

OPINION

of the French Agency for Environmental and Occupational Health Safety

Concerning the update of the expert appraisal relating to radiofrequencies

The mission of the French Agency for Environmental and Occupational Health Safety (Afsset) is to help ensure environmental and occupational health safety and assess potential health risks in these areas. It provides the competent authorities with all information required on these risks, as well as the expertise and technical support needed to draft legislative and statutory provisions and implement risk management strategies (article L. 1336-1 of the French Public Health Code).

Presentation of the question

On 14 August 2007, Afsset received a solicited request from the French Ministries of Health and Environment to publish a state of scientific knowledge and to update previous opinions on the biological and health effects of mobile phones, and to extend it to cover the entire subject area relating to radiofrequencies.

Afsset was asked to pay particular attention to the signals identified in the previous reports (2003 and 2005) concerning, notably, the modification of the permeability of the haematoencephalic barrier, an epidemiological study on the risk of neurinoma associated with the use of mobile phones, as well as the development and deployment of new technologies (Wi-Fi, personal mobile television, etc.). Furthermore, it was recommended to identify, with the greatest level of attention, the concerns of society and consequently to contribute to the public debate on this topic.

The work of the expert appraisal is mainly concerned with the exposure of the general population to electromagnetic radiofrequency fields. In some specific cases however, particularly in the absence of available data on public exposure, information from the occupational environment has been used.

Scientific context

The development of technologies using radiofrequencies and their associated applications - i.e. those using electromagnetic fields with a frequency range between 9 kHz and 300 GHz - has increased heavily over the last 20 years with the appearance of new functionalities for the mobile phone, the rapid development of *Bluetooth*, Wi-Fi, WiMAX, etc. The sources of electromagnetic radiofrequency fields are multiplying and are accompanied by multiple

questions in terms of their use, metrology, biological and clinical effects, epidemiology, regulations and human and social science. These developments are also accompanied by various concerns, depending on the applications involved, mainly based on their possible health impacts. Scientific research is being pursued in these different fields.

Afsset provides herewith an update on the scientific knowledge relating to all applications using electromagnetic radiofrequency fields, excluding RFID for which recent work has been conducted elsewhere.

Organisation of the expert appraisal

The expert appraisal was carried out in compliance with French standard NF X 50-110 "Quality in Expert Appraisal Activities – General Requirements of Competence for Expert Appraisals" (May 2003) with the objective of respecting the following points: competence, independence, transparency and traceability.

Within this framework, Afsset entrusted the request from the Ministries of Health and Environment to its Committee of Specialised Experts "Physical agents, new technologies and large developments" (CES "Physical agents") since its creation in April 2008. After validation of the latter, during the meeting on 29 April 2008, it commissioned a working group "Radiofrequencies" to carry out the expert appraisal.

From its first meeting, the CES "Physical Agents" has questioned three of the five French associations active on the theme of mobile phone health risks (Priartém, Agir pour l'environnement and Criirem). The fourth (Robin des toits) was questioned at the following meeting. The fifth, the association Next-up, has not replied to the invitation from Afsset. To maintain transparency, the chairman of the CES "Physical Agents", jointly with the Directorate General of Afsset, suggested to the associations, during these hearings, that a representative common to these four associations should be nominated to be an observer on the radiofrequencies working group's progress. While Criirem and Robin des toits responded unfavourably to this suggestion, a member of the Priartém association has been put forward by Priartém and Agir pour l'environnement. He has therefore been appointed observer within the radiofrequencies working group and has been invited to attend all the meetings as well as various hearings since December 2008.

The "radiofrequencies" working group coordinated by Afsset was formed during the summer of 2008, following a public call for applications. This multidisciplinary working group was formed by experts in the fields of medicine, biology, biophysics, electromagnetic field metrology, epidemiology as well as human and social sciences. These expert appraisal activities are therefore the result of the work of a group of experts with complementary competences.

In order to conduct an investigation into this solicited request on the effects of radiofrequencies on health, the group met 13 times (22 days between September 2008 and October 2009). Within this framework, 19 hearings were also carried out (see appendix). In addition to these hearings, 13 written contributions on more precise questions from the working group have been requested, of which 9 have obtained a response.

The progress status of this work was regularly submitted to the CES "Physical Agents" and discussed during its working meetings. The report produced by the group consequently takes into account the observations and additional items passed on by the members of the CES "Physical Agents" having taken part in the discussions.

Description of the method

The originality of the work carried out lies particularly in:

- taking account of all radiofrequencies and not only those from mobile phones;
- addressing the question of electromagnetic hypersensitivity;
- the multidisciplinary nature of the working group that particularly integrates experts from the field of human and social sciences;
- the presence of an observer from the not-for-profit sector at the working group meetings.

To carry out this expert appraisal, the working group relied on a very large review of international scientific literature completed by numerous hearings of scientists, experts and associations.

The literature review undertaken by the group was as exhaustive as possible. The scientific work taken into account in the report is mostly from written publications from English-language international scientific peer-reviewed journals. However, the group did not want to limit itself to these publications alone and took into account scientific texts published outside of these journals. In total, close to 3500 references have thus been made available to the Afsset experts. They have examined around 1000 of them in depth (see bibliography of the report): the work examined in this report, being an update of the knowledge relating to the health effects of radiofrequencies, is mainly that published between the issuing of the report in 2005 and April 2009 concerning the range of frequencies greater than 400 MHz (including mobile phones), as well as other work from the same period or earlier, for frequency bands that have not previously been studied by Afsset. Finally, in order to carry out work that is as complete as possible, references thus used have been compared to those from other international reports (reports from Scenih¹ 2007 and 2009, report from MTHR² 2007, BioInitiative 2007, etc.).

The expert appraisal by the members of the group concerned several areas:

- the analysis of the biological and health effects of electromagnetic fields;
- the assessment of exposure of individuals;
- the assessment of international regulations;
- the study of the perception of risks and an assessment of the public controversy.

A measurement programme has been carried out within the framework of this study. It has allowed electromagnetic field levels emitted by certain mobile phone masts to be assessed and, in particular, the low frequency magnetic field level in the immediate vicinity.

¹ *Scientific Committee on Emerging and Newly Identified Health Risks*

² *Mobile Telecommunications and Health Research Program*

Results of the collective expert appraisal

The work of the expert appraisal, the conclusions and the recommendations of the "Radiofrequencies" working group, were submitted to the CES "Physical Agents" in the form of a report and a summary of the collective expert appraisal.

The CES adopted the work of the collective expert appraisal as well as its conclusions and recommendations during its meeting on the 8 October 2009 and shared it with the Directorate General of Afsset while welcoming the important work of the study and the expert appraisal carried out by the group and furthermore regretting the tight time constraints on this work.

This Afsset opinion, in terms of scientific aspects, is based on the work, conclusions and recommendations adopted by its committee of specialised experts.

Conclusions of the expert appraisal

Public controversy and social anxieties

The investigations into opinions show that the public's anxieties concerning certain applications of radiofrequencies are real and reinforce each other, in spite of a strong desire for wireless telecommunication technology. However, these anxieties do not only concern the possible health risks of electromagnetic fields, but also other aspects such as the quality of information, the degree of trust that is given, or even the methods of decision-making in this field. This partly explains why the installation of mobile phone masts is currently the focus of concern, even though the radiofrequency exposure level that they cause is much weaker than that linked to the use of mobile phones.

But the public controversy on radiofrequencies cannot be reduced to the supposed discrepancy between a risk assessed by science and a "perceived risk", which would be measured by opinion polls. It involves different groups of players calling on different scientific, ethical and economic arguments at the same time. In this context, the treatment of public controversy can, with difficulty, amount to the improvement of information on the subject, but it should happen by the implementation of consultation and research procedures combining the many people involved who are capable of setting up some mutual learning mechanisms. Beyond the scientific risk assessment, the current controversy on radiofrequencies poses the more general question of the governance of this type of question. This requires that further thought be given on the opening up of the scientific expert appraisal to society, as well as on the procedures allowing the organisation of the public debate on the scientific and technical issues.

Exposure to radiofrequencies

A very large number of communication systems and applications based on wireless connections exist, which use electromagnetic waves in the radiofrequency field in order to transmit information. Although all of these systems have their own specifications, they are all based on the physics of wave propagation and radiation in the electromagnetic field from an antenna in the environment.

Frequency range	Services / Applications
9 kHz – 30 MHz	Long Wave, Medium Wave and Short Wave Radio Transmission - Avalanche Victim Detectors - Amateur radio band - Anti-theft detection systems (RFID) - Non-contact card readers (RFID) - Medical Applications (*)
30 MHz - 87.5 MHz	Analogue and digital (band 1) television transmission - Occupational networks (taxis, emergency services, independent wireless networks, etc.) - Amateur radio - Cordless microphones - Aeronautical radio-tracking - Radars - Medical applications (*)
87.5 – 108 MHz	Frequency modulation transmission (FM band)
108 – 136 MHz	Aeronautical band (ground lighting and air band)
136 – 400 MHz	Analogue and digital (bands II and III) television transmission - Occupational networks (emergency services, etc.) - Frequencies reserved for hang-gliding (walkie-talkies) - Amateur radio (2 metre band) - VHF marine band - ERMES messaging service
400 – 470 MHz	ARGOS beacon - Occupational networks (police, SNCF, EDF, etc.) - Amateur Radio (432 band) - Medical remote controls and telemetry - Remote control systems (cars, RFID) - TETRA and TETRAPOL cellular networks - Medical applications (*)
470 – 860 MHz	Television broadcast bands IV and V (analogue and digital)
860 – 880 MHz	ISM (Industrial, Scientific, Medical) band: short-range appliances e.g. alarms, remote controls, home automation, wireless sensors, RFID
880 – 960 MHz	GSM 900 mobile phone: uplink and downlink
960 – 1710 MHz	Digital radio - Private networks - Electromagnetic waves
1710 – 1880 MHz	GSM 1800 mobile phone: uplink and downlink
1880 – 1900 MHz	DECT wireless telephones
1920 – 2170 MHz	UMTS mobile phones
2400 – 2500 MHz	ISM band: Wi-Fi networks - <i>Bluetooth</i> - Microwave ovens
3400 – 3600 MHz	WiMAX broadband local radio loop
> 3600 MHz	Radar - Local radio loop - Ground stations - Electromagnetic waves

* *The medical applications using electromagnetic radiofrequency fields are thermal, imaging and electrosurgery applications.*

Among the systems using radiofrequencies, one can cite:

- content distribution networks (radio and television transmission) for which a transmitter transmits at constant power in order to cover a certain area in which receivers (radio, television, etc.) are found;
- cellular networks (professional mobile networks, TETRA, GSM 900 and 1,800 mobile telephony, UMTS mobile telephony, etc.) for which fixed base stations (phone masts) are spread over an area in order to maintain a continuity of service for the mobile terminal equipment. In this case, the emission powers are variable according to the volume of communication traffic over the network;
- medium and short range wireless systems, of variable power according to the technology: Wi-Fi (internet connection between access terminals and computers), *Bluetooth* (wireless connection for example between computer peripherals), DECT cordless domestic telephones, cordless systems for home automation (energy management) and security (alarm), etc.;

- WiMAX by its design fits between the cellular networks and the short and medium range systems.

Developments in these wireless technologies are very rapid and should largely continue in the coming years. They affect both the methods and applications.

The transmitters associated with all of these applications using radiofrequencies contribute to the surrounding electromagnetic field present in the environment.

In order to characterise the exposure of individuals to electromagnetic radiofrequency fields, two indicators are used depending on the frequency and known interactions (thermal or electric) that can occur in the body. Up to a frequency of around 10 MHz, the measurement of the induced currents in the human body is used. From 0.1 MHz, the absorption of electromagnetic energy, which can translate into an increase in tissue temperature, is used as the indicator. It is characterised by the Specific Absorption Rate (SAR), which is expressed in W/kg. In practice, it can be extremely complex to carry out measurements of SAR or of the induced current in the body, particularly when the exposure is weak, as is generally the case for distant sources. Consequently, in order to characterise the public exposure to electromagnetic radiofrequency fields, physics of wave propagation can be used for two situations:

- when one is situated close to an emitter (in the near field zone), the distribution of the electromagnetic fields is complex and cannot be described by simple methods. The exposure must be quantified by the SAR value or the induced currents that can either be simulated by digital methods or measured in the laboratory on models;
- beyond a certain distance from the emitter (far field zone), it is easier to characterise the exposure using simulation methods or by the *in situ* measurement of the intensity of the electric or magnetic field.

The amount of available data on the public exposure to electromagnetic radiofrequency fields is relatively large for applications using frequencies greater than 400 MHz but more limited for lower frequencies.

Thus, in the near field zone, numerous SAR measurements have been carried out in the laboratory for emitters such as mobile phones, DECT cordless phones, baby monitors, Wi-Fi cards, USB sticks, 3G, etc. In the framework of compulsory certification of mobile terminals, in order to verify the compliance with the regulations in force, these measurement methodologies are covered by standards.

In the far field zone, *in situ* measurements of the electromagnetic fields allow the public exposure, due to all emitters that are present in the environment, to be assessed (radio and television transmission, mobile phone masts, etc.) without resorting to an assessment of the SAR, which is extremely complex to carry out in these conditions. The measurements carried out in accordance with the protocol of the ANFR (French National Frequency Agency) allow the characterisation of maximum exposure levels produced by fixed radiofrequency emitters. These measurements are essential in determining the exposure levels in a given situation (school playground, accommodation of an individual, etc.) and the distribution between the various radio emitters but also, within the framework of the ANFR protocol, in verifying compliance with the regulatory exposure limits. They also allow the overall development of the exposure levels to be assessed. Furthermore, measurement programmes have already been carried out using recently developed portable personal exposimeters which should

allow the exposure levels of individuals to be monitored over time periods (a day, a week, etc.).

Sources close to the body			Distant sources (in the environment)		
Application	Power	Exposure (SAR)	Application	Power	Exposure (E field)
Mobile telephone	2 W max	< 2 W/kg	Radar	Up to several times 1,000,000 W	Extremely strong at 5 m
Walkie-talkie	0.5 W max	<< 2 W/kg	AM radio transmitter	1,000,000 W	Extremely strong at 5 m
DECT cordless telephone	0.25 W max	< 0.1 W/kg	Television transmitter	Up to 780,000 W	Very strong at 5 m
RFID	Between 0.01 W and 2 W max	<< 2 W/kg	FM radio transmitter	Up to 300,000 W	Very strong at 5 m
Wi-Fi	0.1 W max	< 0.2 W/kg	Personal mobile television	Up to 12,000 W	Strong at 5 m
Baby monitor	0.01 W max	< 0.1 W/kg	Mobile phone mast	Up to 30 W	Weak (at 5 m: $E < \approx 10$ V/m)
Bluetooth	Between 0.001 and 0.025 W max	< 0.01 W/kg	WiMAX	Up to 30 W	Weak (at 5 m: $E < \approx 10$ V/m)
			Wi-Fi	Up to 1 W	Very weak (at 5 m: $E < 0.1$ V/m)

Alongside public controversy on the health effects of electromagnetic fields, numerous products and systems that protect against electromagnetic fields are appearing on the market (anti-wave patch, anti-wave spray, metallic clothing, wave compensator, etc.). The efficacy of these products has not been shown.

From the analysis of different technologies and wireless communication networks and from data on public exposure, a certain number of points can be made:

- the very rapid development in technologies and applications of wireless telecommunication systems requires a progressive change in the exposure level assessment standards and protocols (developments underway for the ANFR protocol, developments in SAR measurement standards in order to take account of new mobile phone applications, research underway on the assessment of SAR for children and foetus, etc.);
- the measurement of SAR or electromagnetic fields *in situ* requires a significant level of expertise in metrology and physics: precise knowledge of the technical characteristics of the equipment and the measured signals, estimation of the associated uncertainties, analysis of the results, etc.;
- concerning the mobile telephone cellular networks, all of the studies analysed confirm the complexity in the distribution of exposure levels around the base station mast. This complexity is particularly due to the large variability in the signals, the positioning and orientation of the mast, as well as to the presence of obstacles (buildings, hills, etc.). Furthermore, the architecture of these networks relies on a balance between

the power emitted by the base station mast and the power emitted by the mobile phones. Estimating public exposure requires all of these parameters to be taken into account;

- in terms of exposure levels, it is necessary to remember the very high predominance of mobile phones compared to phone masts;
- at the request of the working group, measurements of very low frequencies have been taken in the surrounding area of phone masts. From these measurements, it appears that the radiofrequency emitters, and particularly mobile phone masts, do not emit extremely low frequency radiation of a few tens of Hz. This result is consistent with the characteristics of the radiation expected from these masts. The only measurable low frequency radiation comes from the emitter's supply (50 Hz mains power or telephone battery). The time-slicing of information cannot be compared to the very low frequency electromagnetic field radiation.

Regulatory aspects

Regulations relating to the health effects of electromagnetic fields in the range of radiofrequencies lead to the setting of exposure limits (for example, for induced currents, the SAR or the intensity of electromagnetic fields) for all radiofrequencies. In the majority of countries, as is the case for France, the regulatory exposure limits used are those defined by the ICNRP³ and recommended by the European Union, based on known health effects.

In certain countries (in Europe: Switzerland, Italy, Austria, etc), different specific exposure limits have been put in place, particularly at local or regional levels. In all cases, these new definitions of exposure limits are accompanied by characteristics (notion of average over a certain duration, definition of at-risk locations, focusing on certain frequency bands, etc.) that make the comparison between these regulations very difficult, particularly the estimation of their impact on the real public exposure.

Simply lowering the exposure limits does not necessarily guarantee the appeasement of social controversy (as in the case of Paris or Italy). In general, it is important that the effectiveness of lowering the exposure limit is verified by measurement programmes, that its consequences on exposure are assessed and that its implementation is included in discussions.

Studies of biological, epidemiological and clinical effects

A biological effect starts from the moment when a change in the functioning of a cell or in a biological function is observed, typically *in vitro*, but even *in vivo*. It does not necessarily lead to damage and is even less likely to cause a change in health. The human body is permanently subjected to a collection of internal and external stimuli, potentially leading to adaptive biological reactions, having an impact on cells, the functioning of organs and health. An impact on health only occurs when the biological effects caused by an attack exceed the limits up to which the biological system in question can adapt. As in the example of ionising radiation, this can happen acutely, either following repeated attacks or over the long term.

The biological phenomena taken into account in order to prevent health effects depend on the interaction of the waves with matter at the frequency concerned. They differ depending on the type of field (electric or magnetic) and its frequency. Up to 0.1 MHz, fields and

³ *International Commission on Non-Ionizing Radiation Protection*

currents are capable of leading to stimulation of excitable tissues (nervous system and muscles). Above 10 MHz, the absorption of radiofrequencies becomes predominant and heating the basic process. At intermediate frequencies, between 0.1 MHz and 10 MHz, a mixture of the two processes can be observed.

Concerning the frequency bands for which the effects due to overheating are predominant, the thermal effects are distinguished from those termed "non-thermal":

- The thermal effects refer to the biological effects that can be shown on animal or human cellular culture models when an increase in temperature of the cells or tissues is observed, following exposure to radiofrequencies. These are the effects that concern the upper part of the radiofrequency spectrum, above 0.1 MHz, but especially over 10 MHz. These thermal effects are used in particular in therapeutic applications of radiofrequencies;
- The non-thermal effects, or "athermic" effects, might appear at non-thermal exposure levels for which the body can regulate its temperature, without a macroscopic increase being observed. In the experimental case where cellular cultures are exposed to radiofrequencies, it is a question of "non-thermal" effects if no rise in temperature, capable of causing them, can be measured.

Biological and epidemiological studies in the range 9 kHz – 400 MHz

Biological and epidemiological studies in the range 9 kHz - 10 MHz

In the range 9 kHz - 10 MHz at non-thermal levels, few experimental and epidemiological studies are available concerning the effects of electromagnetic fields of these frequencies on health. The difficulty in characterising the exposure in this range and the necessity of undertaking pilot studies to characterise the emission sources before launching epidemiological studies, is however accepted. It should be noted that the occupational exposure limits currently recommended are sometimes exceeded in certain industrial applications.

Due to the increase in exposure to radiation in this frequency range, it is important to undertake new studies, particularly for chronic exposure at low power, to ensure that the exposure limits are adequate.

It is also noted that some publications mention effects on dividing cell systems, which should be pursued.

Considering the small amount of data, an area of uncertainty remains which prevents definitive conclusions from being suggested. It would therefore seem necessary to carry out epidemiological studies and *in vitro* and *in vivo* research in this frequency range, paying particular attention to reproduction and the nervous system.

Biological and epidemiological studies in the 10 MHz - 400 MHz range

This frequency range (10 MHz - 400 MHz) is dominated by industrial applications (for example: welding) and medical applications (for example: treatment of auricular cardiac arrhythmia). In certain situations, selected studies have shown that the public or occupational exposure limits were sometimes exceeded.

In practice, the real exposure is often unknown because of the variety in time and space. This leads to severe limitations in the epidemiological studies. However, the development in

modelling and calculation methods in recent years has reduced these limitations and the use of individual multi-range exposimeters should lead to improvements.

The assessment of exposure is still complicated by the existence of dimensional resonances for which the absorption is increased, as well as by the existence of partial overexposures for exposures consistent with the "whole body" exposure limits, or even by positional and dimensional dependencies (for example, in the case of children). Currently, significant work relating to dosimetry in these frequency ranges is being undertaken.

The results of the few studies carried out in this frequency range are contradictory. These results relate to the cardiovascular system (variation in heart beat for example), the nervous system (anomaly in the distribution of frequency ranges of the electroencephalogram and the electrocardiogram for example), or even effects on apoptosis. More in depth studies are required in this frequency range in order to deliver a verdict on the effects.

Biological and clinical experimental studies for frequencies greater than 400 MHz

These frequency bands particularly concern applications associated with mobile telephony. The work aimed to be exhaustive with respect to the assessment of published studies in English-language peer-reviewed journals between January 2005 and April 2009. In this context, 226 studies were examined in detail by Afsset experts on the basis of a standardised analysis scale.

Numerous studies have appeared during the last few years. However, a significant proportion of the studies analysed show methodological gaps, most often in the physical part (assessment of exposure), but also sometimes in the biological part.

As specified previously, it is necessary to take into account the degree of validity in the biological and physical parts of each study.

According to systematic analyses, which have been done in the framework of this expert appraisal, it appears that:

Of the 182 studies that were carried out *in vivo* in animals, and *in vitro*, 82 found biological effects of radiofrequencies and 100 did not show any.

- Among the 82 studies that found some effects, only 37, or 45%, have a dosimetry corresponding to the criteria set by the expert group. Among these, only 9 also showed an adequate methodology for the biological part. As a consequence, 11% of the studies that showed some effects have a methodology corresponding to the criteria set by the expert group for both the physical and biological parts. These effects mainly concern the cellular functions observed *in vitro* (apoptosis, endocytosis, potentialisation of oxidative stress, etc);
- Among the 100 studies not finding any effects, only 87 have a dosimetry corresponding to the criteria set by the expert group. Among these, 69 also show an adequate methodology for the biological part. As a consequence, 69% of studies that do not show an effect have a methodology corresponding to the criteria set by the expert group, for both the physical and biological parts.

There have been 44 studies carried out on humans, of which 20 showed some effects and 24 did not show any.

- Among the 20 studies showing some effects, 2 teams followed methodologies corresponding to the criteria set by the expert group. These effects concern the cerebral blood flow;
- Among the 24 studies not finding any effect, 17 have a methodology corresponding to criteria set by the expert group.

The conclusions relating to the biological effects are mainly based on studies used for their methodological validity. Afsset has also taken into account the existence or not of replication, which constitutes one of the significant criteria in determining the level of evidence of the existence of an effect.

The significant number of works having methodological gaps is explained by the fact that the experiments aimed at finding effects of radiofrequencies are set up to show weak effects and therefore rely on biological system variations that are very susceptible to artefacts.

Although certain biological effects have been shown, no clear mechanism of wave-cell interaction has been identified for non-thermal exposure levels.

In the non-thermal experimental conditions tested, no sufficient level of proof exists in order to conclude that radiofrequencies greater than 400 MHz:

- can modify the major cellular functions such as i) gene expression; ii) the production of reactive oxygen species (ROS); and iii) apoptosis, particularly of the cerebral cells (from human glioma or neuroblastoma) most exposed in the use of a mobile phone;
- can be a stress factor for cells. The only effects of stress observed are the thermal effects associated with high exposure levels;
- can cause genotoxic or co-genotoxic effects reproducible in the short or long term and would be mutagenic in classic mutagenesis tests;
- can cause, in animals, the increase in the incidence or aggravation of cancers, particularly for chronic exposures. The results therefore converge towards an absence of carcinogenic or co-carcinogenic effect of radiofrequencies for non-thermal exposures;
- can have deleterious effects on the nervous system, in terms of cognition and well-being, in terms of the integrity of the haematoencephalic barrier or in terms of general brain function;
- can have effects that are likely to impact on the functioning of the immune system;
- can have an impact on reproduction and development according to the most recent and best defined studies. However, the results are not all the same and several studies should be repeated under reliable experimental conditions, especially with dosimetric data;
- can have deleterious effects on the cochleovestibular system after an acute exposure.

On the basis of a limited number of studies, there is not a sufficient level of proof in order to conclude that radiofrequencies greater than 400 MHz:

- can disrupt the cardiovascular system, in particular the regulation of blood pressure and heart rate;
- can have a deleterious effect on the ocular system;
- can alter the melatonin level in humans.

Epidemiological studies for frequencies greater than 400 MHz

The publication of the last sections and the analysis of the largest case-control study in this field, the Interphone study, is currently still being awaited.

Some study results suggest the possibility of an increase in the risk of gliomas for using a mobile phone for a period of more than 10 years.

The level of proof relating to the increase in the risk of intracranial tumour linked to the regular use of mobile phones by a promotion phenomenon is insufficient.

The observation of some excesses of lymphomas and leukaemias and their repetition in three military cohorts exposed to radar show that the possibility of an association between occupational exposure to radar greater than 2,000 MHz and the risk of lymphomas and leukaemias cannot currently be dismissed.

A certain number of studies, relating to brain tumours, testicular cancers or ocular melanomas, have been carried out for occupational populations who can also be subjected to co-exposures (solvents, chemical substances, etc.). The increase in the risk of these cancers cannot be concluded from these studies.

At this stage, there is not a sufficient level of proof, on the basis of the available epidemiological studies, in order to conclude that there is an excess risk of cancers linked to the exposure to radiofrequencies. Some questions remain, particularly for long-term risks. They must lead to further cohort studies.

Electromagnetic hypersensitivity

Nobody can contest the reality of individuals who attribute their symptoms to the exposure to radiofrequencies. However, no scientific proof of a causal relationship between the exposure to radiofrequencies and electromagnetic hypersensitivity can be provided to date.

Until recently, the majority of research on electromagnetic hypersensitivity has suffered from the unsuitability of the approach for the subjective symptoms (which constitute the essential elements of this clinical situation). Progress has just been made with the quantification of these symptoms and their grouping into components. At the same time, a body of concordant evidence has been collected, which strongly suggests that individual neuro-psychic factors would at least be partly involved in the development of electromagnetic hypersensitivity.

The only positive results obtained to date on the therapeutic level are those obtained by behavioural therapies or from overall treatment.

Effects of radiofrequencies on children

Some people have fears as to the effects of electromagnetic radiofrequency fields on the health of fetuses, children and adolescents. These fears are justified by the ever-increasingly early use of wireless communication methods, by the much longer duration of the exposure to which these children are subjected and by the supposed greater vulnerability of their tissues.

Some specific dosimetric research and studies have been carried out or are currently underway. Their initial results are not all the same. These studies should be pursued to allow the impact of the variability in the different morphologies and physico-chemical characteristics of tissues on the SAR to be better assessed, and in order to validate the models, the calculation methods and the measurement methods used.

Obvious ethical limitations mean that the studies and experiments involving the direct participation of children have been limited in number and remain few. Some of them have shown an improvement in cognitive performance which remains to be repeated. There has been slightly more experimental research on animals. However, the extreme diversity of the models used and the methodological gaps in the majority of these studies do not allow a coherent conclusion to be made on the subject. This experimental research should be pursued. Furthermore, a case-control epidemiological study on brain tumours in children is underway.

Opinion and recommendations

On the basis of the main conclusions of the expert appraisal, Afsset particularly emphasises:

- the large amount of work carried out at an international level during the last few years with a view to identifying possible non-thermal effects of radiofrequencies on the body;
- that nevertheless different frequency ranges, particularly the lowest, or certain uses, particularly occupational, are still poorly described;
- the difficulty in researching possible non-thermal effects. It assumes the use of rigorous methodologies in the characterisation of exposures to radiofrequency fields and their identification;
- that to date, methodological difficulties have weakened the conclusions of a good number of studies that have various shortcomings;
- that the majority of the studies carried out do not show effects for exposures at non-thermal powers;
- that nevertheless a small number of different studies, compared to the number of studies available, show some effects, particularly on the *in vitro* cellular mechanism, for such exposures. The results of these studies could not be replicated by several different studies;
- that the demonstration of a biological effect does not show the existence of an associated health effect;
- that, more generally, the non-existence of a risk cannot be formally shown;
- that available work does not currently allow the mechanism of a non-thermal effect nor a cumulative mechanism of action of radiofrequencies to be identified;

- that, in this context, no non-thermal effect means that new regulatory exposure limits cannot be set;
- that the available epidemiological studies do not suggest short-term effects of mobile phone use but that questions remain as to the possible long-term effects;
- that a certain number of individuals have symptoms that they attribute to exposure to radiofrequencies (EHS) but that, to date, no physiopathological mechanism has been identified in order to describe the link with the exposure to these radiofrequencies;
- that the characterisation of the exposure of children to radiofrequencies and the possible associated effects are poorly described;
- that professionals could be exposed to levels exceeding recommended exposure limits;
- that mobile phones remain very largely the main source of exposure to radiofrequency fields, particularly in comparison to the exposure generated from the masts;
- that mobile phone base station masts do not emit low frequency electromagnetic fields;
- that recently developed information technologies using radiofrequencies do not lead to exposure that is different in nature or intensity to that emitted previously.

The question of the effect of radiofrequencies arouses an active scientific debate, in a context marked by rapid technological development. It comes particularly from the absence of a convincing demonstration relating to the existence of non-thermal effects and the persistence of questions associated with the demonstration of different effects on cellular mechanisms. This question also fits into the more general framework of low-level environmental multi-exposures and health effects that can be associated with them. This scientific debate presumes the pursuit of research work relying on suitable methodologies to be clear-cut.

In this uncertain context, Afsset nevertheless emphasises that as soon as an environmental exposure can be reduced, this reduction must be contemplated, in particular by the implementation of the best available technologies at economically acceptable costs.

There is potential to reduce the exposure to radiofrequencies. For example, it can mean using low SAR mobile phones, lowering exposure levels in areas with the highest intensities, pooling transmitters, or even restraining the use of wireless technologies.

Afsset therefore recommends:

With respect to the recommendations for studies and research

For biological effects

Considering in particular:

- the methodological gaps in the experimental conditions for characterising the exposure observed in numerous studies;
- the possibility of long-term effects on particular pathologies and the need for better documentation of the effects of exposures over long durations (chronic);
- the importance of pursuing research into certain possible biological effects for exposures at "non-thermal" levels;

Afsset recommends:

1. monitoring the methodological quality of *in vitro* and *in vivo* studies concerning mainly the physical part (characterisation of the exposure and form of signals), but also the biological part (blind experiments, appropriate controls, identification of false positives, repetition of experiments, sufficient statistical power, etc.);
2. carrying out studies on, in particular, reproduction and development over several generations of animals (for example on animals provided with a predisposition to diseases for which human susceptibility genes are known - neurodegenerative diseases, certain cancers, autoimmune diseases), to compare with normal animals and with completely characterised realistic exposure conditions;
3. replicating some studies analysed in this report and that show probably physiological biological effects (particularly on the cerebral blood flow);
4. developing studies on frequency bands less than 400 MHz (in particular for low-power chronic effects) and above 2.5 GHz.

For epidemiology

Considering in particular:

- the numerous methodological gaps relating to the characterisation of the exposure of individuals;
- the importance of establishing a watch over population exposure;
- the importance of cohort studies;
- the problems attributed to the exposure to radiofrequencies in the proximity of phone masts;
- the difference observed between the results of two case-control studies obtained by the Hardell research group and other studies;

Afsset recommends:

1. increasing efforts to include as precise characterisation as possible of the exposure of target populations in the epidemiological studies;
2. assessing the possibility of epidemiological studies in worker populations exposed to radiofrequencies (as for example soldiers exposed to certain radar, workers involved with WiMAX and PMT systems, plastic welding workers, etc.) with the aim of identifying possible effects observed for the most exposed populations and assessing the possibility of extrapolating them to the general population;

3. studying the feasibility of French participation in the international studies, particularly the cohort study COSMOS (Cohort study of mobile phone use and health);
4. considering integrating the exposure to radiofrequencies into the existing cohort studies, i.e. ELFE (The French Longitudinal Study of Children), Constances;
5. replicating, with a better statistical power, some cell type studies carried out by Hutter *et al.* and Heinrich *et al.* relating to the sensitivity of individuals in the surrounding areas of mobile phone masts;
6. undertaking a re-analysis of the data included in the studies from the Hardell group relating to tumours, with a view to understanding their differences compared to other studies;
7. analysing the feasibility and, possibly, undertaking new studies of chronic low power exposure to frequencies less than 400 MHz;
8. carrying out meta-analysis with rigorous methodology when the results of the Intercom study are published in full. Afsset suggests implementing the framework of this meta-analysis by combining all interested parties.

For electromagnetic hypersensitivity

Considering in particular:

- the recent progress in terms of quantification of associated symptoms;
- the importance of introducing a support protocol and of monitoring hypersensitive patients;

Afsset recommends:

1. the development and assessment of a clinical diagnostic tool for electromagnetic hypersensitivity based on the work of Eltiti *et al.*, (2007), Hillert *et al.* (2008) and Brandt *et al.* (2009);
2. the definition of the methods of overall care of hypersensitive subjects (treatment of other causes of functional symptoms, symptomatic treatment of residual functional complaints, care of identified psychological factors, etc.);
3. organising monitoring activities of patients and, if possible, centralising these activities;
4. developing information and training for health professionals;
5. developing research activities which have rigorous clinical and exposure methods (relationships between electromagnetic hypersensitivity and other functional syndromes; relationship between electromagnetic hypersensitivity and electrosensitivity; modification of the cerebral functional imaging, etc.).

With respect to recommendations for exposure

For exposure characterisation

Considering in particular:

- the importance of identifying places for which "atypical" exposure levels could be observed (i.e. exceeding the average ambient level);
- the importance of an in-depth knowledge of individual, including continuous and long-term, exposures;
- the importance of consolidating the description of the exposures;
- the importance of having precise and reproducible metrology;
- the importance of assessing real exposure levels in the general population;

Afsset recommends:

1. ensuring a perfect match between the measurement methods and technological developments. The working group encourages, in particular, the ongoing developments of the ANFR protocol in order to take better account of the Wi-Fi, WiMAX and impulse signals (radar) frequency bands;
2. working on the definition and choice of representative size of the real exposure to waves originating from all radiofrequency emitters that an individual is exposed to and paying particular attention to a good description of the exposure for the most vulnerable individuals and children;
3. using exposimeters in order to better characterise individual exposures;
4. developing fixed and autonomous measuring probes and simulation and exposure cartography methods, and precisely defining their conditions of use;
5. working towards a more exhaustive spatial description of the exposure to radiofrequency fields, particularly in the urban environment, within the framework of a monitoring programme and a strategy aimed at identifying geographical areas with the highest exposure levels for the general population;
6. reinforcing the description of exposure levels for the workers most affected.

For exposure levels

Considering in particular:

- the major development in the use of technologies using radiofrequencies, which could lead to an increase in exposure levels;
- the concerns of the public linked to the exposure to radiofrequency sources;
- the desire to moderate radiofrequency exposure levels and the available technical possibilities allowing this reduction for systems such as mobile phones, baby monitors, DECT cordless phones, etc.;

Afsset recommends:

1. choosing low SAR mobile terminals. To do this, it would be advisable to make indicators of maximum exposure (SAR for example) for all personal equipment using radiofrequency technology (mobile phones, baby monitors, etc.) generally available to users. It would also be advisable to make the public aware of these exposure indicators by developing clear labelling;
2. identifying and mapping places with clearly higher values than the average ambient level and suggesting procedures aimed at reducing the exposure in these places;
3. carefully considering the consequences, for the general population (children, etc.) and for mobile phone users, of a reduction in the power of masts that could lead to the increase in the exposure to the head to radiofrequencies emitted by mobile phones;
4. reducing the exposure of children by encouraging moderate use of mobile phones;
5. providing users of personal equipment that emits radiofrequencies with simple measures to allow them to reduce their exposure if they so wish. For example:
 - choosing systems that minimise the power emitted by DECT cordless telephones;
 - bringing Wi-Fi emission on/off switches on "modem" type emitters into general use;
 - allowing multiple cable access on Wi-Fi "modems" at no extra cost;
 - as the exposure level decreases heavily with distance from the transmitter, on equipment such as the base of a DECT telephone, Bluetooth peripherals or baby monitors, a distance of a few tens of centimetres between the equipment and the user could considerably decrease the exposure;
 - simplifying hands-free kits.
6. that the efficacy of "anti-wave" devices are assessed and brought to public knowledge;
7. monitoring electromagnetic compatibility.

In a more general way

Considering in particular:

- the multidisciplinary and the complexity of the description of possible health effects associated with radiofrequencies;
- the necessary independence of experts and research teams involved in this area;
- the need for a continuous watch over new work produced on this constantly evolving subject;
- the necessary involvement of all interested parties in the issues associated with radiofrequencies;

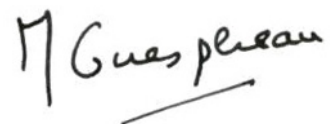
Afsset recommends:

1. close collaboration between physicists, biological dosimetry specialists and biologists in order to carry out studies on the biological effects of radiofrequencies;
2. continued funding of research work by a structure that guarantees independence and transparency of the studies carried out;
3. implementing a permanent structure, combining all stakeholders, ensuring that knowledge on effects of radiofrequencies is monitored and that regular working meetings between scientists of all disciplines concerned are arranged;
4. encouraging discussion and debate on new installations or changes to radiofrequency emitters (mobile phone, personal mobile television, WiMAX, etc.) by involving all those concerned as early as possible;
5. pursuing, at a national level, investigations on representative samples to follow the trends in the concerns of the French with regards to radiofrequencies;
6. improving public information, particularly by setting up a website aimed at local communities.

Finally, Afsset also suggests that the impact of the use of wireless technologies on the quality of life be studied even further.

Maisons-Alfort, France, 12 October 2009

The Director General

A handwritten signature in black ink, reading "Martin Guesperau". The signature is written in a cursive style with a horizontal line underneath the name.

Martin GUESPEREAU

APPENDIX

HEARING OF EXTERNAL PERSONS

Name	Affiliation	Audience	Date
Association Agir pour l'environnement	N/A	Physical Agents CES	29 April 2008
Criirem (Independent Research and Information Centre for Electromagnetic Radiation)	N/A	Physical Agents CES	29 April 2008
Priartem	N/A	Physical Agents CES	29 April 2008
Robin des toits	N/A	Physical Agents CES	23 June 2008
Alain Azoulay	Supélec	RF WG	3 December 2008
Lawrie Challis	MTHR	RF WG	3 December 2008
Frédéric Couturier, Sylvain Germaine and Arnaud Miquel	French National Frequency Agency	RF WG	3 December 2008
Dominique Belpomme	ARTAC	RF WG	28 January 2009
Gérard Ledoigt	N/A	RF WG	11 March 2009
James G. Rubin	King's College (London)	RF WG	11 March 2009
Alain Vian	LASMEA Blaise Pascal University	RF WG	11 March 2009
Olivier Borraz and Danielle Salomon	CNRS/CSO and "Risks & Intelligence"	RF WG	1 April 2009
Michel Setbon	Director of Research, CNRS	RF WG	2 April 2009
Emmanuel Nicolas and François Jacquin	TDF	RF WG sub-group	3 April 2009
Peter Wiedemann	Jülich Forschungszentrum	RF WG	1 April 2009
Jean-François Lacronique, Françoise Boudin, Martine Hours et Michel Petit	Health and Radiofrequency Foundation	RF WG sub-group	10 April 2009
Jean-Paul De Haro et Frédéric Surdel	Paris City Hall	RF WG sub-group	10 April 2009

Rüdiger Matthes	Bundesamt für Strahlenschutz (BfS)	RF WG sub-group	24 April 2009
Aslak Harbo Poulsen	Institute of Cancer Epidemiology Danish Cancer Society	RF WG	28 April 2009
Jean-François Viel	Chrono-Environment Laboratory, CNRS, University of Franche-Comté	RF WG	29 April 2009
Lennart Hardell	Department of Oncology University Hospital Orebro, Sweden	RF WG sub-group	7 May 2009
Olle Johansson	Department of Neuroscience, Karolinska Institute, Sweden	RF WG	27 May 2009
Michael Kundi	Institute of Environmental Health of the Medical University, Austria	RF WG sub-group	8 June 2009
Lena Hillert	Department of Public Health Sciences, Division of Occupational and Environmental Medicine Karolinska Institute, Sweden	Written contribution	23 April 2009
Swedish National Board of Health and Welfare	-	Written contribution	2 July 2009
Luc Montagnier	Academy of Science	Written contribution	29 May 2009
Julie Barnett	University of Surrey	Written contribution	11 July 2009
André Aurengo	Academy of Medicine	Written contribution	2 June 2009
ARCEP	-	Written contribution	3 June 2009
Nicolas Treich	Laboratory of Economy of Natural Resources Toulouse School of Economics	Written contribution	25 May 2009
Francis Chateauraynaud, Josquin Debaz and Christopher Marlowe	Pragmatic and Reflexive Sociology Group EHESS	Written contribution	12 July 2009
AFOM	-	Written contribution	5 June 2009