric induction, **can therefore provoke induced currents and be linked to the proximity of an extra high voltage line**.

But on an animal farm, **numerous other sources** can explain these two phenomena:

- **Electrical installation faults** that can be difficult to detect, for they vary according to weather conditions that influence the ground's conductivity.

- The simultaneous presence of different metals and of chemically active environments (liquid manure, fertilizer) that can produce an electrochemical reaction known as the "**battery effect**". An electric current is therefore created without any connection to other sources. This current provokes the accelerated corrosion of metal parts.

- The accumulation of electric charges in **certain devices** via friction (conveyor belt).

(2) The effects on animals

If all of these electric phenomena are important, it is because reared animals are sensitive to them, for they are not insulated from the ground (hooves in contact with wet ground, wet mussels, etc.).

The animals can receive these electrical discharges when they **come into contact with metallic equipment**: drinking and feeding troughs, headgates, gates, fences, etc.

The reaction threshold of animals has been the subject of recent studies (Rigalma, 2009). For heifers and milk cows, it was evaluated at 2.3 V in the feeding trough and 1.8 V in the drinking trough. The threshold was higher among lambs: in the region of 3.5 V. At these voltages, neither the quantity nor the production (milk or meat) are modified over a duration of 6 to 8 weeks.

The animals' sensitivity is extremely variable: of the order of 1 to 5, according to this same author. This difference could be explained by physical as well as behavioural data.

If sufficiently strong, these induced currents can significantly impact the animals' health, resulting in:

- **Behavioural modifications**: refusal to be milked, refusal to drink or lapping to reduce the duration of electrical contact, ingesting the urine of other animals, etc.

- **A decrease in production, mastitis** and an increased cell rate in the milk.

It should be pointed out that **this diagnosis enjoys a wide consensus among experts, having been established for at least 12 years, ever since the publication of the Blatin-Benetière report**.

(3) What are the solutions?

The proposed solutions also enjoy a wide consensus.

These phenomena are complex, for they are difficult to detect and objectify. Detecting electric abnormalities is a specialist's job that must be carried out with rigour to identify and measure the induction phenomena and other parasitic currents.

At the time a farmer complains, the animal farm's difficulties have a marked **multifactorial dimension and oftentimes the electric fault, no matter its origin, has engendered additional difficulties whose combined effect has led to a crisis**. The pathologies linked to electrification have often facilitated other diseases. It is also possible that the animal farm itself be confronted with other veterinary questions, such as diet or feeding.

In 1997, Dominique Blatin and Jean-Jacques Benetière **proposed a method that remains entirely topical**.

Your *rapporteur* will here present the main stages.

Before pointing the finger at any power line, one must first verify the reality of the dysfunction, evaluate its significance, and examine all possible causes.

To this end, the herd or flock of animals must undergo a technical evaluation. This consists of evaluating production via various physical data (absolute value) and in comparison to other similar herds/flocks (relative value).

The animals and their behaviour must then be observed.

Once the dysfunction has been established, its causes must be analyzed; according to Blatin and Benetière, these can be broken down into three main categories:

- The quality and compliance of the electrical installations.
- The health profile of the herd/flock.
- The "technical level" of the herd/flock and of its environment (genetic level, diet/feeding, technical management).

c) Assessing the GPSE

In France, since 1998, assessing the GPSE has been a unique subject of questioning.

Indeed, in 1997, animal farmers submitted the matter to the Ministry of Agriculture, which commissioned a report on the impact of electric and magnetic fields on animal husbandry; the Blatin-Benetière report was published in July 1998.

In addition to the elements touched upon above, one of the main consequences of this report was **the implementation of the GPSE ("Permanent Group for Electrical Safety")**, presided by Pr Gallouin of AgroParis Tech.

The GPSE was the result of a protocol signed between the Ministry of Agriculture and EDF on 19 July 1999.

The original mission of the GPSE was to formulate a methodological framework for solving the electrical difficulties encountered on animal farms and to inform farmers of the possible solutions. **The guidelines circular**, addressed to the departments' agricultural and veterinary services, **specified that it was not within the mission of the GPSE to regulate possible conflicts between EDF and farmers.**

This initial GPSE functioned like an open club, gathering together officials from the Ministry of Agriculture, teacher-researchers from Paris-Grignon and veterinary schools, EDF officials, Promotelec, lightning-protection companies, farmers unions (Confédération Paysanne, FNSEA, APCA), insurance companies (Groupama), and electric distribution technicians.

It carried out an inventory of the available knowledge, revealed the electrical problems existing on farms, and proposed a methodology for resolving the contentious issues with EDF. In this regard, it confirmed the methodology that had been proposed in 2008 by Blatin and Benetière, but underlined its desire to avoid lawsuits between farmers and EDF.

The 1999 protocol was not renewed upon expiration, but the GPSE continued to base its activity on this expired protocol.

The protocol was eventually renewed in 2006 for a period of three years. The mission of the GPSE was renewed around three main lines: understanding phenomena, preventing problems, and dealing with contentious issues.

The GPSE therefore pursued, on the experimental AgroParisTech farm, research on the electrical sensitivity and disturbance threshold of cattle and sheep. This research gave birth to a theory in 2009, as well as to several publications.

The GPSE's educational actions continued via its participation in various farming events.

The heart of its operations increasingly appeared to be solving disagreements between RTE and animal farmers. These interventions confirmed the methodology employed. An important asset of the GPSE is its ability to call upon significant means that are not necessarily available to farmers or local players:

- An exhaustive verification of the installation's electrical compliance (circuit-breakers, leakage currents, electric fences, equipotentiality, etc.).

- A health assessment, including, if necessary, bacterial, serologic, blood, etc. analyses. This assessment is carried out by the farm's attending veterinarian, under the supervision of teacher-researchers from the national veterinary schools and in association with the competent departmental offices.

- A zootechnical assessment; in particular, a performance analysis of the production management, with the GPSE capable of maintaining contact with the milk-control authority, the chambers of agriculture, etc.

This triple assessment is carried out at several levels via successive cycles: assessment-recommendation-observation, the upper stage being employed only if the problems persist.

For the GPSE to intervene, **the farmer must first sign a written protocol binding it to the GPSE, as well as to RTE and the chamber of agriculture**. **The farmer renounces bringing an action against RTE and binds himself to secrecy.** This triptych of "assistance-secrecy-renunciation of legal action" is to be explained by the contentiousness of this type of intervention and, sometimes, by the farmer's preference that his difficulties not be disclosed. However, this nontransparent measure has become a central argument for opponents, who denounce RTE's "buying" the farmers' silence.

Since 1999, the GPSE has been solicited 34 times: 10 times for consultancy requests in view of constructing an agricultural facility and 24 times by farmers suspecting an electrical cause of their difficulties.

Year	Solicitations	Consultancy requests
Prior to 2006	10	1
2006	1	2
2007	1	1
2008	5	3
2009	7	3
Total	**24**	**10**

The four French departments in which the GPSE has been the most active are the Manche, Corrèze, Loire-Altantique and Rhône departments.

17 farms are still being monitored by the GPSE, 7 within the framework of a protocol. Indeed, the resolution of these problems is long and gradual, and frequently the monitoring effort stretches out over several years. What is more, it would seem that the geological aspect of electrical problems is the most complex group of factors to take into account and can modify the normal earthing role played by the ground.

The GPSE's operations are financed by RTE, excepting possible contributions in kind, such as equipment/facilities made available to the GPSE or time consecrated to the assessment by government officials.

4. Conclusions and Recommendations

The extensive international scientific literature, going back many years, shows that **electric and magnetic fields are not the direct causes of veterinary pathologies**.

However, the proximity of a high voltage line or power transforming station can be **the cause of leakage currents; it can also reveal a faulty installation**. **Therefore, such lines can be the indirect causes of problems among reared animals.**

The diagnosis and proposals presented by the Blatin-Benetière report remain entirely pertinent, twelve years later.

Accompanying the agricultural profession faced with the problems encountered remains important, despite the small number of cases. Such assistance is desired by both the professionals and RTE.

It is therefore **desirable to renew the GPSE**; however, **its renewal should be carried out in depth**:

- Since its founding, the GPSE has only dealt with farm-reared animals.

- The GPSE is currently an informal club. While this loose structure offers certain advantages, it seems to have led to the withdrawal of several partners, including the French state, leaving RTE to play a central role. This situation is unhealthy.

It is desirable that the **GPSE participants be better defined** and that they gather together once a year for a plenary session led by a **president named by the Minister of Agriculture and Fishing**; this president would be assisted by a **general secretary**, a senior official of the ministry in charge of the body's administrative, financial and legal operations.

- **With regard to funding, the state's noninvolvement directs the costs onto RTE**, but for this reason diminishes the credibility of all that is undertaken. Can farmers not be mistrustful of research, information and, possibly, on-farm interventions that are financed by the operator? While RTE's technical and financial participation is certainly desirable, **the state must assume all of its responsibilities**, both by making the most of its contributions in kind and by providing additional funding.

- This withdrawal on the part of the state is partly to be explained by the fact that **the GPSE is increasingly seen as** a field intervention tool and, above all, as **a facilitator between RTE and farmers in the negotiation of financial coverage**.

However, it is undoubtedly warranted to return to the proposals of the Blatin-Benetière report, which proposed **separately establishing a national commission** in charge of research and information **and local commissions** created on the initiative of the prefect, which would only be set up as needed and which would handle contentious issues. Today's GPSE plays both roles, creating a certain confusion.

- These field interventions **must no longer be shrouded in secrecy**. Originally intended to protect RTE – and, undoubtedly, the farmer as well - this secrecy is currently counterproductive. Such discretion must be preserved only on the request of the farmer, who must be free to share his experience with others. **Reasonable publicity** for the GPSE's interventions would have numerous advantages:

.A better understanding of the GPSE's actions and methodology.

.An educational impact, demonstrating the difficulties encountered by the farmer, the GPSE's diagnosis, the results, the complex issues, and, possibly, those issues remaining to be resolved.

.Transparency with regard to RTE's financial intervention conditions (criteria, amounts, work/research covered, etc.).

- Over and beyond the GPSE's intervention in contentious issues, **its educational mission must once again be accorded priority**. It is imperative that a **Web site** be set up to inform the public of the existence and possible interventions of the GPSE.

In this regard, the agricultural professionals' request for **control farms** near the Cotentin-Maine line must be evaluated.

This project could have as its goal – in cooperation with one or more farmers working in immediate proximity to the lines – the development of educational projects allowing for dialogue and the distribution of good practices.

- With regard to research, it is undoubtedly desirable to pursue further studies for a better understanding of these phenomena, but it would undoubtedly also be pertinent to **develop a multidisciplinary cultural-veterinary-sociological approach so as to involve farmers working near the lines in participative measures for observing the long-term effects**.

CONCLUSION

France is the European country with the most extensive network of high and extra high voltage lines (+ 50 kV and + de 200 kV). It is also a country in which electricity distribution has been seen, ever since the interwar years, as an essential public service. Following the Second World War and thanks to its nationalization, the network was standardized and developed as part of a modernization and socio-economic development project.

Even today, RTE – the manager-operator of France's high voltage system that is responsible for its construction and maintenance and the quality of its power transmissions – is a 100% state-owned company. **A reliable, well-performing network is an absolute necessity for a developed economy. It corresponds, today as it did yesterday, to public decisions made by the national democratic authorities in accordance with the general interest.**

Its importance in our country is undoubtedly connected in part to the importance of a company such as EDF and in part to the development of a system of nuclear reactors. But a power network, no matter the source of energy, serves as the link between production sites and consumption sites, in such a way as to guarantee the provision of power even in the event of one element of the system failing. For the high voltage network, tomorrow's challenge is the incorporation of renewable energy production plants.

These new evolutions are linked to decisions made by our society, notably expressed within the framework of the Grenelle Environment Round Table.

The nature of high voltage lines as a public good, the role of the French state and the role of the democratic decision-making authorities must be kept in mind when considering a subject that some would like to over simplify as an opposition between the "monopolistic, omnipotent" operator and residents living near the installations. This point must be kept in mind when an opposition movement arises that, while certainly legitimate, is as implacable as it is narrowly supported.

As your *rapporteur* has emphasized, it is desirable that **the French state once again assume its full responsibility in informing the public and financing research and expertise**. It is also necessary that, via **a renewed dialogue between the operator and local elected officials, the latter once again play a central role in the system** and act as the initiators - thanks to the operator's expertise - of the network's evolutions, such as a common regional

project. Finally, **the operator must** widen its methods of dialogue and information distribution, so as to **sustainably involve a much wider public**, well beyond just the immediate residents and the preparation and installation of lines. **A dialogue must be implemented and sustained throughout the entire lifetime of a power line.**

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The difficulties encountered in installing high and extra high voltage lines or in updating the network often result in **burying** being proposed as a solution.

Burying power lines offers real advantages and allows for **a significant reduction of the magnetic field, while at the same time eliminating the electric field**.

But each decision to bury a line must be **the subject of a cost-benefit analysis**.

For high voltages, the costs are often under control and it can be in RTE's interest to bury the lines.

On the other hand, burying quickly becomes very costly and complex for extra high voltages, even excessively so for a voltage of 400 kV.

However, your *rapporteur* believes that we should **facilitate the elimination of existing 225-kV lines beneath or immediately next to which lie homes**, more to improve residents' quality of life than for safety reasons.

This could be organized thanks to an evolution of the public service contract between RTE and the French state. The financial means would have to be specified in such a manner as to create a project jointly funded by the regional authorities and RTE.

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These high and extra high voltage lines **emit** extremely low frequency fields.

These fields are of two distinct types: **magnetic fields and electric fields**. These fields must not be confused with the very high frequency fields emitted by relay antennas and mobile telephones.

Electric fields are constant, but magnetic fields vary according to the strength of the current flowing through the line. Magnetic fields therefore vary throughout the day and year, as well as from one line to another.

High and extra high voltage lines are far from being the only emission sources of these fields**.** Many other sources exist, both within homes and offices, such as electrical devices - notably household and office appliances – and outside residences, such as SNCF lines.

Household exposure is therefore estimated at around 0.2 µT. Exterior exposure varies constantly. A **computer screen** emits a field in the

region of **0.7 µT**. Travelling via **TGV high-speed rail** would expose a traveller to a field averaging **2.5 to 7 µT**.

RTE estimates that around **0.6% of the French population (375,000 people) is exposed to over 0.4 µT due to nearby power transmission lines.**

The exposure of the overall population and individual exposure typologies are still not well known. This question should incite **new research**.

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Do magnetic and electric fields emitted by power lines have an **impact on human health**?

This question has been asked for over the past 30 years. The international research carried out to-date **provides a clear answer, given the current state of knowledge**.

A solid international consensus - expressed by global, European, foreign and national health authorities - exists with regard to this question, even if certain divergent opinions also exist.

The international standards in place to protect the population (limit of 100µT at 50 Hz) and workers **are effective to protect the population from the short-term effects linked to acute exposures. They therefore do not require modification.**

With regard to **chronic exposures to small doses and in the long term**, extremely low frequency electric and magnetic fields in general – and, naturally, those emitted by high and extra high voltage lines – **have no impact on human health (except, perhaps, for three specific pathologies** touched upon below). Collective assessments indicate that those factors pointing to a possible link between these fields and other diseases are either too weak, inexistent or, on the contrary, have allowed for this connection to be dismissed.

The three pathologies for which a debate persists are: electromagnetic hypersensitivity, certain neurodegenerative diseases, and acute juvenile leukaemias.

Concerning **electromagnetic hypersensitivity, no causal link has been established**. Furthermore, the diversity of the syndromes and the "auto-declarative" nature of the ailment (in other words, it is the patient who declares himself to be suffering from EHS, rather than any doctor rendering a diagnosis) make it **a subject of clinical research**. **The patients' suffering must be taken seriously.**

Your *rapporteur* proposes that **support be lent to the setting up of a national network of coverage and research** on this issue.

Concerning certain **neurodegenerative diseases, the link is currently but a hypothesis**. Your *rapporteur* encourages France's public health authorities **not to ignore the risk**, for recent epidemiological data

concerning professional populations (train drivers) have demonstrated a possible dose-effect relationship and the number of ill people is possibly quite high. He therefore recommends that an **epidemiological study be carried out at SNCF and that pertinent research also be pursued.**

As for **acute juvenile leukaemias, their possible link with extremely low frequency magnetic fields of 0.4 µT has led the IARC to categorize them within Group 2B (possible carcinogens)**.

This categorization, **established in 2002, was based solely on epidemiological data**. While these data establishing a statistical link have not been invalidated since, they **do not indicate any dose-effect relationship or threshold**.

No mechanism of action has been demonstrated in the laboratory or with animals.

This statistical link therefore establishes a risk, but **it does not indicate any causal link between the fields and the disease**.

These acute leukaemias affect **children aged from 0 to 6 years**. It constitutes **a multifactorial disease whose causes are not well known**. In any case, power lines could only explain a fraction of the cases.

Luckily, these leukaemias are **extremely rare**. Their incidence rate is such that one can estimate - taking into account the extent of the French population currently exposed to over 0.4 µT due to high and extra high voltage lines - that less than five children per year would suffer and less than one would die from the disease, if the causal link were established.

The risk is low. Indeed, your *rapporteur* firmly believes that the risk is most likely very limited.

That said, he believes that **the anxiety surrounding this subject is, however, legitimate**, for the possibility of a **link** has been accepted as being **sufficiently solid for the IARC to include these fields in Group 2B**, even if the possibility of such a relationship was judged too weak to justify a higher classification.

It is therefore necessary **to move beyond the current situation and to attempt to solve the scientific uncertainty**.

Your *rapporteur* proposes that **the research be relaunched** and **a new risk assessment be conducted in five years' time**; this evaluation could be carried out on the request of the government via AFSSET.

The three main avenues of research are: to reinforce the ongoing **epidemiological** studies in France, to carry out studies on an appropriate **animal model**, and to pursue research on the causes of leukaemia. This must be **undertaken rapidly and with the appropriate means**.

By 2015, awaiting these new results, your *rapporteur* **recommends - in a prudent manner** and taking into account the scientific uncertainties - that

parents and authorities (in particular, elected officials) **seek to avoid, whenever possible and at a reasonable cost, the exposure of children aged 0 to 6 years, as well as unborn children, to fields greater than 0.4 µT on average**.

Drawing inspiration from the Netherlands, the French government should recommend - in a nonbinding manner - that one avoid building new constructions in which very young children spend a considerable amount of time all year long (households, day nurseries, nursery schools, etc.) within a "caution zone" in which exposure would be greater than this value. Conversely, lines or other significant sources of fields should not be installed in proximity to these "sensitive" sites frequented by very young children.

*

Second question: Do the electric and magnetic fields emitted by high and extra high voltage lines have an **impact on the environment**?

With regard to **wild flora and fauna**, your *rapporteur* regrets the **insufficiency of the scientific data** dealing directly with this subject. However, **observation data** for flora and fauna show that **nature can opportunistically benefit from the artificial and, to a certain extent, protected environment created by the lines** and forest corridors to reproduce and prosper.

In this regard, your *rapporteur* **requests that RTE** – in addition to its already existing partnerships, for the most part with associations - **establish a greater number of scientific partnerships** to help it measure the impact of existing or planned lines on the environment, so as to eventually lead to the publication of further peer-validated results/knowledge. This would serve to widen the information base available to elected officials, associations, local residents and the general public.

The scientific literature dealing with agriculture is abundant and clear: fields have no direct impact.

However, power lines can **indirectly impact farm-raised animals** via induction or leakage phenomena. **This problem is globally well understood and the methodology to remedy it is well established.** These difficulties are few in number, for, since 1999, the GPSE ("Permanent Group for Electrical Safety" on animal farms) has only been solicited 3.5 times per year on average.

A **renovation of the current system** is nevertheless necessary, **to emphasize the informing of farmers and encourage their participation**. The educational aspect is essential. To this end, it is indispensable to adopt a **transparent system** in which the **responsibilities and roles of the French state and RTE are much more clearly defined** and in which the **mechanisms for covering farmers obey rules known to all parties**.

LIST OF PROPOSALS

1- Concerning our knowledge of the French population's exposure:

- While the exposure of the overall population and especially the exposure of individuals to extremely low frequency magnetic fields is certainly better known, it **remains in reality little understood**.

Consequently, **new studies must be carried out** in order to further our understanding of exposure, based on measurements rather than calculated reconstitutions:

- **At the overall population level**, by seeking to reliably determine the average exposure level and, for instance, according to housing type and location.

- **At the individual level**, to better determine the exposure of very young children and, more generally, of individual typologies.

2- With regard to burying power lines:

- While burying can be chosen for aesthetic and/or political reasons, this solution **should normally remain a technical-economic decision based on the procedure's cost-effectiveness**. The costs and constraints are far from being negligible for both the line's manager and concerned farmers. **In municipalities**, concerns about security/safety and aesthetics **disfavour the installation of overhead power lines**.

- **Particular attention must be paid to pre-existing, extra-high-voltage overhead power lines located in urban settings.**

Your *rapporteur* therefore proposes that the following be **included in the public service contract between the French state and RTE**:

- The carrying out of **a national inventory of zones in which homes are located beneath or immediately next to extra high voltage lines**.

- The implementation of **financial measures - cofunded by the municipalities and an appropriate user's fee** - to allow for the progressive elimination of these lines.

- This contract must be accompanied with **an objective laid out in precise figures**, in addition to the current goals.

3- With regard to the acceptability of installations:

- Restore meaning to power lines, as the expression of a public project.

- **Reposition local elected officials in the centre of the system**, by keeping them better informed, by maintaining a permanent dialogue with them, even in the absence of any immediate project, and by identifying with them their region's priorities with regard to its power network (for instance, via a 10-year energy assessment**).**

- **Strengthen the RTE-AMF agreement** by allowing mayors to request that not only magnetic field measurements be carried out, but also **a simulation of these fields** based on the hypothetical functioning of the line.

- **Better inform associations** on the lines' impact.

- **Create a state-run Web site dedicated to providing information** on high voltage lines.

- **Encourage citizen involvement in the "life" of high voltage lines**, notably via ornithological, hunting and beekeepers' associations, as well as associations of farmers and local residents.

4-With regard to research and expertise:

- **Increase French state funding**; RTE must not be the sole funder of expertise and research.

- **RTE should no longer provide either direct funding or funding via a body directly dependent upon the research company.**

- **Concerning health, it could fall within the competence of AFSSET to launch invitations to tender** for research on the potential health impact of magnetic fields.

- With regard to **wild flora and fauna, the CNA ("National Avifauna Committee") could be enlarged** or a separate *ad hoc* body set up.

- With regard to **animal husbandry**, research should be financed by **a restructured and enlarged GPSE in which the French state would have reassumed its full role**.

These bodies would finance this research via funds provided by the French state, the research bodies themselves, economic players such as the chambers of agriculture, manufacturers of electric cables and, naturally, RTE, though in an indirect and diluted manner.

5- Concerning electromagnetic hypersensitivity (EHS)

- Take the patients seriously and treat their suffering.

- **Set up a national clinical research network**, so as to provide them with coverage, define their symptoms, and offer them an appropriate treatment.

6- Concerning certain neurodegenerative diseases

- Do not ignore the risk, even if currently but a hypothesis.

- **Support research** in the direction recommended by the national, European and international community of experts.

- Launch an **epidemiological study at SNCF and among its retired workers**.

7- Concerning juvenile leukaemias

- **Solve the current lack of certainty.**

- Request that AFSSET carry out **a new risk assessment in five years' time**.

- **Relaunch research:**

- **Epidemiological studies, by reinforcing the GEOCAP study** and by planning for **a replication of the Draper study in France**, based on the national child cancer registry and by facilitating access to certain data.

- In vivo and in vitro studies, to **identify a mechanism of action**.

- Studies on **the causes of juvenile leukaemias**.

- **Take a temporary, cautious measure: By 2015**, awaiting these new results, **recommend - in a prudent manner** and taking into account the scientific uncertainties - that parents and authorities (in particular, elected officials) **seek to avoid, whenever possible and at a reasonable cost, the exposure of children aged 0 to 6 years, as well as unborn children, to fields greater than 0.4 µT on average**.

Drawing inspiration from the Netherlands, the French government should recommend - in a nonbinding manner - that one avoid building new constructions in which very young children spend a considerable amount of time all year long (households, day nurseries, nursery schools, etc.) within a "caution zone" in which exposure would be greater than this value. Conversely, lines or other significant sources of fields should not be installed in proximity to these "sensitive" sites frequented by very young children.

8- Concerning wild flora and fauna

- **RTE should further develop** (the number and fields of) **its scientific partnerships** relative to the study of wild flora and fauna.

- These partnerships could be **formalized either within a CNA extended to include all wild flora and fauna** and incorporating all interested partners or within an *ad hoc* body.

These scientific partnerships would notably allow us to answer **two scientific questions**:

- Do fields have a **health impact** on the populations?

- To what extent **does a high or extra high voltage line disrupt its surrounding environment**?

These questions are particularly important with regard to the **demands of local residents**.

Replicating, specifying or widening the observations already made, these studies could consider:

- The impact of fields on populations of birds nesting on or near pylons, at the national level.

- The impact of power lines on wild mammals (weasels, rodents and ungulates).

- The impact of power lines on species of fish potentially sensitive to very weak electric fields.

- Carrying out floral inventories in other regions besides Ile-de-France.

9- Concerning agriculture

- With regard to **beekeeping, complement all protocols with beekeeping companies with an appropriate scientific monitoring effort**.

- With regard to **animal husbandry, it remains important to accompany the agricultural profession**, even given the low number of problematic cases. It is therefore **desirable to renew the GPSE**.

- **Renew in-depth the GPSE:**

- **A recommitment on the part of the French state in managing and funding the GPSE.** The GPSE must not be a commission in which RTE, in private discussion with farmers, solves individual, contentious situations.

- A **stricter formalization** of its make-up, missions and functioning, with **a president named by the Minister of Agriculture and Fishing** and assisted by **a general secretary**, a senior ministry official in charge of the body's administrative, financial and legal operations.

- **Extend its field of action to include all agricultural professions (beekeepers, cereal growers, animal rearers, etc.).**

- Take up the proposals of the Blatin-Benetière report, which proposed **separately establishing a national commission, in charge of research and information, and departmental commissions,** created as needed and on the initiative of the prefect to handle contentious issues.

- **Put an end to the secrecy surrounding the resolution of contentious issues.** Such discretion must be preserved only on the request of the farmer, who must be free to share his experience with others. **Reasonable publicity** for the GPSE's interventions would have numerous advantages:

. A better understanding of the GPSE's actions and methodology.

. An educational impact, demonstrating the difficulties encountered by the farmer, the GPSE's diagnosis, the results, the complex issues, and, possibly, those issues remaining to be resolved.

. Transparency with regard to RTE's financial intervention conditions (criteria, amounts, work/research covered, etc.).

- **The Educational mission must once again be given priority. It is imperative that a Web site be set up** to inform the public of the existence and possible interventions of the GPSE. The agricultural professionals' request for **control farms** near the Cotentin-Maine line must be evaluated.

This project could have as its goal – in cooperation with one or more farmers working in immediate proximity to the lines – the development of educational projects allowing for dialogue and the spreading of good practices.

- With regard to **research**, it is desirable to pursue studies for **a better understanding of the phenomena in the real, multifactorial conditions of the animal farms**.

APPENDICES

APPENDIX 1 – LIST OF PERSONS INTERVIEWED

- Mr Jérôme AMIELH, Chargé d'affaires for EMFs – Société nationale des chemins de fer (SNCF, France's "National Railway Company"), Laboratory for Electrical Testing of the Engineering Department

- Mr Jean ARTHUIS, Senator, President - Mayenne Departmental Council

- Ms Marie-Paule AUDOUIN, Director of Regulations and Civil Liberties - Mayenne Prefecture

- Pr André AURENGO, President - Conseil supérieur d'hygiène publique de France (CSPHF, "French Council on Public Health"), Member of EDF's Board of Directors

- Pr Alain AZOULAY – Ecole supérieure d'électricité (SUPELEC, "French Graduate School of Engineering"), Electromagnetism Department

- Dr Robert BAAN (Genetic toxicology) – International Agency for Research on Cancer (IARC)

- Ms Sarah BANDECCHI, Jurist, Member of the State Commission of Inquiry on the Cotentin-Maine Extra High Voltage Power Line Project

- Mr Philippe BARDIN, Director of the Conservation Unit - National Botanical Conservatory of the Paris Basin, Department of Ecology and Biodiversity Management

- Mr Yannick BARTHE, Sociologist - Sociology of Innovation Centre (UMR CNRS 7185), MINES ParisTech

- Pr Dominique BELPOMME, President - Association for Research and Treatments Against Cancer (ARTAC)

- Dr Lamia BENBRAHIM-TALLAA (Toxicology/carcinogenesis) – International Agency for Research on Cancer (IARC)

- Pr Bernadette BENSAUDE-VINCENT, Director of the Research Centre for the History and Philosophy of Science – Université Paris 10

- Mr Jean-François BERAUD, General Secretary of the Commission nationale du débat public (CNDP, "National Commission on Public Discussion")

- Dr Laurent BONTOUX, Expert - Joint Research Centre (JRC), European Commission, Directorate-General for Research

- Mr Patrick BOURREL, Policy Officer, European Commission, Directorate-General for Energy and Transport, Unit C1: Energy Policy & Security of Supply

- Mr Bruno BOUSSION, President of the State Commission of Inquiry on the Cotentin-Maine Extra High Voltage Power Line Project, Expert on Agriculture and Property

- Mr Norbert BOUVET – Association des Maires de France (AMF, "Association of French Mayors")

- Mr Daniel BOY, Director of Research – CEVIPOF (Political Research Centre at Sciences Po)

- Pr Henri BRUGERE – ENVA (veterinary school)

- Mr Mathieu BRUGIDOU, Senior Researcher - Electricité de France (EDF), Research & Development Department

- Ms Christine CADILLON, Head of the Water and Biodiversity Department - Prefecture for the Pays de la Loire region, Direction départementale des territoires (DDT)

- Mr Claude CHARON, President – Chamber of Agriculture (Mayenne)

- Mr Yves CHAUVIN, President – Association Cardamine (Mayenne)

- Ms Anne CHERIN, Occupational Physician in Charge of Magnetic Fields at the Medical Department of the Société nationale des chemins de fer (SNCF, France's "National Railway Company")

- Ms Jacqueline CLAVEL, Director – Institut national de la santé et de la recherche médicale (INSERM, "National Institute of Health and Medical Research"), Unit 754

- Dr Vincent COGLIANO, Programme Head – International Agency for Research on Cancer (IARC), IARC Monographs Department

- Mr Jean-Michel COLIN, Assistant Director – Réseau de transport d'électricité (RTE, France's electricity transmission network), western France

- Mr Hervé CORNEE, Mayor of Beaulieu-sur-Oudon

- Mr Stéphane COSSE, Assistant Director – Réseau de transport d'électricité (RTE, France's electricity transmission network), "Contact with Elected Officials and Local Authorities" Department

- Mr Hugues de GROMARD, Chief Representative – Syndicat professionnel des fabricants de fils et de câbles électriques et de communication (SYCABEL, "Professional Trade Union of Manufacturers of Electric and Communication Wires and Cables")

- Mr Michel DERDEVET, Director of Communications and Public Affairs – Réseau de transport d'électricité (RTE, France's electricity transmission network)

- Mr Michel DUBREUIL, Assistant Director – Réseau de transport d'électricité (RTE, France's electricity transmission network)

- Dr Fatiha EL GHISSASSI (biochemistry/genetic toxicology) – International Agency for Research on Cancer (IARC)

- Mr Yannick FAVENNEC, Deputy (Mayenne) – National Assembly

- Mr Pascal FEREY, Vice President, President of the Environmental Commission, Fédération nationale des syndicats d'exploitants agricoles (FNSEA, "National Federation of Farmers Unions")

- Pr Gilles FLEURY – Ecole supérieure d'électricité (SUPELEC, "French Graduate School of Engineering"), Electronic Signals and Systems Department

- Mr Jean-Claude FREBAULT, Adviser to the President, Member of the Board of Directors – PRYSMIAN

- Pr François GALLOUIN, President of the GPSE – Institut national agronomique Paris-Grignon ("National Institute of Agronomy, Paris-Grignon")

- Mr Patrick GIRAUD, Assistant Director – Prefecture for the Pays de la Loire region, DDCSPP ("Departmental Office for Social Cohesion and Public Protection") for Mayenne

- Ms Pascale GOULARD, Head of the Environment and Sustainable Development Office

- Ms Karine GROSSETETE, Parliamentary Adviser – Société nationale des chemins de fer (SNCF, France's "National Railway Company"), General Secretary for Public Affairs

- Mr Martin GUESPEREAU, Director General – Agence française de sécurité sanitaire de l'environnement et du travail (AFSSET, "French Agency for Environmental and Occupational Health Safety")

- Mr Jean-Charles HERRIAU, Vice President – Mayenne survoltée (environmental association)

- Mr Michel HOUSSIN, Manager of the "Property" dossier – Confédération paysanne (farmers union)

- Mr Bruno HUBERT, Coordinator of the Interregional Epidemiology Unit, Institut de veille sanitaire (INVS, "National Institute of Health Monitoring")

- Mr Pierre-Alain JACOB, in Charge of Dialogue – Réseau de transport d'électricité (RTE, France's electricity transmission network), western France

- Mr Jean JAUJAY, Ingénieur général des Ponts, des Eaux et des Forêts ("General Engineer - Bridges, Waters and Forests") – Conseil général de l'agriculture, de l'alimentation et des espaces ruraux (CGAAER, "Departmental Council for Agriculture, Food Production and Rural Areas")

- Mr Didier LAINE, Group Leader, "Supporting Project Development" – Réseau de transport d'électricité (RTE, France's electricity transmission network), Network Studies and Projects Department

- Dr Jacques LAMBROZO, Director - Electricité de France (EDF)-DG2S, Medical Studies Department

- Mr Stéphane LE BOULER, Head of Research – DREES – Ministry of Health, Youth and Sports

- Mr Pierre LE RUZ, President – CRIIREM

- Mr Christian LECLERC, Mayor of Champlan, President of the Association de défense des habitants de Champlan ("Association for the Defense of the Inhabitants of Champlan")

- Ms Nezha LEFTAH-MARIE, Engineer – Institut de veille sanitaire (INVS, "National Institute of Health Monitoring")

- Mr Gérard LEMONNIER, Departmental Councillor (Mayenne), Mayor of Ernée

- Mr Hervé LIST, in Charge of Relations with Parliament – Réseau de transport d'électricité (RTE, France's electricty transmission network), Communications and Public Affairs Department

- Mr Dominique MAILLARD, President, Director General – Réseau de transport d'électricité (RTE, France's electricity transmission network)

- Mr Gérard MARIE, Member of the State Commission of Inquiry on the Cotentin-Maine Extra High Voltage Power Line Project, retired Police Major

- Mr Philippe MASSY, Head of the Radio Networks Section – Société nationale des chemins de fer (SNCF, France's "National Railway Company"), Telecommunications Section of the Engineering Department, in charge of affairs concerning human exposure

- Mr Olivier MERCKEL, Head of the Physical Agents, New Technologies and Large-Scale Facilities Unit – Agence française de sécurité sanitaire de l'environnement et du travail (AFSSET, "French Agency for Occupational and Environmental Health Safety")

- Mr Yves MOULIERE, President – Fédération départementale des chasseurs de la Mayenne ("Departmental Federation of Hunters of Mayenne")

- Ms Nadine NORMAND, in Charge of Relations with Parliament – Fédération nationale des syndicats d'exploitants agricoles (FNSEA, "National Federation of Farmers Unions")

- Mr Jean-Marc PERRIN, National Project Director – Réseau de transport d'électricité (RTE, France's electricity transmission network), Normandy-Paris electric power system

- Ms Frédérique RIES, Deputy (Belgium) – European Parliament

- Mr Michel ROMAGNOLI, Departmental Head, Energy and Climate Change Mission – Prefecture for the Pays de la Loire region, Direction régionale de l'environnement, de l'aménagement et du logement (DREAL, "Regional Department for the Environment, Development and Housing") for the Pays de la Loire.

- Mr Stéphane SICOT, Mayor of Fougerolles-du-Plessis (Mayenne)

- Dr Martine SOUQUES – Electricité de France (EDF), Medical Studies Services, Health Safety Group Delegation

- Mr Matti SUPPONEN, Administrator, Electricity and Gas – European Commission, Directorate-General for Energy and Transport

- Mr Laurent TARDIF, President – Syndicat professionnel des fabricants de fils et de cables électriques et de communication (SYCABEL, "Professional Trade Union of Manufacturers of Electric and Communication Wires and Cables")

- Mr Bernard VEYRET, Researcher – Université de Bordeaux 1, IMS CNRS/EPHE Laboratory

- Mr François WALLACH, Departmental Head, Occupational Health and Risk Prevention – Société nationale des chemins de fer (SNCF, France's "National Railway Company")

English translation of *Appendix 2 – Letter of Commission* (see following page)

French Republic

Mr Claude BIRRAUX
President
Parliamentary Office for the
Evaluation of Scientific and
Technological Choices
National Assembly
126 rue de l'Université
75355 PARIS 07 SP

Paris, 27 May 2008

Ref: CE-9469 (ja)

Mr President,

Last April 8th, Mr Henri Revol sent me a request to commission a report by the Parliamentary Office for the Evaluation of Scientific and Technological Choices (OPECST) on the health and environmental effects of electromagnetic fields produced by high and extra high voltage lines.

Within the context of the publication of a CRIIREM study bearing on this subject, the conclusions of which would seem highly questionable, it appeared necessary to Mr Revol that the OPECST fully take up this question, the various aspects of which are of fundamental importance to human health, so as to study the issue with all the scientific rigour required.

Consequently, on the proposal of his Office, I included this request in the agenda of the Economic Affairs Commission, which debated the request on Wednesday, 21 May 2008. On this occasion, it appeared essential to the Commission to approve this request, judging that the OPECST constituted the most competent body for the carrying out of such a study.

I therefore have the honour of officially submitting to you a study request bearing on the health and environmental effects of electromagnetic fields produced by high and extra high voltage lines.

It is my sincere hope that the OPECST will be able to satisfy this request.

Respectfully yours,

Jean-Paul EMORINE

APPENDIX 2 – LETTER OF COMMISSION

RÉPUBLIQUE FRANÇAISE

SÉNAT

M. Claude BIRRAUX
Président
Office parlementaire d'évaluation des choix scientifiques et technologiques
Assemblée nationale
126 rue de l'Université
75355 PARIS 07 SP

Paris, le 27 mai 2008

COMMISSION DES AFFAIRES ECONOMIQUES

Réf : CE-9469 (js)

LE PRESIDENT

Monsieur le Président,

Le 8 avril dernier, M. Henri Revol m'a adressé une demande de saisine de l'Office parlementaire des choix scientifiques et technologiques portant sur les effets sur la santé et l'environnement des champs électromagnétiques produits par les lignes à haute et très haute tension.

Dans le contexte de la parution d'une étude du CRIIREM sur ce sujet, dont les conclusions semblent hautement discutables, il lui apparaissait nécessaire que l'Office puisse se saisir pleinement de cette question, dont les enjeux pour la santé humaine sont fondamentaux, afin de l'étudier avec toute la rigueur scientifique nécessaire.

En conséquence, j'ai, sur proposition de son Bureau, inscrit cette demande à l'ordre du jour de la commission des affaires économiques, qui en a débattu le mercredi 21 mai dernier. A cette occasion, il lui est apparu indispensable de donner une suite favorable à cette sollicitation, jugeant que l'Office constituait l'enceinte la plus appropriée pour réaliser une telle étude.

Dans ces conditions, j'ai l'honneur de vous transmettre officiellement une demande d'étude sur les effets sur la santé et l'environnement des champs électromagnétiques produits par les lignes à haute et très haute tension.

Espérant que l'Office pourra accéder à cette demande, je vous prie d'agréer, Monsieur le Président, l'expression de mes sentiments les meilleurs.

Jean-Paul EMORINE

15 rue de Vaugirard– 75291 PARIS CEDEX 06 - TELEPHONE : 01 42 34 23 06 - TELECOPIE : 01 42 34 20 76

APPENDIX 3 - PARTNERSHIP AGREEMENT BETWEEN THE ASSOCIATION DES MAIRES DE FRANCE ("ASSOCIATION OF FRENCH MAYORS") AND RTE

Wednesday, 17 December 2008

Gestionnaire du Réseau de Transport d'Electricité

The Association des Maires de France and RTE sign a partnership agreement

Jacques Pélissard, President of the Association des Maires de France (AMF, "Association of French Mayors"), and Dominique Maillard, Chairman of the Board of Directors of RTE, signed a partnership agreement on this Wednesday, 17 December 2008. By this agreement, the AMF and RTE commit themselves to the implementation of joint measures relative to those issues linked to electrical power transmission, notably with regard to regional planning and sustainable development.

Given the current context of an evolving French and European electricity market, well-informed mayors are essential in order to explain these issues to the French population.

The objective of the AMF-RTE partnership is to promote dialogue, at both the local and national level, between mayors and the company in charge of France's high and extra high voltage network. The AMF and RTE thereby commit themselves to implementing operations for raising public awareness and to facilitating meetings and the exchange of information and expertise, notably between the departmental associations of mayors (in partnership with Mairie 2000) and RTE's regional offices.

The transmission of electricity and a secure power supply are essential for the economic development of France's municipalities and the competitiveness of its territories. This partnership will therefore allow RTE to become more familiar with the needs of mayors, particularly during the preparation of regional plans for the development of the electricity transmission network. Furthermore, information will also be communicated as far in advance as possible of any power-failure risks.

COMMUNIQUE DE

AMF press contacts:
Marie-Hélène Galin: +33 (0)1 44 18 13 59

RTE press contacts:
Thierry Lartigau: +33(0)1 41 02 16 78 or +33 (0)6 23 67 83 93
Alexia Rière: +33 (0)1 41 02 15 69 or +33 (0)6 60 54 22 17

For more information:

http://www.amf.asso.fr/

http://www.rte-france.com/

"Energy is rare, so let's save it!"

The modernisation and reinforcement of the electricity transmission network and the quality of the electricity supply are also important for the regions' sustainable development. RTE is particularly committed, via this agreement, to involving mayors to the greatest extent possible in discussions bearing on projects for the development of its power network, so as to remain sensitive to local and environmental equilibriums.

The AMF and RTE both subscribe to pursuing exemplary conduct with regard to sustainable development and fighting climate change, notably in the spirit of the conclusions of the Grenelle Environment Round Table. RTE's expertise in monitoring regional energy consumption could be used to support measures in line with the objective of "Mastering Energy Demand". The AMF and RTE would also like to promote the protection of biodiversity and landscapes, by strengthening their dialogue on and efforts for the environmental insertion of France's electricity transmission network and the preservation of natural environments bordering this network's installations (including via the eventual construction of green belts along power lines).

Furthermore, initiatives to raise public awareness on the safety of third parties in proximity to power lines will be carried out by the members of the AMF, so as to prevent electrical accidents to the greatest extent possible.

As the first concrete measure of this partnership, RTE proposes making available to mayors a background paper, as well as a practical and independent system for meeting requests to carry out magnetic field measurements in "living environments" located near high and extra high voltage lines. Magnetic fields of very low frequency (50 Hz) generated by electric power lines increasingly raise questions among local residents regarding the fields' magnitude and their possible impact on human health. RTE commits itself to maintaining transparency vis-à-vis the mayors. This measurement system, the practical details of which will be jointly defined by the AMF and RTE, could be made available to mayors in 2009.

Finally, the agreement allows for @rteria, a subsidiary of RTE, to provide greater information to mayors regarding its expertise for projects to develop broadband telecommunication networks (via the fibre-optic network already installed on the electric power lines). This partnership could therefore work towards the AMF's objective of encouraging the regions' digital development and reducing France's digital divide.

The AMF gathers together nearly 36,000 sitting mayors and urban area presidents, exercising their offices in the municipalities of France's metropolitan and overseas departments and territories, without discriminating in any way with regard to the size of the municipality/urban area or the political affiliation of its mayor or president. Its representativeness makes the AMF an essential negotiating partner.

RTE is the manager of France's electricity transmission network. A public service company, its mission consists of operating, maintaining and developing the country's high and extra high voltage power system. It guarantees the proper functioning and safety of the system. RTE transfers electricity from the (French and European) suppliers to consumers, whether they be distributors of electricity or manufacturers directly connected to the electricity transmission network.

APPENDIX 4 – IARC MONOGRAPHS ON THE EVALUATION OF CARCINOGENIC RISKS TO HUMANS

List of IARC Evaluations

Important: These lists must only be read in conjunction with the "Preamble to the IARC Monographs" and it is strongly recommended to consult the respective monographs (published in English only) for the agents, mixtures and exposures of interest to you. These lists will be regularly updated.

Each monograph consists of a brief description, if need be, of the potential exposure to the agent or mixture and presents data on the chemical and physical properties, the methods of analysis, the methods and volumes of production, the utilization, and the frequency of utilization. For the circumstances of exposure, a history and description of exposure are provided. Next, the various pertinent epidemiological studies are summarized. The subsequent sections cover the indications of carcinogenicity obtained by studying laboratory animals, as well as a brief description of other pertinent information, such as toxicity and genetic effects. The IARC strives to ensure that the facts/phenomena are described without any bias or prejudice, and all data are verified with regard to their exactitude.

The monographs are widely used by researchers, public health authorities, and national and international regulatory bodies. These users apply and make use of the information contained in various ways; however, no one should utilize the global evaluations of carcinogenicity in isolation from the body of scientific indications and data on which these evaluations are based.

In the following lists, the agents are classified according to their degree of carcinogenic risk to humans, in accordance with the "Preamble to the IARC Monographs":

- Liste de tous les agents évalués à ce jour (classement par ordre alphabétique) (en anglais seulement)
- Liste de tous les agents évalués à ce jour (classement par *CAS*) (en anglais seulement)
- List of all agents evaluated to date (classification by group)

  Group 1: The agent is carcinogenic to humans.

  Group 2A: The agent is probably carcinogenic to humans.

  Group 2B: The agent is possibly carcinogenic to humans.

  Group 3: The agent is not classifiable as to its carcinogenicity to humans.

  Group 4: The agent is probably not carcinogenic to humans.

Group 1: Carcinogens to humans (108)

Based on Volumes 1 to 100A of the IARC monographs.

This list enumerates all health dangers evaluated to date, according to the type of danger and the type of exposure. When available, the reference number for the *Chemical Abstracts Registry* is provided in brackets. For more details, please consult the pertinent monograph (published in English only) (volume number in parentheses, followed by the year of publication for the most recent evaluation). Use **"Search in Monographs"** in text mode to locate a specific compound.

1. Agents and agent groups

Aristolochic acid (Vol. 82, Vol. 100A; in preparation)
(NB: Overall evaluation upgraded from 2B to 1 based on mechanistic and other relevant data)

Asbestos [1332-21-4] (Vol. 14, Suppl. 7; 1987)

4-Aminobiphenyle [92-67-1] (Vol. 1, Suppl. 7, Vol. 99; in preparation)

Arsenic [7440-38-2] and its compounds (Vol. 23, Suppl. 7; 1987)
(NB: This evaluation applies to the group as a whole, but not necessarily to each agent within the group)

Gallium arsenide [1303-00-0] (Vol. 86; 2006)

Azathioprine [446-86-6] (Vol. 26, Suppl. 7, Vol. 100A; in preparation)

Benzene [71-43-2] (Vol. 29, Suppl. 7; 1987)

Benzidine [92-87-5] (Vol. 29, Suppl. 7, Vol. 99; in preparation)

Benzo[*a*]pyrene [50-32-8] (Vol. 32, Suppl. 7, Vol. 92; in preparation)
(NB: Overall evaluation upgraded from 2B to 1 based on mechanistic and other relevant data)

Beryllium [7440-41-7] and its compounds (Vol. 58; 1993)

N,N-Bis(2-chloroethyl)-2-naphthylamine (Chlornaphazine) [494-03-1] (Vol. 4, Suppl. 7, Vol. 100A; in preparation)

Bis(chloromethyl)ether [542-88-1] and chloromethyl methyl ether [107-30-2] (technical-grade)
(Vol. 4, Suppl. 7; 1987)

1,3-Butadiene [106-99-0] (Vol. 71, Vol. 97; 2008)

1,4-Butanediol dimethanesulfonate (Busulphan; Myleran) [55-98-1] (Vol. 4, Suppl. 7, Vol. 100A; in preparation)

Cadmium [7440-43-9] and its compounds (Vol. 58; 1993)

Chlorambucil [305-03-3] (Vol. 26, Suppl. 7, Vol. 100A; in preparation)

Semustine [1-(2-Chloroethyl)-3-(4-methylcyclohexyl)-1-nitrosourea, Methyl-CCNU]
[13909-09-6] (Suppl. 7, Vol. 100A; in preparation)

Vinyl chloride [75-01-4] (Vol. 19, Suppl. 7, Vol. 97; 2008)

Hexavalent chromium (CrVI) (Vol. 49; 1990)

Dyes metabolized to benzidine (Vol. 99; in preparation)
(NB: Overall evaluation upgraded from 2B to 1 based on mechanistic and other relevant data)

Nickel compounds (Vol. 49; 1990)

Estrogen-progestogen oral contraceptives (combined) (Vol. 72, Vol. 91, Vol. 100A; in preparation)
(NB: There is also convincing evidence in humans that these agents confer a protective effect against cancer in the endometrium and ovary)

Sequential oral contraceptives (Suppl. 7, Vol. 100A; in preparation)

Cyclophosphamide [50-18-0] [6055-19-2] (Vol. 26, Suppl. 7, Vol. 100A; in preparation)

Cyclosporine [79217-60-0] (Vol. 50, Vol. 100A; in preparation)

Diethylstilboestrol [56-53-1] (Vol. 21, Suppl. 7, Vol. 100A; in preparation)

Erionite [66733-21-9] (Vol. 42, Suppl. 7; 1987)

Ethanol [64-17-5] in alcoholic beverages (Vol. 96; 2007)

Etoposide [33419-42-0] (Vol. 76, Vol. 100A; in preparation)
(NB: Overall evaluation upgraded from 2B to 1 based on mechanistic and other relevant data)

Etoposide in combination with cisplatin and bleomycin (Vol. 76, Vol. 100A; in preparation)

Formaldehyde [50-00-0] (Vol. 88; 2006)

Mustard gas (sulfur mustard) [505-60-2] (Vol. 9, Suppl. 7; 1987)

Helicobacter pylori (infection with) (Vol. 61; 1994)

Iodines (short-lived radioactive isotopes), including iodine-131, from nuclear reactor accidents and nuclear weapon detonations (exposure during childhood) (Vol. 78; 2001)

Melphalan [148-82-3] (Vol. 9, Suppl. 7, Vol. 100A; in preparation)

Methoxsalen (8-methoxypsoralen) [298-81-7] plus ultraviolet A radiation (Vol. 24, Suppl. 7, Vol. 100A; in preparation)

Methylenebis(chloraniline) (MOCA) [101-14-4] (Vol. 57, Vol. 99; in preparation)
(NB: Overall evaluation upgraded from 2B to 1 based on mechanistic and other relevant data)

MOPP (combined therapy using mustargen, oncovin, procarbazine and prednisone) and other combined chemotherapies using alkylating agents (Suppl. 7, Vol. 100A; in preparation)

2-Naphthylamine [91-59-8] (Vol. 4, Suppl. 7, Vol. 99; in preparation)

Neutrons (Vol. 75; 2000)
(NB: Overall evaluation upgraded from 2B to 1 based on mechanistic and other relevant data)

N'-Nitrosonornicotine (NNN) [16543-55-8] and 4-(*N*-Nitrosomethylamino)-1-(3-pyridyl)-1-butanone (NNK) [64091-91-4] (Vol. 37, Suppl. 7, Vol. 89; 2007)

Estrogen therapy for postmenopausal women (Vol. 72, Vol. 100A; in preparation)

Estrogens (non-steroidal) (Suppl. 7, Vol. 100A; in preparation)
(NB: This evaluation applies to the group as a whole, but not necessarily to each agent of the group)

Estrogens (steroidal) (Suppl. 7, Vol. 100A; in preparation)
(NB: This evaluation applies to the group as a whole, but not necessarily to each agent of the group)

Opisthorchis viverrini (infection with) (Vol. 61; 1994)

Ethylene oxide [75-21-8] (Vol. 60, Vol. 97; 2008)
(NB: Overall evaluation upgraded from 2B to 1 based on mechanistic and other relevant data)

Phenacetin [62-44-2] (Vol. 24, Suppl. 7, Vol. 100A; in preparation)
(NB: Overall evaluation upgraded from 2B to 1 based on mechanistic and other relevant data)

Phosphorus-32, as phosphate (Vol. 78; 2001)

Plutonium 239 and its decay products (can contain plutonium 240 and other isotopes), as an aerosol (Vol. 78; 2001)

Radionuclides, alpha-particle-emitting, internally deposited (Vol. 78; 2001)

Radionuclides, beta-particle-emitting, internally deposited (Vol. 78; 2001)

Radium 224 and its decay products (Vol. 78; 2001)

Radium 226 and its decay products (Vol. 78; 2001)

Radium 228 and its decay products (Vol. 78; 2001)

Radon 222 [10043-92-2] and its decay products (Vol. 43, Vol. 78; 2001)

Solar radiation (Vol. 55; 1992)

X- and gamma radiation (Vol. 75; 2000)

Schistosoma haematobium (infection with) (Vol. 61; 1994)

Silica dust, crystalline [14808-60-7] inhaled in the form of quartz or cristobalite (professional source) (Vol. 68, 1997)

Talc containing asbestiform fibres (Vol. 42, Suppl. 7; 1987)

Tamoxifen [10540-29-1] (Vol. 66, Vol. 100A; in preparation)
(NB: There is also conclusive evidence that tamoxifen reduces the risk of contralateral breast cancer in breast cancer patients)

2,3,7,8-Tetrachlorodibenzo-*para*-dioxin [1746-01-6] (Vol. 69; 1997)
(NB: Overall evaluation upgraded from 2B to 1 based on mechanistic and other relevant data)

Estrogen-progestogen menopausal therapy (combined) (Vol. 72, Vol. 91, Vol. 100A; in preparation)

Thiotepa [52-24-4] (Vol. 50, Vol. 100A; in preparation)

Thorium 232 and its decay products, administered by intravenous route in the form of a colloidal dispersion of thorium dioxyde 232 (Vol. 78; 2001)

ortho-Toluidine [95-53-4] (Vol. 77, Vol. 99; in preparation)

Treosulfan [299-75-2] (Vol. 26, Suppl. 7, Vol. 100A; in preparation)

Epstein-Barr virus (Vol. 70 ; 1997)

Hepatitis B virus (HBV) (chronic infection with) (Vol. 59; 1994)

Hepatitis C virus (VHC) (chronic infection with) (Vol. 59; 1994)

Human immunodeficiency virus type 1 (HIV-1) (infection with) (Vol. 67; 1996)

Human papillomavirus (HPV) types 16, 18, 31, 33, 35, 39, 45, 51, 52, 56, 58, 59 and 66 (Vol. 64, Vol. 90; 2007)
(NB: The HPV types that have been classified as carcinogenic to humans can differ by an order of magnitude in risk for cervical cancer)

Human T-lymphotropic virus Type 1 (HTLV-I) (Vol. 67; 1996)

2. Mixtures

Aflatoxins, natural mixtures [1402-68-2] (Vol. 56, Vol. 82; 2002)

Alcoholic beverages (Vol. 44, Vol. 96; 2007)

Coal-tar pitch [65996-93-2] (Vol. 35, Suppl. 7; 1987)

Betel quid with tobacco (Vol. 85; 2004)

Betel quid without tobacco (Vol. 85; 2004)

Coal, indoor emissions from household combustion of (Vol. 95; in preparation)

Coal tars [8007-45-2] (Vol. 35, Suppl. 7; 1987)

Shale oils [68308-34-9] (Vol. 35, Suppl. 7; 1987)

Mineral oils, untreated or mildly treated (Vol. 33, Suppl. 7; 1987)

Areca nut (Vol. 85; 2004)

Phenacetin, analgesic mixtures containing (Suppl. 7, Vol. 100A; in preparation)

Plants containing aristolochic acid (Vol. 82, vol. 100A; in preparation)

Salted fish (Chinese-style) (Vol. 56; 1993)

Wood dust (Vol. 62; 1995)

Soot (Vol. 35, Suppl. 7; 1987)

Tobacco, smokeless (Vol. 37, Suppl. 7, Vol. 89; 2007)

3. Occupational and other exposures

Isopropyl alcohol manufacture using strong acids (Suppl. 7; 1987)

Aluminium production (Vol. 34, Suppl. 7; 1987)

Arsenic in drinking water (Vol. 84; 2004)

Auramine production (Suppl. 7, Vol. 99; in preparation)

Strong-inorganic-acid mists containing sulfuric acid (occupational exposure) (Vol. 54; 1992)

Rubber manufacturing industry (Vol. 28, Suppl. 7; 1987)

Coal gasification (Vol. 34, Suppl. 7, Vol. 92; in preparation)

Shoe manufacture and repair (Vol. 25, Suppl. 7; 1987)

Coke production (Vol. 34, Suppl. 7; 1987, Vol. 92; in preparation)

Coal-tar distillation (Vol. 92; in preparation)

Iron and steel founding (Vol. 34, Suppl. 7; 1987)

Haematite mining (underground, with concomitant exposure to radon) (Vol. 1, Suppl. 7; 1987)

Magenta production (Vol. 57, Vol. 99; in preparation)

Furniture and cabinet making (Vol. 25, Suppl. 7; 1987)

Painter (occupational exposure as a) (Vol. 47, Vol. 98; in preparation)

Chimney sweeping (Vol. 92; in preparation)

Tobacco smoking (Vol. 38, Suppl. 7, Vol. 83; 2004)

Tobacco smoke, second-hand (Vol. 83; 2004)

Last updated: 16 January 2009

Group 2A: Probably carcinogenic to humans (66)

Based on Volumes 1 to 99 of the IARC monographs.

This list enumerates all agents, mixtures and exposures evaluated to date and classified in Group 2A. When available, the reference number for the *Chemical Abstracts Registry* is provided in brackets. For more details, please consult the corresponding monograph (published in English only) (volume number in parentheses, followed by the year of publication for the most recent evaluation). Use **"Search in Monographs"** in text mode to locate a specific compound.

1. Agents and agent groups

Aristolochic acids (natural mixtures) (Vol. 82; 2002)

Acrylamide [79-06-1] (Vol. 60; 1994)
(NB: Overall evaluation upgraded from 2B to 2A based on mechanistic and other relevant data)

Adriamycin [23214-92-8] (Vol. 10, Suppl. 7; 1987)
(NB: Overall evaluation upgraded from 2B to 2A based on mechanistic and other relevant data)

Azacitidine [320-67-2] (Vol. 50; 1990)
(NB: Overall evaluation upgraded from 2B to 2A based on mechanistic and other relevant data)

Bischloroethyl nitrosourea (BCNU) [154-93-8] (Vol. 26, Suppl. 7; 1987)

Vinyl bromide [593-60-2] (Vol. 39, Suppl. 7, Vol. 71, Vol. 97; in preparation)
(NB: (1) Overall evaluation upgraded from 2B to 2A based on mechanistic and other relevant data; (2) For practical purposes, vinyl bromide should be considered to act similarly to the human carcinogen vinyl chloride.)

Captafol [2425-06-1] (Vol. 53; 1991)
(NB: Overall evaluation upgraded from 2B to 2A based on mechanistic and other relevant data)

Ethyl carbamate (Urethane) [51-79-6] (Vol. 7, Suppl. 7, Vol. 96; 2007)
(NB: Overall evaluation upgraded from 2B to 2A based on mechanistic and other relevant data)

Chloramphenicol [56-75-7] (Vol. 50; 1990)
(NB: Overall evaluation upgraded from 2B to 2A based on mechanistic and other relevant data)

Procarbazine hydrochloride [366-70-1] (Vol. 26, Suppl. 7; 1987)
(NB: Overall evaluation upgraded from 2B to 2A based on mechanistic and other relevant data)

1-(2-Chloroethyl)-3-cyclohexyl-1-nitrosourea (CCNU) [13010-47-4] (Vol. 26, Suppl. 7; 1987)
(NB: Overall evaluation upgraded from 2B to 2A based on mechanistic and other relevant data)

4-Chloro-*ortho*-toluidine [95-69-2] (Vol. 77, Vol. 99; in preparation)

Chlorozotocin [54749-90-5] (Vol. 50; 1990)
(NB: Overall evaluation upgraded from 2B to 2A based on mechanistic and other relevant data)

Dimethylcarbamoyl chloride [79-44-7] (Vol. 12, Suppl. 7, Vol. 71; 1999)
(NB: Overall evaluation upgraded from 2B to 2A based on mechanistic and other relevant data)

Cisplatin [15663-27-1] (Vol. 26, Suppl. 7; 1987)
(NB: Overall evaluation upgraded from 2B to 2A based on mechanistic and other relevant data)

Clonorchis sinensis (infection with) (Vol. 61; 1994)
(NB: Overall evaluation upgraded from 2B to 2A based on mechanistic and other relevant data)

Cyclopenta[*cd*]pyrene [27208-37-3] (Vol. 32, Suppl. 7, Vol. 92; in preparation)
(NB: Overall evaluation upgraded from 2B to 2A based on mechanistic and other relevant data)

Dibenz[*a*,*h*]anthracene [53-70-3] (Vol. 32, Suppl. 7, Vol. 92; in preparation)
(NB: Overall evaluation upgraded from 2B to 2A based on mechanistic and other relevant data)

Dibenzo[*a*,*l*]pyrene [191-30-0] (Vol. 32, Suppl. 7, Vol. 92; in preparation)
(NB: Overall evaluation upgraded from 2B to 2A based on mechanistic and other relevant data)

1,2 Dibromoethane [106-93-4] (Vol. 15, Suppl. 7, Vol. 71; 1999)
(NB: Overall evaluation upgraded from 2B to 2A based on mechanistic and other relevant data)

1,2-Dimethylhydrazine [540-73-8] (Vol. 4, Suppl. 7, Vol. 71; 1999)
(NB: Overall evaluation upgraded from 2B to 2A based on mechanistic and other relevant data)

Epichlorohydrin [106-89-8] (Vol. 11, Suppl. 7, Vol. 71; 1999)
(NB: Overall evaluation upgraded from 2B to 2A based on mechanistic and other relevant data)

Etoposide [33419-42-0] (Vol. 76; 2000)
(NB: Overall evaluation upgraded from 2B to 2A based on mechanistic and other relevant data)

N-Ethyl-*N*-nitrosourea [759-73-9] (Vol. 17, Suppl. 7; 1987)
(NB: Overall evaluation upgraded from 2B to 2A based on mechanistic and other relevant data)

Vinyl fluoride [75-02-5] (Vol. 63, Vol. 97; in preparation)
(NB: (1) Overall evaluation upgraded from 2B to 2A based on mechanistic and other relevant data; (2) For practical purposes, vinyl fluoride should be considered to act similarly to the human carcinogen vinyl chloride.)

Glycidol [556-52-5] (Vol. 77; 2000)
(NB: Overall evaluation upgraded from 2B to 2A based on mechanistic and other relevant data)

Kaposi sarcoma herpesvirus / Human herpesvirus type 8 (Vol. 70; 1997)

IQ (2-Amino-3-methylimidazo[4,5-*f*]quinoline) [76180-96-6] (Vol. 56; 1993)
(NB: Overall evaluation upgraded from 2B to 2A based on mechanistic and other relevant data)

Methyl methanesulfonate [66-27-3] (Vol. 7, Suppl. 7, Vol. 71; 1999)
(NB: Overall evaluation upgraded from 2B to 2A based on mechanistic and other relevant data)

5-Methoxypsoralen [484-20-8] (Vol. 40, Suppl. 7; 1987)
(NB: Overall evaluation upgraded from 2B to 2A based on mechanistic and other relevant data)

N-Methyl-*N´*-nitro-*N*-nitrosoguanidine (MNNG) [70-25-7] (Vol. 4, Suppl. 7; 1987)
(NB: Overall evaluation upgraded from 2B to 2A based on mechanistic and other relevant data)

N-Methyl-*N*-nitrosourea [684-93-5] (Vol. 17, Suppl. 7; 1987)
(NB: Overall evaluation upgraded from 2B to 2A based on mechanistic and other relevant data)

Nitrogen mustard [51-75-2] (Vol. 9, Suppl. 7; 1987)

Nitrate or nitrite (ingested) under conditions that result in endogenous nitrosation (Vol. 94; in preparation)

N-Nitrosodiethylamine [55-18-5] (Vol. 17, Suppl. 7; 1987)
(NB: Overall evaluation upgraded from 2B to 2A based on mechanistic and other relevant data)

N-Nitrosodimethylamine [62-75-9] (Vol. 17, Suppl. 7; 1987)
(NB: Overall evaluation upgraded from 2B to 2A based on mechanistic and other relevant data)

Styrene-7,8-oxide [96-09-3] (Vol. 60; 1994)
(NB: Overall evaluation upgraded from 2B to 2A based on mechanistic and other relevant data)

Phenacetin [62-44-2] (Vol. 24, Suppl. 7; 1987)

Tris(2,3-dibromopropyl) phosphate [126-72-7] (Vol. 20, Suppl. 7, Vol. 71; 1999)
(NB: Overall evaluation upgraded from 2B to 2A based on mechanistic and other relevant data)

Indium phosphide [22398-80-7] (Vol. 86; 2006)
(NB: Overall evaluation upgraded from 2B to 2A)

Lead compounds, inorganic (Vol. 87; 2006)

Ultraviolet A radiation (Vol. 55; 1992)
(NB: Overall evaluation upgraded from 2B to 2A based on mechanistic and other relevant data)

Ultraviolet B radiation (Vol. 55; 1992)
(NB: Overall evaluation upgraded from 2B to 2A based on mechanistic and other relevant data)

Ultraviolet C radiation (Vol. 55; 1992)
(NB: Overall evaluation upgraded from 2B to 2A based on mechanistic and other relevant data)

Androgenic (anabolic) steroids (Suppl. 7; 1987)

Diethyl sulfate [64-67-5] (Vol. 54, Vol. 71; 1999)

Dimethyl sulfate [77-78-1] (Vol. 4, Suppl. 7, Vol. 71; 1999)
(NB: Overall evaluation upgraded from 2B to 2A based on mechanistic and other relevant data)

Teniposide [29767-20-2] (Vol. 76; 2000)
(NB: Overall evaluation upgraded from 2B to 2A based on mechanistic and other relevant data)

alpha-Chlorinated toluenes (benzotrichloride [98-07-7], benzal chloride [98-87-3], benzyl chloride [100-44-7]) and benzoyl chloride [98-88-4] (combined exposures) (Vol. 29, Suppl. 7, Vol. 71; 1999)

Tetrachloroethylene [127-18-4] (Vol. 63; 1995)

Trichloroethylene [79-01-6] (Vol. 63; 1995)

1,2,3-Trichloropropane [96-18-4] (Vol. 63; 1995)

[Urethane: see Ethyl carbamate]

2. Mixtures

Polychlorinated biphenyls [1336-36-3] (Vol. 18, Suppl. 7; 1987)

Biomass fuel (primarily wood), indoor emissions from household combustion of (Vol. 95; in preparation)

Creosotes [8001-58-9] (Vol. 35, Suppl. 7, Vol. 92; in preparation)

Frying, emissions from high-temperature (Vol. 95; in preparation)

Engine exhaust, diesel (Vol. 46; 1989)

Non-arsenical insecticides (occupational exposures in spraying and application of) (Vol. 53; 1991)

Mate, hot (Vol. 51; 1991)

3. Occupational and other exposures

Carbon electrode manufacture (Vol. 92; in preparation)

Cobalt metal with tungsten carbide (Vol. 86; 2006)

Hairdresser or barber (occupational exposure as a) (Vol. 57, Vol. 99; in preparation)

Sunlamps and sunbeds (utilization) (Vol. 55; 1992)

Petroleum refining (occupational exposures in) (Vol. 45; 1989)

Shiftwork that involves circadian disruption (Vol. 98; in preparation)

Art glass, manufacture of glass containers and pressed ware (Vol. 58; 1993)

Last updated: 1 April 2008

Overall Evaluations for Humans

Group 2B: Possibly carcinogenic to humans (248)

Based on Volumes 1 to 100A of the IARC monographs.

This list enumerates all agents, mixtures and exposures evaluated to date and classified in Group 2B. When available, the reference number for the *Chemical Abstracts Registry* is provided in brackets. For more details, please consult the corresponding monograph (published in English only) (volume number in parentheses, followed by the year of publication for the most recent evaluation). Use **"Search in Monographs"** in text mode to locate a specific compound.

1. Agents and agent groups

A-alpha-C (2-Amino-9*H*-pyrido[2,3-*b*]indole) [26148-68-5] (Vol. 40, Suppl. 7; 1987)

Acetaldehyde [75-07-0] (Vol. 36, Suppl. 7, Vol. 71; 1999)

Acetamide [60-35-5] (Vol. 7, Suppl. 7, Vol. 71; 1999)

Acétate de médroxyprogestérone [71-58-9] (Vol. 21, Suppl. 7; 1987)

Medroxyprogesterone acetate [592-62-1] (Vol. 10, Suppl. 7; 1987)

Vinyl acetate [108-05-4] (Vol. 63; 1995)

Caffeic acid [331-39-5] (Vol. 56; 1993)

Chlorendic acid [115-28-6] (Vol. 48; 1990)

Dichloroacetic acid [79-43-6] (Vol. 84; 2004)

Nitrilotriacetic acid [139-13-9] and its salts (Vol. 73; 1999)
(NB: Evaluated as a group)

Ethyl acrylate [140-88-5] (Vol. 39, Suppl. 7; Vol. 71; 1999)

Acrylonitrile [107-13-1] (Vol. 71; 1999)

AF-2 [2-(2-Furyl)-3-(5-nitro-2-furyl)acrylamide] [3688-53-7] (Vol. 31, Suppl. 7; 1987)

Aflatoxin M1 [6795-23-9] (Vol. 56; 1993)

para-Aminoazobenzene [60-09-3] (Vol. 8, Suppl. 7; 1987)

ortho-Aminoazotoluene [97-56-3] (Vol. 8, Suppl. 7; 1987)

2-Amino-5-(5-nitro-2-furyl)-1,3,4-thiadiazole [712-68-5] (Vol. 7, Suppl. 7; 1987)

Amsacrine [51264-14-3] (Vol. 76; 2000)

ortho-Anisidine [90-04-0] (Vol. 73; 1999)

Aramite® [140-57-8] (Vol. 5, Suppl. 7; 1987)

Auramine [492-80-8] (qualité technique) (Vol. 1, Suppl. 7, Vol. 99; in preparation)

Azaserine [115-02-6] (Vol. 10, Suppl. 7; 1987)

Aziridine [151-56-4] (Vol. 9, Suppl. 7, Vol. 71; 1999)
(NB: Overall evaluation upgraded from 3 to 2B based on mechanistic and other relevant data)

Michler's base [4,4'-methylenebis(*N*,*N*-dimethyl)-benzenamine] [101-61-1] (Vol. 27, Suppl. 7, Vol. 99; in preparation)

Benz[*j*]aceanthrylene [202-33-5] (Vol. 92; in preparation)
(NB: Overall evaluation upgraded from 3 to 2B based on mechanistic and other relevant data)

Benz[*a*]anthracene [56-55-3] (Vol. 32, Suppl. 7, Vol. 92; in preparation)

Benzo[*b*]fluoranthene [205-99-2] (Vol. 32, Suppl. 7, Vol. 92; in preparation)

Benzo[*j*]fluoranthene [205-82-3] (Vol. 32, Suppl. 7, Vol. 92; in preparation)

Benzo[*k*]fluoranthene [207-08-9] (Vol. 32, Suppl. 7, Vol. 92; in preparation)

Benzofuran [271-89-6] (Vol. 63; 1995)

Benzo[*c*]phenanthrene [195-19-7] (Vol. 32; Suppl. 7, Vol. 92; in preparation)
(NB: Overall evaluation upgraded from 3 to 2B based on mechanistic and other relevant data)

2,2-Bis(bromomethyl)propane-1,3-diol [3296-90-0] (Vol. 77; 2000)

Bleomycins [11056-06-7] (Vol. 26, Suppl. 7; 1987)
(NB: Overall evaluation upgraded from 3 to 2B based on mechanistic and other relevant data)

CI Direct Blue 15 [2429-74-5] (Vol. 57; 1993)

Disperse Blue 1 [2475-45-8] (Vol. 48; 1990)

HC Blue No. 1 [2784-94-3] (Vol. 57; 1993)

Trypan blue [72-57-1] (Vol. 8, Suppl. 7; 1987)

Potassium bromate [7758-01-2] (Vol. 73; 1999)

Bromodichloromethane [75-27-4] (Vol. 52, Vol. 71; 1999)

Butylated hydroxyanisole (BHA) [25013-16-5] (Vol. 40, Suppl. 7; 1987)

beta-Butyrolactone [3068-88-0] (Vol. 11, Suppl. 7, Vol. 71; 1999)

Catechol [120-80-9] (Vol. 15, Suppl. 7, Vol. 71; 1999)

Michler's ketone [4,4'-Bis(dimethylamino)benzophenone] [90-94-8] (Vol. 99; in preparation)

Magnetic fields (extremely low frequency) (Vol. 80; 2002)

Chlordane [57-74-9] (Vol. 79; 2001)

Chlordecone (Kepone) [143-50-0] (Vol. 20, Suppl. 7; 1987)

Phenazopyridine hydrochloride [136-40-3] (Vol. 24, Suppl. 7; 1987)

Phenoxybenzamine hydrochloride [63-92-3] (Vol. 24, Suppl. 7; 1987)

para-Chloroaniline [106-47-8] (Vol. 57; 1993)

3-Chloro-4-(dichloromethyl)-5-hydroxy-2(*5H*)-furanone [77439-76-0] (Vol. 84; 2004)

Chloroform [67-66-3] (Vol. 73; 1999)

1-Chloro-2-methylpropene [513-37-1] (Vol. 63; 1995)

[Chlorophenols: see Polychlorophenols]

4-Chloro-*ortho*-phenylenediamine [95-83-0] (Vol. 27, Suppl. 7; 1987)

Chloroprene [126-99-8] (Vol. 71; 1999)

Chrysene [218-01-9] (Vol. 32, Suppl. 7, Vol. 92; in preparation)

Cobalt [7440-48-4] and its compounds (Vol. 52; 1991)
(NB: Evaluated as a group)

Iron-dextran complex [9004-66-4] (Vol. 2, Suppl. 7; 1987)

Methylmercury compounds (Vol. 58; 1993)
(NB: Evaluated as a group)

Progestogen-only contraceptives (Vol. 72; 1999)

Foreign bodies: see Surgical implants and other foreign bodies.

para-Cresidine [120-71-8] (Vol. 27, Suppl. 7; 1987)

Cycasin [14901-08-7] (Vol. 10, Suppl. 7; 1987)

Dacarbazine [4342-03-4] (Vol. 26, Suppl. 7; 1987)

Dantron (Chrysazin; 1,8-Dihydroxyanthraquinone) [117-10-2] (Vol. 50; 1990)

Daunomycin [20830-81-3] (Vol. 10, Suppl. 7; 1987)

DDT (*para*, *para'*-DDT) [50-29-3] (Vol. 53; 1991)

N,*N'*-Diacetylbenzidine [613-35-4] (Vol. 16, Suppl. 7; 1987)

2,4-Diaminoanisole [615-05-4] (Vol. 79; 2001)

4,4'-Diaminodiphenyl ether [101-80-4] (Vol. 29, Suppl. 7; 1987)

2,4-Diaminotoluene [95-80-7] (Vol. 16, Suppl. 7; 1987)

Dibenzo[*a,h*]acridine [226-36-8] (Vol. 32, Suppl. 7; 1987)

Dibenzo[*a,j*]acridine [224-42-0] (Vol. 32, Suppl. 7; 1987)

7*H*-Dibenzo[*c,g*]carbazole [194-59-2] (Vol. 32, Suppl. 7; 1987)

Dibenzo[*a,h*]pyrene [189-64-0] (Vol. 32, Suppl. 7, Vol. 92; in preparation)

Dibenzo[*a,i*]pyrene [189-55-9] (Vol. 32, Suppl. 7, Vol. 92; in preparation)

1,2-Dibromo-3-chloropropane [96-12-8] (Vol. 20, Suppl. 7, Vol. 71; 1999)

2,3-Dibromopropan-1-ol [96-13-9] (Vol. 77; 2000)

para-Dichlorobenzene [106-46-7] (Vol. 73; 1999)
(NB: Overall evaluation based on mechanistic and other relevant, supplementary data)

3,3'-Dichlorobenzidine [91-94-1] (Vol. 29, Suppl. 7; 1987)

3,3'-Dichloro-4,4'-diaminodiphenyl ether [28434-86-8] (Vol. 16, Suppl. 7; 1987)

1,2-Dichloroethane [107-06-2] (Vol. 20, Suppl. 7, Vol. 71; 1999)

Dichloromethane (Methylene chloride) [75-09-2] (Vol. 71; 1999)

1,3-Dichloropropene [542-75-6] (technical-grade) (Vol. 41, Suppl. 7, Vol. 71; 1999)

Dichlorvos [62-73-7] (Vol. 53; 1991)

Diepoxybutane [1464-53-5] (Vol. 11, Suppl. 7, Vol. 71, Vol. 97; 2008)

4-Vinylcyclohexene diepoxide [106-87-6] (Vol. 60; 1994)

1,2-Diethylhydrazine [1615-80-1] (Vol. 4, Suppl. 7, Vol. 71; 1999)

Dihydrosafrole [94-58-6] (Vol. 10, Suppl. 7; 1987)

Toluene diisocyanates [26471-62-5] (Vol. 39, Suppl. 7, Vol. 71; 1999)

3,3'-Dimethoxybenzidine (*ortho*-Dianisidine) [119-90-4] (Vol. 4, Suppl. 7; 1987)

para-Dimethylaminoazobenzene [60-11-7] (Vol. 8, Suppl. 7; 1987)

trans-2-[(Dimethylamino)methylimino]-5-[2-(5-nitro-2-furyl)-vinyl]-1,3,4-oxadiazole [25962-77-0] (Vol. 7, Suppl. 7; 1987)

2,6-Dimethylaniline (2,6-Xylidine) [87-62-7] (Vol. 57; 1993)

3,3'-Dimethylbenzidine (*ortho*-Tolidine) [119-93-7] (Vol. 1, Suppl. 7; 1987)

1,1-Dimethylhydrazine [57-14-7] (Vol. 4, Suppl. 7, Vol. 71; 1999)

3,7-Dinitrofluoranthene [105735-71-5] (Vol. 65; 1996)

3,9-Dinitrofluoranthene [22506-53-2] (Vol. 65; 1996)

1,6-Dinitropyrene [42397-64-8] (Vol. 46; 1989)

1,8-Dinitropyrene [42397-65-9] (Vol. 46; 1989)

2,4-Dinitrotoluene [121-14-2] (Vol. 65; 1996)

2,6-Dinitrotoluene [606-20-2] (Vol. 65; 1996)

1,4-Dioxane [123-91-1] (Vol. 11, Suppl. 7, Vol. 71; 1999)

Titanium dioxide [13463-67-7] (Vol. 47, Vol. 93; in preparation)

1,2-Epoxybutane [106-88-7] (Vol. 47, Vol. 71; 1999)
(NB: Overall evaluation upgraded from 3 to 2B based on mechanistic and other relevant data)

Diglycidyl resorcinol ether [101-90-6] (Vol. 36, Suppl. 7, Vol. 71; 1999)

Phenyl glycidyl ether [122-60-1] (Vol. 47, Vol. 71; 1999)

Ethylbenzene [100-41-4] (Vol. 77; 2000)

Refractory ceramic fibres (Vol. 43, Vol. 81; 2002)

Special-purpose fibres (such as E-glass and '475' glass fibres) (Vol. 81; 2002)

2-(2-Formylhydrazino)-4-(5-nitro-2-furyl)thiazole [3570-75-0] (Vol. 7, Suppl. 7; 1987)

Bracken fern (Vol. 40, Suppl. 7; 1987)

Fumonisin B_1 [116355-83-0] (Vol. 82; 2002)

Furan [110-00-9] (Vol. 63; 1995)

Glu-P-1 (2-Amino-6-methyldipyrido[1,2-*a*:3',2'-*d*]imidazole) [67730-11-4] (Vol. 40, Suppl. 7; 1987)

Glu-P-2 (2-Aminodipyrido[1,2-*a*:3',2'-*d*]imidazole) [67730-10-3] (Vol. 40, Suppl. 7; 1987)

Glycidaldehyde [765-34-4] (Vol. 11, Suppl. 7, Vol. 71; 1999)

Griseofulvin [126-07-8] (Vol. 79; 2001)

Heptachlor [76-44-8] (Vol. 79; 2001)

Chlorophenoxy herbicides (Vol. 41, Suppl. 7; 1987)

Hexachlorobenzene [118-74-1] (Vol. 79; 2001)

Hexachlorocyclohexanes (Vol. 20, Suppl. 7; 1987)

Hexachloroethane [67-72-1] (Vol. 73; 1999)

Hexamethylphosphoramide [680-31-9] (Vol. 15, Suppl. 7, Vol. 71; 1999)

Hydrazine [302-01-2] (Vol. 4, Suppl. 7, Vol. 71; 1999)

1-Hydroxyanthraquinone [129-43-1] (Vol. 82; 2002)

Surgical implants and other foreign bodies: (Vol. 74; 1999)
- Polymeric implants prepared as thin smooth film (with the exception of poly(glycolic acid)).
- Metallic implants prepared as thin smooth films.
- Implanted foreign bodies of metallic cobalt, metallic nickel and an alloy powder containing 66-67% nickel, 13-16% chromium and 7% iron.

Indeno[1,2,3-*cd*]pyrene [193-39-5] (Vol. 32, Suppl. 7, Vol. 92; in preparation)

Isoprene [78-79-5] (Vol. 60, Vol. 71; 1999)

Lasiocarpine [303-34-4] (Vol. 10, Suppl. 7; 1987)

Magenta (mixtures made up of CI Basic Red 9 [569-61-9], methyl fuchsin [632-99-5], dimethyl fuchsin [26261-57-4] or trimethyl fuchsin [3248-91-7] (Vol. 57, Vol. 99; in preparation)

MeA-alpha-C (2-Amino-3-methyl-9*H*-pyrido[2,3-*b*]indole) [68006-83-7] (Vol. 40, Suppl. 7; 1987)

MeIQ (2-Amino-3,4-dimethylimidazo[4,5-*f*]quinoline) [77094-11-2] (Vol. 56; 1993)

MeIQx (2-Amino-3,8-dimethylimidazo[4,5-*f*]quinoxaline) [77500-04-0] (Vol. 56; 1993)

Merphalan [531-76-0] (Vol. 9, Suppl. 7; 1987)

Ethyl methanesulfonate [62-50-0] (Vol. 7, Suppl. 7; 1987)

2-Methylaziridine (Propyleneimine) [75-55-8] (Vol. 9, Suppl. 7, Vol. 71; 1999)

5-Methylchrysene [3697-24-3] (Vol. 32, Suppl. 7, Vol. 92; in preparation)

4,4'-Methylene bis(2-methylaniline) [838-88-0] (Vol. 4, Suppl. 7; 1987)

4,4'-Methylenedianiline [101-77-9] (Vol. 39, Suppl. 7; 1987)

2-Methyl-1-nitroanthraquinone (uncertain purity) (Vol. 27, Suppl. 7; 1987)

N-Methyl-*N*-nitrosourethane [615-53-2] (Vol. 4, Suppl. 7; 1987)

Methylthiouracil [56-04-2] (Vol. 79; 2001)

Metronidazole [443-48-1] (Vol. 13, Suppl. 7; 1987)

Microcystin-LR [101043-37-2] (Vol. 94; in preparation)
(NB: Overall evaluation upgraded from 3 to 2B based on mechanistic and other relevant data)

Mirex [2385-85-5] (Vol. 20, Suppl. 7; 1987)

Mitomycin C [50-07-7] (Vol. 10, Suppl. 7; 1987)

Mitoxantrone [65271-80-9] (Vol. 76; 2000)

Monocrotaline [315-22-0] (Vol. 10, Suppl. 7; 1987)

5-(Morpholinomethyl)-3-[(5-nitrofurfurylidene)amino]-2-oxazolidinone [3795-88-8] (Vol. 7, Suppl. 7; 1987)

Uracil mustard [66-75-1] (Vol. 9, Suppl. 7; 1987)

Nafenopin [3771-19-5] (Vol. 24, Suppl. 7; 1987)

Naphthalene [91-20-3] (Vol. 82; 2002)

Nickel, metallic [7440-02-0] and its alloys (Vol. 49; 1990)

Niridazole [61-57-4] (Vol. 13, Suppl. 7; 1987)

5-Nitroacenaphthene [602-87-9] (Vol. 16, Suppl. 7; 1987)

2-Nitroanisole [91-23-6] (Vol. 65; 1996)

Nitrobenzene [98-95-3] (Vol. 65; 1996)

6-Nitrochrysene [7496-02-8] (Vol. 46; 1989)

Nitrofen [1836-75-5] (technical-grade) (Vol. 30, Suppl. 7; 1987)

2-Nitrofluorene [607-57-8] (Vol. 46; 1989)

1-[(5-Nitrofurfurylidene)amino]-2-imidazolidinone [555-84-0] (Vol. 7, Suppl. 7; 1987)

N-[4-(5-Nitro-2-furyl)-2-thiazolyl]acetamide [531-82-8] (Vol. 7, Suppl. 7; 1987)

Nitromethane [75-52-5] (Vol. 77; 2000)

2-Nitropropane [79-46-9] (Vol. 29, Suppl. 7, Vol. 71; 1999)

1-Nitropyrene [5522-43-0] (Vol. 46; 1989)

4-Nitropyrene [57835-92-4] (Vol. 46; 1989)

N-Nitrosodi-*n*-butylamine [924-16-3] (Vol. 17, Suppl. 7; 1987)

N-Nitrosodiethanolamine [1116-54-7] (Vol. 17, Suppl. 7, Vol. 77; 2000)

N-Nitrosodi-*n*-propylamine [621-64-7] (Vol. 17, Suppl. 7; 1987)

3-(*N*-Nitrosomethylamino)propionitrile [60153-49-3] (Vol. 37, Suppl. 7, Vol. 85; 2004)

N-Nitrosomethylethylamine [10595-95-6] (Vol. 17, Suppl. 7; 1987)

N-Nitrosomethylvinylamine [4549-40-0] (Vol. 17, Suppl. 7; 1987)

N-Nitrosomorpholine [59-89-2] (Vol. 17, Suppl. 7; 1987)

N-Nitrosopiperidine [100-75-4] (Vol. 17, Suppl. 7; 1987)

N-Nitrosopyrrolidine [930-55-2] (Vol. 17, Suppl. 7; 1987)

N-Nitrososarcosine [13256-22-9] (Vol. 17, Suppl. 7; 1987)

Carbon black [1333-86-4] (Vol. 65, Vol. 93; in preparation)

Ochratoxin A [303-47-9] (Vol. 56; 1993)

Oil Orange SS [2646-17-5] (Vol. 8, Suppl. 7; 1987)

Oxazepam [604-75-1] (Vol. 66; 1996)

Nitrogen mustard *N*-oxide [126-85-2] (Vol. 9, Suppl. 7; 1987)

Propylene oxide [75-56-9] (Vol. 60; 1994)

Palygorskite (Attapulgite) [12174-11-7], long fibres (> 5 micrometres) (Vol. 68; 1997)

Panfuran-S [794-93-4] (containing dihydroxymethylfuratrizine) (Vol. 24, Suppl. 7; 1987)

Vanadium pentoxide [1314-62-1] (Vol. 86; 2006)

Phenobarbital [50-06-6] (Vol. 79; 2001)

Phenolphthalein [77-09-8] (Vol. 76; 2000)

Sodium *ortho*-phenylphenate [132-27-4] (Vol. 73; 1999)

Phenytoin [57-41-0] (Vol. 66; 1996)

PhIP (2-Amino-1-methyl-6-phenylimidazo[4,5-*b*]pyridine) [105650-23-5] (Vol. 56; 1993)

Lead [7439-92-1] (Vol. 23, Suppl. 7; 1987)

Polychlorophenols and their sodium salts (mixed exposures) (Vol. 41, Suppl. 7, Vol. 53, Vol. 71; 1999)

Ponceau MX [3761-53-3] (Vol. 8, Suppl. 7; 1987)

Ponceau 3R [3564-09-8] (Vol. 8, Suppl. 7; 1987)

Progestins (Suppl. 7; 1987)

1,3-Propane sultone [1120-71-4] (Vol. 4, Suppl. 7, Vol. 71; 1999)

beta-Propiolactone [57-57-8] (Vol. 4, Suppl. 7, Vol. 71; 1999)

Propylthiouracil [51-52-5] (Vol. 79; 2001)

Riddelliine [23246-96-0] (Vol. 10, Suppl. 7, Vol. 82; 2002)

CI Acid Red 114 [6459-94-5] (Vol. 57; 1993)

CI Basic Red 9 [569-61-9] (Vol. 57, vol. 99; in preparation)

Citrus Red No. 2 [6358-53-8] (Vol. 8, Suppl. 7; 1987)

Safrole [94-59-7] (Vol. 10, Suppl. 7; 1987)

Schistosoma japonicum (infection with) (Vol. 61; 1994)

Sterigmatocystin [10048-13-2] (Vol. 10, Suppl. 7; 1987)

Streptozotocin [18883-66-4] (Vol. 17, Suppl. 7; 1987)

Styrene [100-42-5] (Vol. 60, Vol. 82; 2002)

Sulfallate [95-06-7] (Vol. 30, Suppl. 7; 1987)

Cobalt sulfate [10026-24-1] and other soluble cobalt(II) salts (Vol. 86; 2006)

Diisopropyl sulfate [2973-10-6] (Vol. 54, Vol. 71; 1999)

Tetrachloroisophtalonitrile (chlorothalonil) [1897-45-6] (Vol. 73; 1999)

Carbon tetrachloride [56-23-5] (Vol. 20, Suppl. 7, Vol. 71; 1999)

Tetrafluoroethylene [116-14-3] (Vol. 19, Suppl. 7, Vol. 71; 1999)

Tetranitromethane [509-14-8] (Vol. 65; 1996)

Thioacetamide [62-55-5] (Vol. 7, Suppl. 7; 1987)

4,4'-Thiodianiline [139-65-1] (Vol. 27, Suppl. 7; 1987)

Thiouracil [141-90-2] (Vol. 79; 2001)

Trichlormethine (Trimustine hydrochloride) [817-09-4] (Vol. 50; 1990)

Antimony trioxide [1309-64-4] (Vol. 47; 1989)

Trp-P-1 (3-Amino-1,4-dimethyl-5*H*-pyrido[4,3-*b*]indole) [62450-06-0] (Vol. 31, Suppl. 7; 1987)

Trp-P-2 (3-Amino-1-methyl-5*H*-pyrido[4,3-*b*]indole) [62450-07-1] (Vol. 31, Suppl. 7; 1987)

4-Vinylcyclohexene [100-40-3] (Vol. 60; 1994)

Benzyl violet 4B [1694-09-3] (Vol. 16, Suppl. 7; 1987)

Human immunodeficiency virus (HIV) type 2 (infection with) (Vol. 67; 1996)

Human papillomavirus (HPV) types 6 and 11 (Vol. 90; 2007)

Human papillomavirus genus beta (various types of) (Vol. 90; 2007)

Zalcitabine [7481-89-2] (Vol. 76; 2000)

Zidovudine (AZT) [30516-87-1] (Vol. 76; 2000)

2. Mixtures

Polybrominated biphenyls [Firemaster BP-6, 59536-65-1] (Vol. 41, Suppl. 7; 1987)

Bitumens [8052-42-4], steam-refined and air-refined (Vol. 35, Suppl. 7; 1987)

Coffee (urinary bladder) (Vol. 51; 1991)
(NB: There is some evidence of an inverse relationship between coffee drinking and cancer of the large bowel; coffee drinking could not be classified as to its carcinogenicity to other organs).

Diesel fuel, marine (Vol. 45; 1989)
(NB: Overall evaluation upgraded from 3 to 2B based on mechanistic and other relevant data)

Carrageenan, degraded [9000-07-1] (Vol. 31, Suppl. 7; 1987)

Gasoline (Vol. 45; 1989)
(NB: Overall evaluation upgraded from 3 to 2B based on mechanistic and other relevant data)

Fuel oils, residual (heavy) (Vol. 45; 1989)

Welding fumes (Vol. 49; 1990)

Gasoline engine exhaust (Vol. 46; 1989)

Pickled vegetables (traditional in Asia) (Vol. 56; 1993)

Chlorinated paraffins of average carbon chain length C12 and average degree of chlorination approximately 60% (Vol. 48; 1990)

Toxaphene (Polychlorinated camphenes) [8001-35-2] (Vol. 79; 2001)

Toxins derived from *Fusarium moniliforme*: fumonisin B1 and B2 and fusarin C (Vol. 56; 1993)

3. Occupational and other exposures

Carpentry and joinery (Vol. 25, Suppl. 7; 1987)

Cobalt metal without tungsten carbide (Vol. 86; 2006)

Textile manufacturing industry (work in) (Vol. 48; 1990)

Dry cleaning (occupational exposures in) (Vol. 63; 1995)

Firefighter (occupational exposure as a) (Vol. 98; in preparation)

Talc-based body powder (perineal use of) (Vol. 93; in preparation)

Printing processes (occupational exposures in) (Vol. 65; 1996)

Last updated: 1 April 2008

Group 3: Not classifiable as to their carcinogenicity to humans (515)

Based on Volumes 1 to 99 of the IARC monographs.

This list enumerates all agents, mixtures and exposures evaluated to date and classified in Group 3.
When available, the reference number for the *Chemical Abstracts Registry* is provided in brackets. For more details, please consult the pertinent monograph (published in English only) (volume number in parentheses, followed by the year of publication for the most recent evaluation). Use **"Search in Monographs"** in text mode to locate a specific compound.

1. Agents and agent groups

Acenaphthene [83-32-9] (Vol. 92; in preparation)

Acepyrene (3,4-dihydrocyclopenta[*cd*]pyrene) [25732-74-5] (Vol. 92; in preparation)

Benzyl acetate [140-11-4] (Vol. 40, Vol. 71; 1999)

Polyvinyl acetate [9003-20-7] (Vol. 19, Suppl. 7; 1987)

Aciclovir [59277-89-3] (Vol. 76; 2000)

Acrylic acid [79-10-7] (Vol. 19, Vol. 71; 1999)

para-Aminobenzoic acid (4-Aminobenzoic acid) [150-13-0] (Vol. 16, Suppl. 7; 1987)

11-Aminoundecanoic acid [2432-99-7] (Vol. 39, Suppl. 7; 1987)

Anthranilic acid [118-92-3] (Vol. 16, Suppl. 7; 1987)

Hydrochloric acid [7647-01-0] (Vol. 54; 1992)

cis-9,10-Epoxystearic acid [2443-39-2] (Vol. 11, Vol. 71; 1999)

Kojic acid [501-30-4] (Vol. 79; 2001)

N-Nitrosofolic acid [29291-35-8] (Vol. 17, Suppl. 7; 1987)

Parasorbic acid [10048-32-5] (Vol. 10, Suppl. 7; 1987)

Penicillic acid [90-65-3] (Vol. 10, Suppl. 7; 1987)

Polyacrylic acid [9003-01-4] (Vol. 19, Suppl. 7; 1987)

Shikimic acid [138-59-0] (Vol. 40, Suppl. 7; 1987)

Tannic acid and tannins [1401-55-4] et tanins (Vol. 10, Suppl. 7; 1987)

Trichloroacetic acid [76-03-9] (Vol. 84; 2004)

Acrolein [107-02-8] (Vol. 63; 1995)

n-Butyl acrylate [141-32-2] (Vol. 39, Vol. 71; 1999)

2-Ethylhexyl acrylate [103-11-7] (Vol. 60; 1994)

Methyl acrylate [96-33-3] (Vol. 39, Vol. 71; 1999)

Actinomycin D [50-76-0] (Vol. 10, Suppl. 7; 1987)

Di(2-ethylhexyl) adipate [103-23-1] (Vol. 77; 2000)

Agaritine [2757-90-6] (Vol. 31, Suppl. 7; 1987)

Polyvinyl alcohol [9002-89-5] (Vol. 19, Suppl. 7; 1987)

Aldicarb [116-06-3] (Vol. 53; 1991)

Aldrin [309-00-2] (Vol. 5, Suppl. 7; 1987)

Amaranth [915-67-3] (Vol. 8, Suppl. 7; 1987)

Musk ambrette [83-66-9] (Vol. 65; 1996)

5-Aminoacenaphthene [4657-93-6] (Vol. 16, Suppl. 7; 1987)

2-Aminoanthraquinone [117-79-3] (Vol. 27, Suppl. 7; 1987)

1-Amino-2-methylanthraquinone [82-28-0] (Vol. 27, Suppl. 7; 1987)

2-Amino-4-nitrophenol [99-57-0] (Vol. 57; 1993)

2-Amino-5-nitrophenol [121-88-0] (Vol. 57; 1993)

4-Amino-2-nitrophenol [119-34-6] (Vol. 16, Suppl. 7; 1987)

2-Amino-5-nitrothiazole [121-66-4] (Vol. 31, Suppl. 7; 1987)

Amitrole [61-82-5] (Vol. 79; 2001)
(NB: Overall evaluation upgraded from 2B to 3 based on mechanistic and other relevant data)

Ampicillin [69-53-4] (Vol. 50; 1990)

Anaesthetics, volatile (Vol. 11, Suppl. 7; 1987)

Angelicin [523-50-2] plus ultraviolet A radiation (Vol. 40, Suppl. 7; 1987)

Succinic anhydride [108-30-5] (Vol. 15, Suppl. 7; 1987)

Aniline [62-53-3] (Vol. 27, Suppl. 7; 1987)

para-Anisidine [104-94-9] (Vol. 27, Suppl. 7; 1987)

Anthanthrene [191-26-4] (Vol. 32, Suppl. 7, Vol. 92; in preparation)

Anthracene [120-12-7] (Vol. 32, Suppl. 7, Vol. 92; in preparation)

Cinnamyl anthranilate [87-29-6] (Vol. 77; 2000)

Apholate [52-46-0] (Vol. 9, Suppl. 7; 1987)

Atrazine [1912-24-9] (Vol. 73; 1999)
(NB: Overall evaluation upgraded from 2B to 3 based on mechanistic and other relevant data)

Aurothioglucose [12192-57-3] (Vol. 13, Suppl. 7; 1987)

2-(1-Aziridinyl)ethanol [1072-52-2] (Vol. 9, Suppl. 7; 1987)

Aziridyl benzoquinone [800-24-8] (Vol. 9, Suppl. 7; 1987)

Azobenzene [103-33-3] (Vol. 8, Suppl. 7; 1987)

11*H*-Benz[*bc*]aceanthrylene [202-94-8] (Vol. 92; in preparation)

Benz[*l*]aceanthrylene [211-91-6] (Vol. 92; in preparation)

Benz[*a*]acridine [225-11-6] (Vol. 32, Suppl. 7; 1987)

Benz[*c*]acridine [225-51-4] (Vol. 32, Suppl. 7; 1987)

Benzo[*b*]chrysene [214-17-5] (Vol. 92; in preparation)

Benzo[*g*]chrysene [196-78-1] (Vol. 92; in preparation)

Benzo[*a*]fluoranthene [203-33-8] (Vol. 92; in preparation)

Benzo[*ghi*]fluoranthene [203-12-3] (Vol. 32, Suppl. 7, Vol. 92; in preparation)

Benzo[*a*]fluorene [238-84-6] (Vol. 32, Suppl. 7, Vol. 92; in preparation)

Benzo[*b*]fluorene [243-17-4] (Vol. 32, Suppl. 7, Vol. 92; in preparation)

Benzo[*c*]fluorene [205-12-9] (Vol. 32, Suppl. 7, Vol. 92; in preparation)

Benzo[*ghi*]perylene [191-24-2] (Vol. 32, Suppl. 7, Vol. 92; in preparation)

Benzo[*e*]pyrene [192-97-2] (Vol. 32, Suppl. 7, Vol. 92; in preparation)

para-Benzoquinone dioxime [105-11-3] (Vol. 29, Vol. 71; 1999)

Bis(2-chloroethyl)ether [111-44-4] (Vol. 9, Vol. 71; 1999)

Bis(2-chloro-1-methylethyl)ether [108-60-1] (Vol. 41, Vol. 71; 1999)

1,2-Bis(chloromethoxy)ethane [13483-18-6] (Vol. 15; Vol. 71; 1999)

1,4-Bis(chloromethoxymethyl)benzene [56894-91-8] (Vol. 15, Vol. 71; 1999)

Bis(2,3-epoxycyclopentyl)ether [2386-90-5] (Vol. 47, Vol. 71; 1999)

Bisulfites (Vol. 54; 1992)

Brilliant Blue FCF (disodium salt) [3844-45-9] (Vol. 16, Suppl. 7; 1987)

Evans blue [314-13-6] (Vol. 8, Suppl. 7; 1987)

HC Blue No. 2 [33229-34-4] (Vol. 57; 1993)

Blue VRS [129-17-9] (Vol. 16, Suppl. 7; 1987)

Bromochloroacetonitrile [83463-62-1] (Vol. 52, Vol. 71; 1999)

Bromoethane [74-96-4] (Vol. 52, Vol. 71; 1999)

Bromoform [75-25-2] (Vol. 52, Vol. 71; 1999)

Methyl bromide [74-83-9] (Vol. 41, Suppl. 7, Vol. 71; 1999)

Sudan Brown RR [6416-57-5] (Vol. 8, Suppl. 7; 1987)

Piperonyl butoxide [51-03-6] (Vol. 30, Suppl. 7; 1987)

2-Butoxyethanol [111-76-2] (Vol. 88; 2006)

1-*tert*-Butoxypropan-2-ol [57018-52-7] (Vol. 88; 2006)

gamma-Butyrolactone [96-48-0] (Vol. 11, Vol. 71; 1999)

Caffeine [58-08-2] (Vol. 51; 1991)

Cantharidin [56-25-7] (Vol. 10, Suppl. 7; 1987)

Captan [133-06-2] (Vol. 30, Suppl. 7; 1987)

Methyl carbamate [598-55-0] (Vol. 12, Suppl. 7; 1987)

n-Propyl carbamate [627-12-3] (Vol. 12, Suppl. 7; 1987)

Carbaryl [63-25-2] (Vol. 12, Suppl. 7; 1987)

Carbazole [86-74-8] (Vol. 32, Vol. 71; 1999)

3-Carbethoxypsoralen [20073-24-9] (Vol. 40, Suppl. 7; 1987)

3,4-Epoxy-6-methylcyclohexylmethyl-3,4-epoxy-6-methylcyclo-hexanecarboxylate [141-37-7] (Vol. 11, Vol. 71; 1999)

Carmoisine [3567-69-9] (Vol. 8, Suppl. 7; 1987)

Carrageenan, native [9000-07-1] (Vol. 31, Suppl. 7; 1987)

Electric fields (extremely low frequency) (Vol. 80; 2002)

Electric fields (static) (Vol. 80; 2002)

Magnetic fields (static) (Vol. 80; 2002)

Chloral [75-87-6] (Vol. 63; 1995)

Chloramine [10599-90-3] (Vol. 84; 2004)

Chlordimeform [6164-98-3] (Vol. 30, Suppl. 7; 1987)

Pronetalol hydrochloride [51-02-5] (Vol. 13, Suppl. 7; 1987)

Semicarbazide hydrochloride [563-41-7] (Vol. 12, Suppl. 7; 1987)

Sodium chlorite [7758-19-2] (Vol. 52; 1991)

Chloroacetonitrile [107-14-2] (Vol. 52, Vol. 71; 1999)

Chlorodibromomethane [124-48-1] (Vol. 52, Vol. 71; 1999)

Chlorodifluoromethane [75-45-6] (Vol. 41, Vol. 71; 1999)

Chloroethane [75-00-3] (Vol. 52, Vol. 71; 1999)

Chlorofluoromethane [593-70-4] (Vol. 41, Vol. 71; 1999)

3-Chloro-2-methylpropene [563-47-3] (Vol. 63; 1995)

Chloronitrobenzenes (isomer mixture) [88-73-3; 121-73-3; 100-00-5] (Vol. 65; 1996)

4-Chloro-*meta*-phenylenediamine [5131-60-2] (Vol. 27, Suppl. 7; 1987)

Chloropropham [101-21-3] (Vol. 12, Suppl. 7; 1987)

Chloroquine [54-05-7] (Vol. 13, Suppl. 7; 1987)

5-Chloro-*ortho*-toluidine [95-79-4] (Vol. 77; 2000)

2-Chloro-1,1,1-trifluoroethane [75-88-7] (Vol. 41, Vol. 71; 1999)

Acriflavinium chloride [8018-07-3] (Vol. 13, Suppl. 7; 1987)

Allyl chloride [107-05-1] (Vol. 36, Vol. 71; 1999)

Methyl chloride [74-87-3] (Vol. 41, Suppl. 7, Vol. 71; 1999)

Polyvinyl chloride [9002-86-2] (Vol. 19, Suppl. 7; 1987)

Vinylidene chloride [75-35-4] (Vol. 39, Suppl. 7, Vol. 71; 1999)

Cholesterol [57-88-5] (Vol. 31, Suppl. 7; 1987)

Chromium, metallic [7440-47-3] (Vol. 49; 1990)

Chromium (III) compounds (Vol. 49; 1990)

Chrysoidine [532-82-1] (Vol. 8, Suppl. 7; 1987)

Cimetidine [51481-61-9] (Vol. 50; 1990)

Clomiphene citrate [50-41-9] (Vol. 21, Suppl. 7; 1987)

Citrinin [518-75-2] (Vol. 40, Suppl. 7; 1987)

Clofibrate [637-07-0] (Vol. 66; 1996)

Iron-dextrin complex [9004-51-7] (Vol. 2, Suppl. 7; 1987)

Iron sorbitol-citric acid complex [1338-16-5] (Vol. 2, Suppl. 7; 1987)

Acrylonitrile-butadiene-styrene copolymers (Vol. 19, Suppl. 7; 1987)

Vinyl chloride-vinyl acetate copolymers [9003-22-9] (Vol. 19, Suppl. 7; 1987)

Vinylidene chloride-vinyl chloride copolymers [9011-06-7] (Vol. 19, Suppl. 7; 1987)

Styrene-acrylonitrile copolymers [9003-54-7] (Vol. 19, Suppl. 7; 1987)

Styrene-butadiene copolymers [9003-55-8] (Vol. 19, Suppl. 7; 1987)

Coronene [191-07-1] (Vol. 32, Suppl. 7; 1987)

Foreign bodies (see Surgical implants and other foreign bodies)

Coumarin [91-64-5] (Vol. 77; 2000)

meta-Cresidine [102-50-1] (Vol. 27, Suppl. 7; 1987)

Crotonaldehyde [4170-30-3] (Vol. 63; 1995)

Cyclamates (sodium cyclamate) [139-05-9] (Vol. 73; 1999)

Cyclochlorotine [12663-46-6] (Vol. 10, Suppl. 7; 1987)

Cyclohexanone [108-94-1] (Vol. 47, Vol. 71; 1999)

4*H*-Cyclopenta[*def*]chrysene [202-98-2] (Vol. 92; in preparation)

5,6-Cyclopenteno-1,2-benzanthracene [7099-43-6] (Vol. 92; in preparation)

Dapsone [80-08-0] (Vol. 24, Suppl. 7; 1987)

D & C Red No. 9 [5160-02-1] (Vol. 57; 1993)

Deltamethrin [52918-63-5] (Vol. 53; 1991)

Diacetylaminoazotoluene [83-63-6] (Vol. 8, Suppl. 7; 1987)

Diallate [2303-16-4] (Vol. 30, Suppl. 7; 1987)

1,2-Diamino-4-nitrobenzene [99-56-9] (Vol. 16, Suppl. 7; 1987)

1,4-Diamino-2-nitrobenzene [5307-14-2] (Vol. 57; 1993)

1,5-Naphthalenediamine [2243-62-1] (Vol. 27, Suppl. 7; 1987)

2,5-Diaminotoluene [95-70-5] (Vol. 16, Suppl. 7; 1987)

Diazepam [439-14-5] (Vol. 66; 1996)

Diazomethane [334-88-3] (Vol. 7, Suppl. 7; 1987)

Dibenz[*a,c*]anthracene [215-58-7] (Vol. 32, Suppl. 7, Vol. 92; in preparation)

Dibenz[*a,j*]anthracene [224-41-9] (Vol. 32, Suppl. 7, Vol. 92; in preparation)

Dibenzo-*para*-dioxin (Vol. 69; 1997)

Polychlorinated dibenzo-*para*-dioxins (other than 2,3,7,8-tetrachlorodibenzo-*para*-dioxin) (Vol. 69; 1997)

Dibenzo[*a,e*]fluoranthene [5385-75-1] (Vol. 32, Suppl. 7, Vol. 92; in preparation)

13*H*-Dibenzo[*a,g*]fluorene [207-83-0] (Vol. 92; in preparation)

Polychlorinated dibenzofurans (Vol. 69; 1997)

Dibenzo[*h,rst*]pentaphene [192-47-2] (Vol. 3, Suppl. 7, Vol. 92; in preparation)

Dibenzo[*a,e*]pyrene [192-65-4] (Vol. 32, Suppl. 7, Vol. 92; in preparation)

Dibenzo[*e,l*]pyrene [192-51-8] (Vol. 92; in preparation)

Dibromoacetonitrile [3252-43-5] (Vol. 52, Vol. 71; 1999)

Mannomustine dihydrochloride [551-74-6] (Vol. 9, Suppl. 7; 1987)

Dichloroacetonitrile [3018-12-0] (Vol. 52, Vol. 71; 1999)

Dichloroacetylene [7572-29-4] (Vol. 39, Vol. 71; 1999)

ortho-Dichlorobenzene [95-50-1] (Vol. 73; 1999)

meta-Dichlorobenzene [541-73-1] (Vol. 73; 1999)

Ethyl 4,4'-Dichlorobenzilate (chlorobenzilate) [510-15-6] (Vol. 30, Suppl. 7; 1987)

trans-1,4-Dichlorobutene [110-57-6] (Vol. 15, Vol. 71; 1999)

2,6-Dichloro-*para*-phenylenediamine [609-20-1] (Vol. 39, Suppl. 7; 1987)

1,2-Dichloropropane [78-87-5] (Vol. 41, Vol. 71; 1999)

Dicofol [115-32-2] (Vol. 30, Suppl. 7; 1987)

Didanosine [69655-05-6] (Vol. 76; 2000)

Dieldrin [60-57-1] (Vol. 5, Suppl. 7; 1987)

Diethanolamine [111-42-2] (Vol. 77; 2000)

Ethyl selenac [5456-28-0] (Vol. 12, Suppl. 7; 1987)

Sodium diethyldithiocarbamate [148-18-5] (Vol. 12, Suppl. 7; 1987)

Ethyl tellurac [20941-65-5] (Vol. 12, Suppl. 7; 1987)

N,*N*'-Diethylthiourea [105-55-5] (Vol. 79; 2001)

Dihydroxymethylfuratrizine [794-93-4] (Vol. 24, Suppl. 7; 1987)

3,3'-Dimethoxybenzidine-4,4'-diisocyanate [91-93-0] (Vol. 39, Suppl. 7; 1987)

4,4'-Methylenediphenyl diisocyanate [101-68-8] (Vol. 19, Vol. 71; 1999)

1,5-Naphthalene diisocyanate [3173-72-6] (Vol. 19, Vol. 71; 1999)

Dimethoxane [828-00-2] (Vol. 15, Suppl. 7; 1987)

para-Dimethylaminoazobenzenediazo sodium sulfonate [140-56-7] (Vol. 8, Suppl. 7; 1987)

4,4'-Dimethylangelicin [22975-76-4] plus ultraviolet A radiation (Suppl. 7; 1987)

4,5'-Dimethylangelicin [4063-41-6] plus ultraviolet A radiation (Suppl. 7; 1987)

N,*N*-Dimethylaniline [121-69-7] (Vol. 57; 1993)

Methyl selenac [144-34-3] (Vol. 12, Suppl. 7; 1987)

Dimethylformamide [68-12-2] (Vol. 47; Vol. 71; 1999)

1,4-Dimethylphenanthrene [22349-59-3] (Vol. 32, Suppl. 7, Vol. 92; in preparation)

1,3-Dinitropyrene [75321-20-9] (Vol. 46; 1989)

Dinitrosopentamethylenetetramine [101-25-7] (Vol. 11, Suppl. 7; 1987)

3,5-Dinitrotoluene [618-85-9] (Vol. 65; 1996)

Sulfur dioxide [7446-09-5] (Vol. 54; 1992)

2,4'-Diphenyldiamine [492-17-1] (Vol. 16, Suppl. 7; 1987)

Disulfiram [97-77-8] (Vol. 12, Suppl. 7; 1987)

Butylated hydroxytoluene (BHT) [128-37-0] (Vol. 40, Suppl. 7; 1987)

Potassium bis(2-hydroxyethyl)dithiocarbamate [23746-34-1] (Vol. 12, Suppl. 7; 1987)

Dithranol [1143-38-0] (Vol. 13; Suppl. 7; 1987)

Doxefazepam [40762-15-0] (Vol. 66; 1996)

Droloxifene [82413-20-5] (Vol. 66; 1996)

Dulcin [150-69-6] (Vol. 12, Suppl. 7; 1987)

Chlorinated drinking-water (Vol. 52; 1991)

Fluorescent lighting (Vol. 55; 1992)

Endrin [72-20-8] (Vol. 5, Suppl. 7; 1987)

Eosin [15086-94-9] (Vol. 15, Suppl. 7; 1987)

Ethylene sulfide [420-12-2] (Vol. 11, Suppl. 7; 1987)

Estazolam [29975-16-4] (Vol. 66; 1996)

Ethylene [74-85-1] (Vol. 60; 1994)

Methyl *tert*-butyl ether [1634-04-4] (Vol. 73; 1999)

Bisphenol A diglycidyl ether (Araldite□) [1675-54-3] (Vol. 47, Vol. 71; 1999)

Triethylene glycol diglycidyl ether [1954-28-5] (Vol. 11, Vol. 71; 1999)

Ethionamide [536-33-4] (Vol. 13, Suppl. 7; 1987)

Ethylenethiourea [96-45-7] (Vol. 79; 2001)
(NB: Overall evaluation upgraded from 2B to 3 based on mechanistic and other relevant data)

Eugenol [97-53-0] (Vol. 36, Suppl. 7; 1987)

Fenvalerate [51630-58-1] (Vol. 53; 1991)

Ferbam [14484-64-1] (Vol. 12, Suppl. 7; 1987)

Acrylic fibres (Vol. 19, Suppl. 7; 1987)

Modacrylic fibres (Vol. 19, Suppl. 7; 1987)

para-Aramid fibrils [24938-64-5] (Vol. 68; 1997)

Glass filament, continuous (Vol. 43, Vol. 81; 2002)

Fluometuron [2164-17-2] (Vol. 30, Suppl. 7; 1987)

Fluoranthene [206-44-0] (Vol. 32, Suppl. 7, Vol. 92; in preparation)

Fluorene [86-73-7] (Vol. 32, Suppl. 7, Vol. 92; in preparation)

5-Fluorouracil [51-21-8] (Vol. 26, Suppl. 7; 1987)

Vinylidene fluoride [75-38-7] (Vol. 39, Vol. 71; 1999)

Fluorides (inorganic, used in drinking-water) (Vol. 27, Suppl. 7; 1987)

Furazolidone [67-45-8] (Vol. 31, Suppl. 7; 1987)

Furfural [98-01-1] (Vol. 63; 1995)

Furosemide (Frusemide) [54-31-9] (Vol. 50; 1990)

Gemfibrozil [25812-30-0] (Vol. 66; 1996)

Gyromitrin [16568-02-8] (Vol. 31, Suppl. 7; 1987)

Haematite [1317-60-8] (Vol. 1, Suppl. 7; 1987)

Hexachlorobutadiene [87-68-3] (Vol. 73; 1999)

Hexachlorophene [70-30-4] (Vol. 20, Suppl. 7; 1987)

Isopropyl oils (Vol. 15, Suppl. 7, Vol. 71; 1999)

Hydralazine [86-54-4] (Vol. 24, Suppl. 7; 1987)

Chloral hydrate [302-17-0] (Vol. 84; 2004)

Isonicotinic acid hydrazide (Isoniazid) [54-85-3] (Vol. 4, Suppl. 7; 1987)

Maleic hydrazide [123-33-1] (Vol. 4, Suppl. 7; 1987)

Hydrochlorothiazide [58-93-5] (Vol. 50; 1990)

Hydroquinone [123-31-9] (Vol. 15, Vol. 71; 1999)

4-Hydroxyazobenzene [1689-82-3] (Vol. 8, Suppl. 7; 1987)

Copper 8-hydroxyquinoline [10380-28-6] (Vol. 15, Suppl. 7; 1987)

8-Hydroxyquinoline [148-24-3] (Vol. 13, Suppl. 7; 1987)

Hydroxysenkirkine [26782-43-4] (Vol. 10, Suppl. 7; 1987)

Hydroxyurea [127-07-1] (Vol. 76; 2000)

Hypochlorites (Vol. 52; 1991)

Surgical implants and other foreign bodies (Vol. 74; 1999):
- Organic polymeric materials (as a group)
- Orthopaedic implants of complex composition
- Cardiac pacemakers
- Silicone breast implants
- Implanted foreign bodies of metallic chromium or titanium and of cobalt-based, chromium-based and titanium-based alloys, stainless steel and depleted uranium

- Dental materials
- Ceramic implants

Methyl iodide [74-88-4] (Vol. 41, Vol. 71; 1999)

Isatidine [15503-86-3] (Vol. 10, Suppl. 7; 1987)

Allyl isothiocyanate [57-06-7] (Vol. 73; 1999)

Polymethylene polyphenyl isocyanate [9016-87-9] (Vol. 19, Suppl. 7; 1987)

Isophosphamide [3778-73-2] (Vol. 26, Suppl. 7; 1987)

Isopropanol [67-63-0] (Vol. 15, Suppl. 7, Vol. 71; 1999)

Isosafrole [120-58-1] (Vol. 10, Suppl. 7; 1987)

Allyl isothiocyanate [57-06-7] (Vol. 73; 1999)

Allyl isovalerate [2835-39-4] (Vol. 36, Vol. 71; 1999)

Jacobine [6870-67-3] (Vol. 10, Suppl. 7; 1987)

Yellow AB [85-84-7] (Vol. 8, Suppl. 7; 1987)

Disperse Yellow 3 [2832-40-8] (Vol. 48; 1990)

HC Yellow No. 4 [59820-43-8] (Vol. 57; 1993)

Yellow OB [131-79-3] (Vol. 8, Suppl. 7; 1987)

Sunset Yellow FCF [2783-94-0] (Vol. 8, Suppl. 7; 1987)

Vat Yellow 4 [128-66-5] (Vol. 48; 1990)

Kaempferol [520-18-3] (Vol. 31, Suppl. 7; 1987)

Slag wool (Vol. 43, Vol. 81; 2002)

Rock (stone) wool (Vol. 43, Vol. 81; 2002)

Insulation glass wool (Vol. 43, Vol. 81; 2002)

d-Limonene [5989-27-5] (Vol. 73; 1999)
(NB: Overall evaluation upgraded from 2B to 3 based on mechanistic and other relevant data)

Luteoskyrin [21884-44-6] (Vol. 10, Suppl. 7; 1987)

Malathion [121-75-5] (Vol. 30, Suppl. 7; 1987)

Malonaldehyde [542-78-9] (Vol. 36, Vol. 71; 1999)

Maneb [12427-38-2] (Vol. 12, Suppl. 7; 1987)

Medphalan [13045-94-8] (Vol. 9, Suppl. 7; 1987)

Melamine [108-78-1] (Vol. 73; 1999)
(NB: Overall evaluation upgraded from 2B to 3 based on mechanistic and other relevant data)

6-Mercaptopurine [50-44-2] (Vol. 26, Suppl. 7; 1987)

Mercury [7439-97-6] and its inorganic compounds (Vol. 58; 1993)

Hycanthone mesylate [23255-93-8] (Vol. 13, Suppl. 7; 1987)

Metabisulfites (Vol. 54; 1992)

Methyl methacrylate [80-62-6] (Vol. 60; 1994)

Polymethyl methacrylate [9011-14-7] (Vol. 19, Suppl. 7; 1987)

Methimazole [60-56-0] (Vol. 79; 2001)

Methotrexate [59-05-2] (Vol. 26, Suppl. 7; 1987)

Methoxychlor [72-43-5] (Vol. 20, Suppl. 7; 1987)

5-Methylangelicin [73459-03-7] plus ultraviolet A radiation (Suppl. 7; 1987)

1-Methylchrysene [3351-28-8] (Vol. 32, Suppl. 7, Vol. 92; in preparation)

2-Methylchrysene [3351-32-4] (Vol. 32, Suppl. 7, Vol. 92; in preparation)

3-Methylchrysene [3351-31-3] (Vol. 32, Suppl. 7, Vol. 92; in preparation)

4-Methylchrysene [3351-30-2] (Vol. 32, Suppl. 7, Vol. 92; in preparation)

6-Methylchrysene [1705-85-7] (Vol. 32, Suppl. 7, Vol. 92; in preparation)

N-Methyl-*N*,4-dinitrosoaniline [99-80-9] (Vol. 1, Suppl. 7; 1987)

2-Methylfluoranthene [33543-31-6] (Vol. 32, Suppl. 7, Vol. 92; in preparation)

3-Methylfluoranthene [1706-01-0] (Vol. 32, Suppl. 7, Vol. 92; in preparation)

Methylglyoxal [78-98-8] (Vol. 51; 1991)

N-Methylolacrylamide [90456-67-0] (Vol. 60; 1994)

Methyl parathion [298-00-0] (Vol. 30, Suppl. 7; 1987)

1-Methylphenanthrene [832-69-9] (Vol. 32, Suppl. 7, Vol. 92; in preparation)

7-Methylpyrido[3,4-*c*]psoralen [85878-63-3] (Vol. 40, Suppl. 7; 1987)

Microcystis (extracts) (Vol. 94; in preparation)

Monuron [150-68-5] (Vol. 53; 1991)

Morpholine [110-91-8] (Vol. 47, Vol. 71; 1999)

Polyurethane foams [9009-54-5] (Vol. 19, Suppl. 7; 1987)

Oestradiol mustard [22966-79-6] (Vol. 9, Suppl. 7; 1987)

Musk xylene [81-15-2] (Vol. 65; 1996)

1-Naphthylamine [134-32-7] (Vol. 4, Suppl. 7; 1987)

1-Naphthylthiourea (ANTU) [86-88-4] (Vol. 30, Suppl. 7; 1987)

Nithiazide [139-94-6] (Vol. 31, Suppl. 7; 1987)

5-Nitro-*ortho*-anisidine [99-59-2] (Vol. 27, Suppl. 7; 1987)

9-Nitroanthracene [602-60-8] (Vol. 33, Suppl. 7; 1987)

7-Nitrobenz[*a*]anthracene [20268-51-3] (Vol. 46; 1989)

6-Nitrobenzo[*a*]pyrene [63041-90-7] (Vol. 46; 1989)

4-Nitrobiphenyl [92-93-3] (Vol. 4, Suppl. 7; 1987)

3-Nitrofluoranthene [892-21-7] (Vol. 33, Suppl. 7; 1987)

Nitrofural (Nitrofurazone) [59-87-0] (Vol. 50; 1990)

Nitrofurantoin [67-20-9] (Vol. 50; 1990)

1-Nitronaphthalene [86-57-7] (Vol. 46; 1989)

2-Nitronaphthalene [581-89-5] (Vol. 46; 1989)

3-Nitroperylene [20589-63-3] (Vol. 46; 1989)

2-Nitropyrene [789-07-1] (Vol. 46; 1989)

N'-Nitrosoanabasine (NAB) [37620-20-5] (Vol. 37, Suppl. 7, Vol. 89; 2007)

N'-Nitrosoanatabine (NAT) [71267-22-6] (Vol. 37, Suppl. 7, Vol. 89; 2007)

N-Nitrosodiphenylamine [86-30-6] (Vol. 27, Suppl. 7; 1987)

para-Nitrosodiphenylamine [156-10-5] (Vol. 27, Suppl. 7; 1987)

N-Nitrosoguvacine [55557-01-2] (Vol. 85; 2004)

N-Nitrosoguvacoline [55557-02-3] (Vol. 85; 2004)

N-Nitrosohydroxyproline [30310-80-6] (Vol. 17, Suppl. 7; 1987)

3-(*N*-Nitrosomethylamino)propionaldehyde [85502-23-4] (Vol. 85; 2004)

N-Nitrosoproline [7519-36-0] (Vol. 17, Suppl. 7; 1987)

Nitrotoluenes (isomer mixture) [88-72-2; 99-08-1; 99-99-0] (Vol. 65; 1996)

5-Nitro-*ortho*-toluidine [99-55-8] (Vol. 48; 1990)

Nitrovin [804-36-4] (Vol. 31, Suppl. 7; 1987)

Nodularins [118399-22-7] (Vol. 94; in preparation)

Nylon 6 [25038-54-4] (Vol. 19, Suppl. 7; 1987)

Glycidyl oleate [5431-33-4] (Vol. 11, Suppl. 7; 1987)

Opisthorchis felineus (infection with) (Vol. 61; 1994)

CI Acid Orange 3 [6373-74-6] (Vol. 57; 1993)

Acridine orange [494-38-2] (Vol. 16, Suppl. 7; 1987)

CI Orange G [1936-15-8] (Vol. 8, Suppl. 7; 1987)

CI Acid Orange 20 [523-44-4] (Vol. 8, Suppl. 7; 1987)

Decabromodiphenyl oxide [1163-19-5] (Vol. 48, Vol. 71; 1999)

Ferric oxide (III) [1309-37-1] (Vol. 1, Suppl. 7; 1987)

Tris(1-aziridinyl)phosphine oxide [545-55-1] (Vol. 9, Suppl. 7; 1987)

Tris(2-methyl-1-aziridinyl)phosphine oxide [57-39-6] (Vol. 9, Suppl. 7; 1987)

Saccharated iron oxide [8047-67-4] (Vol. 2, Suppl. 7; 1987)

Oxyphenbutazone [129-20-4] (Vol. 13, Suppl. 7; 1987)

Palygorskite (Attapulgite) [12174-11-7] (short fibres, < 5 micrometres) (Vol. 68; 1997)

Paracetamol (Acetaminophen) [103-90-2] (Vol. 73; 1999)

Parathion [56-38-2] (Vol. 30, Suppl. 7; 1987)

Patulin [149-29-1] (Vol. 40, Suppl. 7; 1987)

Pentachloroethane [76-01-7] (Vol. 41, Vol. 71; 1999)

Permethrin [52645-53-1] (Vol. 53; 1991)

Benzoyl peroxide [94-36-0] (Vol. 36, Vol. 71; 1999)

Lauroyl peroxide [105-74-8] (Vol. 36, Vol. 71; 1999)

Hydrogen peroxide [7722-84-1] (Vol. 36, Vol. 71; 1999)

Perylene [198-55-0] (Vol. 32, Suppl. 7, Vol. 92; in preparation)

Petasitenine [60102-37-6] (Vol. 31, Suppl. 7; 1987)

Phenanthrene [85-01-8] (Vol. 32, Suppl. 7, Vol. 92; in preparation)

Phenicarbazide [103-03-7] (Vol. 12, Suppl. 7; 1987)

Phenol [108-95-2] (Vol. 47, Vol. 71; 1999)

Phenylbutazone [50-33-9] (Vol. 13, Suppl. 7; 1987)

meta-Phenylenediamine [108-45-2] (Vol. 16, Suppl. 7; 1987)

para-Phenylenediamine [106-50-3] (Vol. 16, Suppl. 7; 1987)

N-Phenyl-2-naphthylamine [135-88-6] (Vol. 16, Suppl. 7; 1987)

ortho-Phenylphenol [90-43-7] (Vol. 73; 1999)

Tris(2-chloroethyl) phosphate [115-96-8] (Vol. 48, Vol. 71; 1999)

Dimethyl hydrogen phosphite [868-85-9] (Vol. 48, Vol. 71; 1999)

Butyl benzyl phthalate [85-68-7] (Vol. 73; 1999)

di(ethyl-2 hexyl) phthalate [117-81-1] (Vol. 77; 2000)
(NB: Overall evaluation upgraded from 2B to 3 based on mechanistic and other relevant data)

Picene [213-46-7] (Vol. 92; in preparation)

Picloram [1918-02-1] (Vol. 53; 1991)

Lead compounds, organic (Vol. 23, Vol. 87; 2006)
(NB: Organic lead compounds are metabolized at least in part, to ionic lead both in humans and animals. To the extent that ionic lead, generated from organic lead, is present in the body, it will be expected to exert the toxicities associated with inorganic lead.)

Polychloroprene [9010-98-4] (Vol. 19, Suppl. 7; 1987)

Polyethylene [9002-88-4] (Vol. 19, Suppl. 7; 1987)

Polypropylene [9003-07-0] (Vol. 19, Suppl. 7; 1987)

Polystyrene [9003-53-6] (Vol. 19, Suppl. 7; 1987)

Polytetrafluoroethylene [9002-84-0] (Vol. 19, Suppl. 7; 1987)

Polyvinyl pyrrolidone [9003-39-8] (Vol. 19, Suppl. 7, Vol. 71; 1999)

Ponceau SX [4548-53-2] (Vol. 8, Suppl. 7; 1987)

Coal dust (Vol. 68; 1997)

Prazepam [2955-38-6] (Vol. 66; 1996)

Prednimustine [29069-24-7] (Vol. 50; 1990)

Prednisone [53-03-2] (Vol. 26, Suppl. 7; 1987)

Propham [122-42-9] (Vol. 12, Suppl. 7; 1987)

Propylene [115-07-1] (Vol. 60; 1994)

Ptaquiloside [87625-62-5] (Vol. 40, Suppl. 7; 1987)

Pyrene [129-00-0] (Vol. 32, Suppl. 7, Vol. 92; in preparation)

Pyridine [110-86-1] (Vol. 77; 2000)

Pyrido[3,4-*c*]psoralen [85878-62-2] (Vol. 40, Suppl. 7; 1987)

Pyrimethamine [58-14-0] (Vol. 13, Suppl. 7; 1987)

Quercetin [117-39-5] (Vol. 73; 1999)

para-Quinone [106-51-4] (Vol. 15, Suppl. 7, Vol. 71; 1999)

Quintozene (Pentachloronitrobenzene) [82-68-8] (Vol. 5, Suppl. 7; 1987)

Madder root (*Rubia tinctorum*) (Vol. 82; 2002)

Reserpine [50-55-5] (Vol. 24, Suppl. 7; 1987)

Resorcinol [108-46-3] (Vol. 15, Vol. 71, 1999)

Retrorsine [480-54-6] (Vol. 10, Suppl. 7; 1987)

Rhodamine B [81-88-9] (Vol. 16, Suppl. 7; 1987)

Rhodamine 6G [989-38-8] (Vol. 16, Suppl. 7; 1987)

Rifampicin [13292-46-1] (Vol. 24, Suppl. 7; 1987)

Ripazepam [26308-28-1] (Vol. 66; 1996)

Methyl red [493-52-7] (Vol. 8, Suppl. 7; 1987)

Scarlet Red [85-83-6] (Vol. 8, Suppl. 7; 1987)

HC Red No. 3 [2871-01-4] (Vol. 57; 1993)

CI Pigment Red 3 [2425-85-6] (Vol. 57; 1993)

Sudan Red 7B [6368-72-5] (Vol. 8, Suppl. 7; 1987)

Rugulosin [23537-16-8] (Vol. 40, Suppl. 7; 1987)

Saccharin [81-07-2] and its salts (Vol. 73; 1999)
(NB: Overall evaluation upgraded from 2B to 3 based on mechanistic and other relevant data)

Schistosoma mansoni (infection with) (Vol. 61; 1994)

Selenium [7782-49-2] and selenium compounds (Vol. 9, Suppl. 7; 1987)

Proflavine salts (Vol. 24, Suppl. 7; 1987)

Tetrakis(hydroxymethyl)phosphonium salts (Vol. 48, Vol. 71; 1999)

Seneciphylline [480-81-9] (Vol. 10, Suppl. 7; 1987)

Senkirkine [2318-18-5] (Vol. 31, Suppl. 7; 1987)

Sepiolite [15501-74-3] (Vol. 68; 1997)

Silica, amorphous [7631-86-9] (Vol. 68; 1997)

Simazine [122-34-9] (Vol. 73; 1999)

Sudan I [842-07-9] (Vol. 8, Suppl. 7; 1987)

Sudan II [3118-97-6] (Vol. 8, Suppl. 7; 1987)

Sudan III [85-86-9] (Vol. 8, Suppl. 7; 1987)

Spironolactone [52-01-7] (Vol. 79; 2001)

Glycidyl stearate [7460-84-6] (Vol. 11, Suppl. 7; 1987)

Doxylamine succinate [562-10-7] (Vol. 79; 2001)

Sulfafurazole (Sulfisoxazole) [127-69-5] (Vol. 24, Suppl. 7; 1987)

Sulfamethazine [57-68-1] (Vol. 79; 2001)
(NB: Overall evaluation upgraded from 2B to 3 based on mechanistic and other relevant data)

Sulfamethoxazole [723-46-6] (Vol. 79; 2001)

Phenelzine sulfate [156-51-4] (Vol. 24, Suppl. 7; 1987)

Vinblastine sulfate [143-67-9] (Vol. 26, Suppl. 7; 1987)

Vincristine sulfate [2068-78-2] (Vol. 26, Suppl. 7; 1987)

Sulfites (Vol. 54; 1992)

Bis(1-aziridinyl)morpholinophosphine sulfide [2168-68-5] (Vol. 9, Suppl. 7; 1987)

Symphytine [22571-95-5] (Vol. 31, Suppl. 7; 1987)

Talc [14807-96-6], not containing asbestiform fibres (inhaled) (Vol. 42, Suppl. 7, Vol. 93; in preparation)

Temazepam [846-50-4] (Vol. 66; 1996)

2,2',5,5'-Tetrachlorobenzidine [15721-02-5] (Vol. 27, Suppl. 7; 1987)

1,1,1,2-Tetrachloroethane [630-20-6] (Vol. 41, Vol. 71; 1999)

1,1,2,2-Tetrachloroethane [79-34-5] (Vol. 20, Vol. 71; 1999)

Tetrachlorvinphos [22248-79-9] (Vol. 30, Suppl. 7; 1987)

Theobromine [83-67-0] (Vol. 51; 1991)

Theophylline [58-55-9] (Vol. 51; 1991)

Thiourea [62-56-6] (Vol. 79; 2001)

Thiram [137-26-8] (Vol. 53; 1991)

Toluene [108-88-3] (Vol. 47, Vol. 71; 1999)

Toremifene [89778-26-7] (Vol. 66; 1996)

Toxins derived from *Fusarium graminearum, F. culmorum and F. crookwellense*: zearalenone, deoxynivalenol, nivalenol and fusarenone X (Vol. 56; 1993)

Toxins derived from *Fusarium sporotrichioides*: T-2 toxin (Vol. 56; 1993)

Trichlorfon [52-68-6] (Vol. 30, Suppl. 7; 1987)

Trichloroacetonitrile [545-06-2] (Vol. 52, Vol. 71; 1999)

1,1,1-Trichloroethane [71-55-6] (Vol. 20, Vol. 71; 1999)

1,1,2-Trichloroethane [79-00-5] (Vol. 52, Vol. 71; 1999)

Triethanolamine [102-71-6] (Vol. 77; 2000)

Trifluralin [1582-09-8] (Vol. 53; 1991)

4,4',6-Trimethylangelicin [90370-29-9] plus ultraviolet A radiation (Suppl. 7; 1987)

2,4,5-Trimethylaniline [137-17-7] (Vol. 27, Suppl. 7; 1987)

2,4,6-Trimethylaniline [88-05-1] (Vol. 27, Suppl. 7; 1987)

4,5',8-Trimethylpsoralen [3902-71-4] (Vol. 40, Suppl. 7; 1987)

2,4,6-Trinitrotoluene [118-96-7] (Vol. 65; 1996)

Triphenylene [217-59-4] (Vol. 32, Suppl. 7, Vol. 92; in preparation)

Tris(aziridinyl)-*para*-benzoquinone (Triaziquone) [68-76-8] (Vol. 9, Suppl. 7; 1987)

2,4,6-Tris(1-aziridinyl)-*s*-triazine [51-18-3] (Vol. 9, Suppl. 7; 1987)

1,2,3-Tris(chloromethoxy)propane [38571-73-2] (Vol. 15, Vol. 71; 1999)

Antimony trisulfide [1345-04-6] (Vol. 47; 1989)

Light Green SF [5141-20-8] (Vol. 16, Suppl. 7; 1987)

Guinea Green B [4680-78-8] (Vol. 16, Suppl. 7; 1987)

Fast Green FCF [2353-45-9] (Vol. 16, Suppl. 7; 1987)

N-Vinyl-2-pyrrolidone [88-12-0] (Vol. 19, Vol. 71; 1999)

Vinyl toluene [25013-15-4] (Vol. 60; 1994)

Hepatitis D virus (Vol. 59; 1994)

Human T-cell lymphotropic virus type II (Vol. 67; 1996)

Vitamin K [12001-79-5] (substances with) (Vol. 76; 2000)

Wollastonite [13983-17-0] (Vol. 68; 1997)

Xylenes [1330-20-7] (Vol. 47, Vol. 71; 1999)

2,4-Xylidine [95-68-1] (Vol. 16, Suppl. 7; 1987)

2,5-Xylidine [95-78-3] (Vol. 16, Suppl. 7; 1987)

Zectran [315-18-4] (Vol. 12, Suppl. 7; 1987)

Zeolites [1318-02-1] other than erionite (clinoptilolite, phillipsite, mordenite, non-fibrous Japanese zeolite, synthetic zeolites) (Vol. 68; 1997)

Zineb [12122-67-7] (Vol. 12, Suppl. 7; 1987)

Ziram [137-30-4] (Vol. 53; 1991)

2. Mixtures

Bitumens [8052-42-4] steam-refined, cracking-residue and air-refined (Vol. 35, Suppl. 7; 1987)

Jet fuel (Vol. 45; 1989)

Diesel fuels, distillate (light) (Vol. 45; 1989)

Fuel oils, distillate (light) (Vol. 45; 1989)

Printing inks (Vol. 65; 1996)

Mineral oils, highly-refined (Vol. 33, Suppl. 7; 1987)

Mate (Vol. 51; 1991)

Crude oil [8002-05-9] (Vol. 45; 1989)

Terpene polychlorinates (Strobane□) [8001-50-1] (Vol. 5, Suppl. 7; 1987)

Petroleum solvents (Vol. 47; 1989)

Tea (Vol. 51; 1991)

3. Occupational and other exposures

Calcium carbide (production) (Vol. 92; in preparation)

Hair colouring products (personal use) (Vol. 57, Vol. 99, in preparation)

Leather goods manufacture (Vol. 25, Suppl. 7; 1987)

Paint manufacture (occupational exposure in) (Vol. 47; 1989)

Flat-glass and specialty glass (manufacture of) (Vol. 58; 1993)

Pulp and paper manufacture (Vol. 25, Suppl. 7; 1987)

Lumber and sawmill industries (including logging) (Vol. 25, Suppl. 7; 1987)

Leather tanning and processing (Vol. 25, Suppl. 7; 1987)

Last updated: 1 April 2008

Group 4: Probably not carcinogenic to humans (1)

Caprolactam [105-60-2] (Vol. 39, Suppl. 7, Vol. 71; 1998)

Last updated: 1 April 2008

APPENDIX 5 – LEGAL STUDIES

Exposure limits to electromagnetic fields producedby electricity transmission installations (December 2009)

In the following text, the following units of measurement are used: kV for kilovolts, Hz for hertz and µT for microtesla.

1) The European Union

The recommendation of the European Council of 12 July 1999 relative to the exposure limit for the public to electromagnetic fields (of 0 to 300 Ghz) (document no. 1) sets the maximum allowed limit of magnetic induction produced by an installation according to the frequency of the electrical power network. In Europe, high voltage power lines are operated at 50 Hz. Consequently, this limit is set at **100 µT**.

2) Germany

The federal regulation of 16 December 1996 relative to electromagnetic fields (document no. 2), which came into effect on 1 January 1997 and which is one of the application texts of the federal act of 15 March 1974 relative to protecting against environmental pollution, defines **exposure thresholds**. It determines the **maximum allowed magnetic induction** produced by low frequency installations – including, in particular, power lines with a frequency of 50 Hz and a voltage of greater than 1,000 volts – and measured "in those buildings and on those sites in and at which people are not liable to spend only short periods of time".

The reference to "stay" duration notably allows for the exemption of certain household outbuildings and annexes (balconies, sheds, etc.). Furthermore, the text only applies to humans, and not animals.

Electricity transmission installations must be built and used in such a manner to ensure that magnetic induction does not exceed **100 µT**.

Directives for the application of this regulation (document no. 3) were elaborated by a workgroup gathering together representatives of the Ministries of the Environment for both the federal government and the *Länder* (states). These directives, which are entirely **nonobligatory**, recommend that buildings

and non-built-up sites lie outside a strip of land consisting of the ground occupied by the line and by two corridors, with the minimum width of each of these corridors (as measured from the line's external conductor) varying according to voltage:

Less than 110 kV	5 metres
110 kV	10 metres
220 kV	15 metres
380 kV	20 metres

These directives are not applied in certain states (for instance, in Thuringia). **In others, recommendations have been published that are stricter than the federal directives** and that establish minimal distances that must separate high voltage lines from those places in which people spend significant amounts of time.

For instance, in 2004, the German Minister of Social Affairs and Health for the state of **Bremen** published a **recommendation** (document no. 4) in which he indicates that magnetic induction should not exceed 0.3 µT in those places "not meant for short stays". The recommendation specifies that this ceiling corresponds in most cases to the following distances, calculated according to the central axis of the high voltage lines. These distances therefore vary according to voltage:

110 kV	30 metres
220 kV	60 metres
380 kV	80 metres

Likewise, the Minister of the Environment for the state of **Brandenburg** (document no. 5) recommends that the following distances be respected between the sides of high voltage lines and buildings in which people are liable to spend at least six hours a day:

Starting at 110 kV	30 metres
Starting at 380 kV	50 metres

In the state of **North Rhine-Westphalia** (document no. 6), the Ministry of the Environment recommends the following distances, as measured from the lines' central axis:

110 kV	10 metres
220 kV	20 metres
380 kV	40 metres

These recommendations are referred to by the state's local authorities for the planning of installations.

At the end of 2007, the state of Lower Saxony passed a law stating that high voltage lines must be buried when located within a certain distance from residences (200 metres for isolated houses and 400 metres for grouped housing). This law applies to those lines installed following the law's effective date. Its adoption was followed by the submission of several proposals for similar laws in other states (for instance, in Hesse).

3) Belgium

There exists **no national standard** setting an exposure limit to electromagnetic fields produced by high voltage power lines. Rather, it is the European recommendation, which sets the limit at 100 µT, that is applied.

In Flanders, the ministerial order of 11 June 2004, containing measures to counter health risks linked to interior pollution, provides for two limits (document no. 7):

– 10 µT for the minimum "intervention value", signifying that a home is considered uninhabitable.
– 0.2 µT for the "reference value"; in other words, the desired value.

4) Spain

Royal Decree 1066/2001 of 28 September 2001 approving the regulations establishing health protection measures against emissions produced by electrical installations (document no. 8) borrowed the ceilings set by the European Council's recommendation of 12 July 1999 relative to limiting the public's exposure to electromagnetic fields. Consequently, for high voltage lines, the limit is set at **100 µT**.

Royal Decree 223/2008 of 15 February 2008 approving the regulations setting the technical conditions and safety guarantees for high voltage lines includes several technical directives. One of these, Directive ITC-LAT 07 (document no. 9), details the technical requirements applicable to overhead, high voltage power lines. In particular, it specifies that the installation of lines must be avoided, as far as is possible, in those areas capable of being urbanized. It also provides for the existence of corridors (one on either side of the power line) in which construction of any kind is banned. The minimum distance separating constructions from the sides of power lines varies according to the lines' maximum voltage; however, it can be less than 5 metres. For example, the following distances must be respected:

Maximum voltage	Minimum distance
145 kV	5 metres
170 kV	5 metres
245 kV	5 metres
420 kV	6.1 metres

These requirements apply to those lines installed following the coming into effect of Decree 1955/2000 of 1 December 2000 relative to the regulation of electricity transmission, distribution, marketing and provision; in other words, starting in early 2001.

> For older lines, Decree 3151 of 28 November 1968 - approving the regulations relative to overhead, high voltage lines - continues to apply. However, this text did not require that corridors be respected. This decree only required minimal distances as measured in a straight, horizontal line; it therefore did not prevent the installation of high voltage lines above residences. These minimum distances were determined according to voltage, but could not measure less than 5 metres. It was therefore possible to install a 7-metre-high, high voltage line immediately above a 2-metre-high structure.

5) Italy

Framework Law no. 36 of 22 February 2001 on the protection against exposure to electric, magnetic and electromagnetic fields (document no. 10) **defines three values:**

– **The exposure limit**, an absolute limit applicable everywhere.
– **The alert threshold**, a precautionary limit that must be respected in certain locations considered particularly "sensitive", including playgrounds, domestic premises and schools, as well as any location liable to be the subject of a "prolonged stay".
– **The quality objective**, the desired value that must progressively be achieved.

The law entrusts the setting of these different values to a decree of the President of the Council of Ministers. It also lays out that it is the State's responsibility to establish the routes taken by transmission lines with a voltage of greater than 150 kV and to define corridors within which buildings may not be used for residential, scholastic or health purposes, or for any other purpose implying a human presence of 4 or more hours per day.

The decree of the President of the Council of Ministers of 8 July 2003 setting exposure limits, alert thresholds and quality objectives for the protection of the population against exposure to electric and magnetic fields with a frequency of 50 Hz produced by power lines (document no. 11) – issued for the application of the above-cited law - rendered applicable in Italy the recommendation of the European Council of 12 July 1999 and adopted the same **general limit of 100 µT**.

Furthermore, as a precautionary measure, **it establishes in this manner the alert threshold: the 24-hour median value of magnetic induction [1] must not exceed 10 µT** within playgrounds, domestic premises and schools, as well as within all locations liable to be occupied during 4 or more hours per day. The reference to a median signifies that excessive levels are tolerated for short periods of time.

With regard to new lines, the decree recommends that they be installed in such a way as to achieve the quality objective of 3 µT in "sensitive" locations, in which the alert threshold must currently be respected. The same recommendation applies to the creation/setting up of new "sensitive" facilities near pre-existing power lines.

The decree of the Ministry of the Environment of 29 May 2008 (document no. 12) **determines the method of establishing the corridors** within which buildings may not be used for residential, scholastic or health purposes, or any other purpose implying a human presence of 4 or more hours per day. This complex document considers the various technical characteristics of electrical installations.

Before the passage of the national framework law, several regions (including Veneto and Tuscany) had adopted stricter standards that are no longer in effect.

> Regional Law of **Veneto** no. 27 of 30 June 1993 on the prevention of injury/harm resulting from electromagnetic fields produced by power lines established that the routes chosen for high voltage lines be designed in such a manner as to ensure that the magnetic induction measured 1.5 metres above ground does not exceed 0.2 µT between the line's central axis and buildings meant for housing or other activities implying the prolonged, regular presence of people. By court order 1735/2005, the

[1] For the methods of measurement, the decree refers to the documentation of the "Italian Electrotechnical Committee".

administrative tribunal of Veneto judged that these measures of the regional law had been implicitly repealed by the subsequent national legislation. The tribunal's order has become definitive, for not having been debated before the State Council.

In **Tuscany**, the regulation of 20 December 2000 relative to electric power lines passed for the application of Regional Law no. 51 of 11 August 1999 granted the competent authority for delivering authorizations for the installation of power lines the right to set the limits of those zones closed to new construction at:
– 120 metres on either side of a power line with a voltage greater than 150 kV.
– 80 metres for lines with a voltage of between 100 and 150 kV.
The same text instituted regulations specific to facilities located in proximity to power lines of lesser voltage, though still above 20 kV. If people were liable to spend an extended period of time in a location where the level of magnetic induction was 0.2 µT or greater, measures were to be taken to limit the electromagnetic impact (for instance, by burying the lines) and to ensure the monitoring of emissions.

6) The Netherlands

On 3 October 2005, the Minister of the Environment addressed a recommendation to the executive organs of the municipalities and provinces, as well as to the power transmission companies (document no. 13).

According to this document, during the elaboration of urban development plans, as well as during the determination of high-voltage overhead power line routes, one should, to the greatest extent possible, avoid creating "new situations" by which children would remain for sustained periods of time in zones located near high voltage overhead lines for which the magnetic induction averaged out over one year exceeds 0.4 µT.

To facilitate the task for the municipalities, the text introduces the idea of "indicative zones": corridors whose width varies according to the voltage of the line and in which it is recommended to avoid new constructions destined for so-called "sensitive" populations, notably schools, day nurseries and playgrounds.

The width of these corridors is established as follows, the line being located in the centre of the corridor:

Voltage	Corridor width
50 kV	2 x 40 metres
110 kV	2 x 50 metres
150 kV	2 x 80 metres
220 kV	2 x 150 metres
380 kV	2 x 200 metres

This recommendation does not apply to installations built prior to 3 October 2005, unless they are the subject of modifications. Several terms used in the recommendation are discussed in an appendix, which was updated in November 2008 (document no. 14). For instance, the word "child" refers to any person under 15 years of age, while a "long-duration stay" means at least 14 to 18 hours per day, on average, the average being calculated over one year.

The recommendation is non-binding. Several municipalities have decided to not follow the recommendation during the construction of new collective facilities. In the resulting dispute, the tribunals underlined several times that the municipalities were not bound to respect the recommendation, though they were obligated to justify their decision.

7) Sweden

Kraftnät, which is the body corresponding to RTE in Sweden, has set its own exposure limit for electromagnetic fields: during the planning of new power lines, radiation must not exceed **0.4 µT** in any location liable to welcome humans for extended periods of time.

In addition, **the agency for the safety and security of electrical installations** enacted regulations setting, in particular, the minimum distance that must separate high voltage lines from constructions and installations meant to be frequented by people. According to these regulations (document no. 15), the minimum distance (measured horizontally and expressed in metres) is determined as follows:

	Voltage of up to 55 kV	**Voltage greater than 55 kV**
Constructions set up in a zone provided with an urbanization plan	5	10
Constructions set up outside a zone provided with an urbanization plan	5	5 + S according to the earthing system of the electrical installations, S = 0.5 or 0.7 cm for each kV in excess of 55 kV.
Car parks (not used for the stationing of vehicles carrying inflammable or explosive materials)	5	10
Open areas frequented by the public (sports areas, playgrounds, etc.)	20	

8) Switzerland

The order of 23 December 1999 on protecting against non-ionizing radiation (document no. 16) establishes two ceilings:

- The "limit value per installation", which notably applies to transmission lines with a voltage of over 1,000 volts and which must be respected in those "locations used for sensitive purposes" - in other words, buildings "in which people regularly spend an extended period of time" - playgrounds, sites open to construction, and sites on which playgrounds could be built.

- The "limit value of harmfulness/noxiousness", which must be respected "in all locations where people are liable to spend time", even for only short durations.

The limit value per installation is 1 µT: for instance, a high voltage line must not produce a magnetic induction of greater than 1 µT within a home. As for the **limit value of harmfulness/noxiousness**, which applies to all forms of non-ionizing radiation present in a given location, it is set at **100 µT**.

These values apply to all installations, both planned and pre-existing.

See the dossier, notably the brochure of the Office fédéral de l'environnement, des forêts et du paysage ("Federal Office of the Environment, Forests and Landscapes") (document no. 17, pages 26 and 27).

9) Luxembourg

- **Application of European Council Decision 1999/512/EC of 12 July 1999**

The first report of the European Commission on the implementation of Council Recommendation 1999/512/EC of 12 July 1999 states that the applicable standards are stricter than those recommended by this decision (document no. 1, page 29).

For its part, the BIPRO progress report of May 2008 relative to the implementation of the same decision points out that Luxembourg has not established general framework measures setting basic restrictions and reference levels (document no. 2, page 50).

Finally, the Commission Report of 1 September 2008 indicates that **Luxembourg applies the standards set by Council Decision 1999/512/EC of 12 July 1999 for the basic restrictions, but stricter standards for the reference levels** (document no. 3, pages 6 and 7).

- **Specific recommendations relative to the distance separating constructions from extra high voltage power lines**

Circular no. 1644 of 11 March 1994 on the health effects of magnetic fields addressed to municipalities by the Ministry of the Interior is still in effect and constitutes a simple recommendation.

This circular recommends that zones or sites open to construction no longer be created near extra high voltage lines; for lines of 100 to 220 kV, it recommends maintaining a distance of 30 metres between the central axis of the line and the limit of the closest property liable to be built up, and 20 metres for extra high voltage lines of 65 kV (document no. 4, page 3).

It should be pointed out that the installation of extra high voltage lines is subject to the measures laid out by the law of 19 June 1999 relative to listed

sites/buildings. These installations are authorized following a public inquiry by a ministerial order prepared by the Administration of the Environment. This text fixes the general recommendations applicable to such structures, as well as the limits to be respected (document no. 5). The Administration of the Environment has yet to reply to several requests made by the Division des études de législation comparée (French "Department for the Comparative Study of Legislation") and the French embassy in Luxembourg to provide details on this point.