# "ZMIROU REPORT" TO THE FRENCH HEALTH GENERAL DIRECTORATE JANUARY 01



## SUMMARY OF THE REPORT


"*Do the conclusions of recent reports summarizing our current knowledge of the health hazards related to the use of mobile telephones and their fittings justify the adaptation of the risk management regulations recently adopted by the French and European authorities?*". This was the main thrust of the question submitted to the group of experts brought together by the Direction Générale de la Santé (Health General Directorate).

The frequency range used for mobile telephony varies according to companies and their technologies, ranging from 850 to 1900 MHz. The range will be extended to 2200 MHz with the new UMTS technology, and to the 400 MHz waveband with the TETRA system, currently under development. These are part of the much wider range of radio frequencies present everywhere in our environment, at home (microwave cooking, etc.), at work (industrial heating systems, etc.), or in public places (radio and television transmitters, burglar alarm systems and remote-control devices, etc.), especially in urban areas.

The development of telecommunications has been followed by research into the effects of radio-frequency electromagnetic fields (RF) on biological systems. Work first started in this field after the Second World War. This research focused particularly on mechanisms that could link exposure of

human cells to the development of cancers. It is still too soon, however, to assess any long-term effects. The highly-complex physical and biological phenomena involved necessitated the development of new experimental, measuring, and observation procedures that were not always completely controlled in the early research projects. This is why it is still difficult to draw clear conclusions, in spite of the enormous volume of scientific work on the subject. Some research evidenced short-term modifications in certain physiological or biochemical parameters, or even fine neuro-sensory functions, while other work contradicted these results. The significance of these observations in predicting the occurrence of long-term effects is debatable.

The public are naturally concerned by this difficulty in drawing conclusions. The issue of potential health hazards resulting from exposure to RF takes on a very special importance when it is considered that 30 million people are users of mobile telephone in France and that the expected market is 44 million within 4 years. Even if the individual risk were very small, the very number of people involved would produce a considerable impact in terms of public health.
On the other hand, mobile telephones are also a health safety factor. The speed with which the alert can be given in case of accident, fire, or other dangerous situations, and the effectiveness of emergency services have been considerably improved by the widespread availability of this technology, which has already saved many lives, worldwide. An evaluation of the trade-off between risks, if there are any, and potential advantages, was not part of the expert group's brief, which focused solely on *risk assessment*, based on the analysis of scientific data alone.
The first chapter of this report describes, in detail, the critical synthesis approach used to develop the group of experts' opinion and recommendations. The second chapter presents the sources and characteristics of the electromagnetic fields associated with mobile telephony, and the known or investigated mechanisms by which they interact with living matter. The third chapter gives the threshold limit values for public exposure to RF associated with mobile telephony and explains the scientific basis for the figures.

The fourth chapter is the longest. It summarises the group of experts' analysis of the current state of scientific knowledge. Several scientific bodies have recently produced reports containing comprehensive analyses of the biological and medical effects of RF. These bodies, consisting of top-level experts in the various scientific fields involved, have analysed all the scientific data available at the time. The group of experts used five summary documents, covering several hundreds of articles published in the scientific literature, to carry out their mission. In addition to these ‘basic reports’, seven 'additional documents' were taken into consideration: symposium proceedings and summary articles providing interesting information. The group of experts also made sure to take the most recent published work into consideration, right up to the day this report was completed. Finally, the group interviewed about twenty people from scientific organisations, administrations, industry, associations, and politics, both to obtain further information and identify society's concerns on this issue more fully.
The group of experts had two main objectives in carrying out this assessment of scientific knowledge:

- To define the areas in which there were convincing scientific data proving the existence or, *a contrario*, the absence of biological and medical consequences following exposure to RF related to the use of mobile telephones and the operation of base stations (i.e. ‘what we know’),
- To highlight the areas in which currently-available scientific data does not exclude the possibility of biological and medical effects, without necessarily confirming their existence (i.e. ‘what is uncertain’).

The group of experts' conclusions and recommendations are presented in the fifth chapter. They are based on the following considerations:

1- There is considerably less personal exposure in the vicinity of base stations – with the exception of exclusion areas – than there is when making a call with a mobile phone.
2- Scientific data indicate, with relative certainty, that, during exposure to RF from a mobile phone, a variety of biological effects occur (eg. electroencephalogram profile, reaction time, etc.) at energy levels that do not cause any local increase in temperature. However, in the current state

of knowledge of these *non-thermal effects,* it is not yet possible to determine whether they represent a health hazard.

3- Although this assertion is backed up by little scientific argument, the hypothesis that certain medical effects are caused by the low-level RF fields associated with mobile telephones cannot be completely excluded, in the current state of knowledge. Experimental and epidemiological research into a range of health problems, including brain cancers and headaches, is currently in progress; the role of exposure to RF in these symptoms or diseases has not yet been clarified. However, in view of the exposure levels observed, the group of experts does not back the hypothesis that there is a health risk for populations living in the vicinity of base stations.

4- If future research were to validate this hypothesis, i.e. demonstrate the existence of health hazards, the risk, at an individual level, would probably be very low. Indeed, it is reassuring to note that it has not yet been demonstrated, in spite of the considerable amount of work done over the past several years. However, if mobile phone radiofrequency fields were hazardous, the very high number of mobile telephone users could mean that, even if the individual risk were very low, the impact on public health could be considerable.

5- The risk of accident and fatality associated with the use of mobile telephones when driving has definitely been established. In the current state of knowledge, this is the only known health risk, albeit a very serious one.

For all of these reasons, and in view of the brief they were given, the group of experts recommend a risk management approach *based on the precautionary principle*, aimed at reducing public exposure to RF associated with mobile telephony to the lowest possible level compatible with service quality and justified by current scientific data. The various measures recommended are described in the full report. The objective is also to ensure that users and the public have access to comprehensive information on their exposure. The group of experts consider that these recommendations would make it possible to apply the precautionary principle in an enlightened way, i.e. on the basis of a rational approach.

The sixth and last chapter is devoted to recommendations for advanced research to elucidate the remaining uncertainties in priority areas. Proposals are made concerning ways of funding research that would guarantee the scientists' independence from the various interests involved.

At the end of their mission, the group of experts would like to emphasise that they have been able to work completely independently, both from industry and public authorities. The Direction Générale de la Santé (Health General Directorate) provided them with the effective, discreet support necessary to complete their task.

**Reports analysed**

- **"Mc Kinlay"** (September 1996) and **COST 244 bis** (June 1999) reports to the DG XIII.
- **Royal Society of Canada report** « A Review of the Potential Health Risks of Radiofrequency Fields from Wireless Telecommunication Devices » (March 1999).
- **"Stewart report".** "Mobile Phones and Health". Report from the Independant Expert Group on Mobile Phones, (May 2000)
- **ARCS** report (Austrian Research Center Seibersdorf) OEFZS-E-0016 „Studie dokumentierter Forschungresultate über die Wirkung hochfrequenter elektromagnetischer Felder." *B. Kunsch et al.* (December 2000).

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## INTRODUCTION

"*Do the conclusions of recent reports summarizing our current knowledge of the health hazards related to the use of mobile telephones and their fittings justify the adaptation of the risk management regulations recently adopted by the French and European authorities?*". This was the main thrust of the question submitted to the group of experts brought together by the Direction Générale de la Santé (French Health General Directorate).

The electromagnetic fields associated with mobile telephones occur in an environment which is already affected by a wide range of electromagnetic frequencies, particularly in urban areas. These include radiofrequencies (RF, from 30 kHz to 300 GHz), home appliances (micro-wave cookers, radio and television), and systems at work (industrial heating systems, medical diathermic equipment) as well as in public places (radio and television transmitters, radars, security personnel and taxi communication systems, burglar alarms, and remote controls. The frequencies used by mobile telephones, depending on the operator and the technology used, range from 850 to 1,900 MHz, and will reach 2,200 MHz with the development of the new UMTS technology and 400 MHz with the projected TETRA system. Mobile telephones have two specific features which have aroused legitimate concern among the public: the immediate proximity of the telephone aerial to the cranium during conversations, and the proliferation of base station relay aerials in the immediate environment. The huge number of users requires an increasing number of cells to ensure optimal coverage, especially in built-up urban areas where there are many physical obstacles. These aerials are visible for all to see: 'macro cells' on roofs or pylons, and 'micro' or 'pico cells' on the façades of buildings or even inside public premises. As of 28 December 2000, 29,416 base stations had been installed in France (macro cell, micro or pico cell aerials). In the course of the last three months of the year 2000, more than 1,664 new stations were installed and 589 modified, while 403 were abandoned.

The development of telecommunications has been followed by research into the effects of radiofrequency electromagnetic fields on biological systems. Work started in this field after the Second World War and a considerable body of scientific literature has been published. Research was given a new impetus in the United States and then all over the world following legal proceedings taken in 1992 by a citizen who accused RF of being responsible for the death of his wife from brain cancer. Work has focused on this type of pathology, exploring the biological mechanisms which may link the exposure of human cells to this type of field to the development of carcinogenic processes. Results of experiments on animals or isolated cells have been published in a variety of scientific journals. However, we do not have sufficient hindsight to appreciate any possible long-term effects. Some authors have reported a possible link between certain forms of brain cancer and the use of mobile telephones, whereas other recent publications have demonstrated the opposite. All experts recommend continuing this research before drawing any conclusions as to the consequences, which, similar to those of chemical substances and ionising radiation, only appear after many years of exposure. The highly-complex physical and biological phenomena involved necessitated the development of new experimental, measuring, and observation procedures that were not always completely controlled in the early research projects. It is thus difficult to replicate the results, particularly under identical experimental conditions. This is why it is still difficult to draw clear conclusions, in spite of the enormous volume of scientific work on the subject. Some research evidenced short-term modifications in certain physiological or biochemical parameters, or even fine neuro-sensory functions, while other work contradicted these results. The significance of these observations in predicting the occurrence of long-term effects is debatable.

This situation of scientific debate comes as no surprise to specialists who are familiar with studies of environmental risks and know just how difficult it is to demonstrate the harmful effects of a chemical substance or a physical or microbiological agent under everyday exposure conditions. The public are naturally concerned by this difficulty in drawing conclusions. Is it not precisely in such situations where the risk of serious consequences are uncertain that the ‘precaution principle’ applies? The answer is certainly yes, if the scientific elements relating to possible “serious and irreversible” effects

are sufficient to establish a “reasonable doubt”, but if this is the case, how far should the precautions go? Which aspects of exposure to RF should they cover? Public and media pressure is focused on base station aerials, but the field received is much weaker that that during a conversation on a mobile telephone.

The issue of potential health hazards resulting from exposure to RF takes on a very special importance when it is considered that 30 million people (29,681,300 subscribers on 31 December 2000) are mobile telephone users in France and that the expected market is 44 million within 4 years. This is a worldwide phenomenon with more than 27 million users in Great Britain and around 80 million in the United States, for example. Even if the individual risk were very small, the very number of people involved would produce a considerable impact in terms of public health. The search for an answer to this question is thus an urgent one. However, the number of people concerned is not enough to establish the existence of a hazard, if RFs are not dangerous under current exposure conditions. A rapid response may be required, but it will necessarily be conditioned by the current state of knowledge. Furthermore, mobile telephones are also a medical safety factor. The speed with which the alert can be given in case of accident, fire, or other dangerous situations, and the effectiveness of emergency services have been considerably improved by the widespread availability of this technology, which has already saved many lives, worldwide.

The brief of the group of experts convened by the Direction Générale de la Santé did not cover other aspects of the development of this communication technology in business or the fact that it facilitates exchanges between people, although the competent national and international authorities will certainly consider these dimensions. The management of proven or strongly suspected risks is thus a part of a balance, as no technology likely to induce a risk, however small, could be justified if it did not also provide substantial advantages.

An evaluation of the trade-off between risks, if there are any, and potential advantages, was not part of the expert group's brief, which focused solely on *assessing* the *risks* associated with using mobile telephones and their fittingss. The group did not take into account scientific work relating to low or very low frequency fields; and other technologies using radiofrequencies – radio, television, and radar – will only be mentioned in the context of health impact studies which provide indications for future research.

In recent years, several health bodies have produced reports summarising the state of our current knowledge of the biological and health effects of RF. Several groups of top-level experts from the various scientific disciplines involved have worked for several months to collect and summarise all the literature available at the time. This was the case, for example, of the commission led by Professor W. Stewart in Great Britain (May 2000) or the Royal Society of Canada report (March 1999). In preparing their report, the French group of experts examined these documents and many others (see full list in Appendix). They also updated the corpus of knowledge, taking into consideration several works published after the completion of these commissions. Finally, the group interviewed a number of well-known people from scientific organisations, administrations, industry, associations, and politics, both to obtain further information and identify society's concerns on this issue more fully.

The group of experts had two main objectives in carrying out this assessment of scientific knowledge:

- To define the areas in which there were convincing scientific data proving the existence or, *a contrario*, the absence of biological and medical consequences following exposure to RF related to the use of mobile telephones and the operation of base stations (i.e. ‘what we know’),
- To highlight the areas in which currently-available scientific data does not exclude the possibility of biological and medical effects, without necessarily confirming their existence (i.e. ‘uncertainty factors’).

Recommendations were made for research into priority areas, with the objective of eliminating the remaining uncertainties. Guidelines were also defined to ensure that users and the public benefit from the highest level of health protection justified by current scientific data, as well as to encourage manufacturers and operators, as well as users to take every possible measure to reduce exposure to a minimum.

The group of experts would like to emphasise that they have been able to work completely independently, both from industry and public authorities. The Direction Générale de la Santé (Health General Directorate) provided them with the effective, discreet support necessary to complete their task.

## THE GROUP OF EXPERTS' APPROACH

### 1- The necessary assessment of the scientific literature

Scientific knowledge is, by nature, imperfect and ever changing, as science and technologies evolve. When it comes to levels of exposure to environmental factors – in this case electromagnetic fields at radio and associated frequencies – which can be qualified as "weak", the biological and health effects produced are often of modest intensity and expressed in a variety of ways. Effects observed depend on individuals and circumstances, and some may only appear after several years. These aspects characterise many environmentally-related health issues and can lead to the publication of apparently discordant or inconclusive scientific works at any given moment.

In such a context, it is a delicate matter to summarise knowledge with the aim of bringing out the general meaning and formulating recommendations for managing any risks that may have been identified. This is generally referred to as "assessment", i.e. the art of translating current scientific data into guidelines for action or information. This work can only be collective. It must satisfy quality and reliability criteria, as must the scientific work on which it is based. Readers who are keen to understand the scientific approach will perceive this difficulty in discerning a clear message from a limited number of inconsistent results by taking a look at two examples presented in the appendices. Both are taken from epidemiological studies of the risk of brain cancer after exposure to RF. Brain cancer is one of the morbid areas which focuses research and public emotions more than anything else. Here, two large-scale studies have been interpreted or presented in recently published articles by individuals or groups of experts in a highly contrasting or even contradictory manner, as illustrated by quotations and comments relating to their work. Although it is now widely recognised in the scientific community – which is not yet the case in every field – that an isolated study can never be held up as a demonstration or definite confirmation of a complex physical or biological phenomenon, these examples also show how strict the approach must be to analyse and interpret the results of a scientific work, even in the framework of a joint assessment. Epidemiological literature is particularly subject to this interpretation bias, due to the multi-factor nature of the biological and health phenomena observed. We would be mistaken in thinking that the experimental approach does not face the same difficulties, particularly as results are highly sensitive to measurement conditions. This state of affairs is certainly regrettable, but it is also real and generalised. Everyone can thus understand the importance of the collective and explicit character of this process of critical reading and reviewing of all the scientific literature available at a given moment on a scientific subject which is not yet stabilized.

### 2- Biological effects and effects on health

The results of the scientific works on which our assessment is based must therefore be analysed with a critical, panoramic view, covering all the data available at a given moment. It is also necessary to decide on the interpretation that can be attributed to the various 'biological effects' observed after exposure to radio-frequency electromagnetic fields in terms of their risk to health. Adopting the point of view of various international bodies working on the subject[1], the group of experts uses the term '*biological effects*' to refer to changes of a physiological, biochemical or behavioural nature which are induced in an organism, tissue, or cell in response to external stimulation. A biological effect does not necessarily represent a threat to the health of an individual; it may simply be the normal adaptation response of the cell, tissue, or organism to this stimulation. A '*health effect'* is a biological effect which may endanger the normal working of an organism in that it goes beyond the framework of the 'physiological' responses to the action of the external agent. This distinction is important and easy to understand. Thus, nobody could confuse the fact of hearing a sound (the enchanting song of a nightingale or the disturbing noise of a dust-cart early in the morning), which demonstrates a

[1] *See, for example, the report of the Royal Society of Canada of March 1999 (p15) or the introductory document to the EMF program of the WHO (can be viewed on the internet site www.who.int/peh-emf)*

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biological effect (resulting from a complex chain of elementary biological effects: mechanical, biochemical and electrical), on the one hand, and the gradual (or sometimes sudden) loss of hearing after prolonged exposure to noises of great intensity, such as that measured in youngsters who go to concerts with exaggerated amplifiers or in a metalworker after years of hammering without ear protection: this loss is a serious adverse health effect.

Likewise, many people appreciate the biological effects induced by moderate exposure to the sun, leading to the tanning of the skin via an increase in pigment production (melanin) by the specialized cells in the skin, but they make a clear distinction between this effect and the painful burns that come after excessively fast exposure to UV rays without skin protection, as well as the induction of a melanoma, both health effects which pose a serious threat to the health of those who enjoy prolonged, intense sunbathing.
The duration or intensity of exposure to the agent causing the biological effect, and the nature of the cell, tissue, or organism in which it is manifested, as well as other aspects that have not all been elucidated, have a considerable impact on the link (or absence of one) with a possible health effect.

A wide range of biological or functional measurements are taken when studying the effects of exposure to RF; some showing biological effects according to the definition given above. Those which may be *predictive of a health effect* remain to be determined. These biological effects are causes for concern and, if proven, should be subject to preventive measures. Proving the existence of such '*hazardous biological effects*' is not an easy task. First of all, they must regularly precede the occurrence of the feared health disorders or be associated with them. They may also constitute a stage in the chain of biological effects leading to these disorders, in the human species in general or only in some of its representatives (fragile subjects) or, failing that, in several other species of laboratory animals. One example which illustrates this issue, with regard to the non-thermal effects of RF, is the increase which has frequently been described in the biochemical activity of ornithine decarboxylase, an enzyme which may play a role in the development of cancerous cells. This point will be dealt with later.

**3- Should the precaution principle be applied to RF and health?**

World Health Organization memo n° 193, published on 28 June 2000, indicates: "It is clearly established that all the *proven* effects (our own italics) of exposure to radiofrequencies are related to this warming [due to the thermal effects of RF, *ed*]". This statement is inspired by the same principles as those followed by the International Commission for Non-Ionising Radiation Protection (ICNIRP), an independent scientific body whose 1998 recommendations are founded only on the effects established by the available scientific data (see Chapter III). Likewise, the recommendation by the European Union Council of 12 July 1999 concerning the limitation of exposure by the public to electromagnetic fields stipulates that "only proven effects have been used to establish the recommended exposure limitation". But what about those unproven effects which are currently the object of much scientific research and could, according to some hypotheses, result from non-thermal mechanisms? Must we wait for them to be proven or, on the contrary, formally refuted, before decisions are taken to manage these hypothetical risks?

This is the question asked of the industrial and political protagonists concerned by the effects of RF.
The precaution principle is a policy for the prudent management of unproven risks. It can be applied whenever plausible mechanisms or experimental or epidemiological observations provide a minimal scientific foundation. It is essentially a matter of risk management and not of evaluation, and the latter must try to keep to the area of facts or scientifically founded hypotheses destined to be proven by experimentation or strict epidemiological protocols.

This separation between 'objective science' and 'political management' can, however, turn out to be somewhat theoretical and formal in practice. In cases where facts have not been proved by scientific means, the mere act of summarising knowledge leads the scientific community to form judgment criteria on the existence or absence of links between exposure to the agent studied and the biological

or health effect under consideration. These criteria, however objective they may be, are not always totally free of extra-scientific considerations. What constitutes scientific 'proof'? What is the degree of proof required to accept (or refute) the hypothesis of causality? In their desire to protect health, scientists include elements of caution in these criteria. But it is understandable that when they come to examine this 'evidence', they do their utmost to take into consideration the actual nature (serious and irreversible or benign and short-lived) of the health effect under consideration, otherwise their judgment may be biased. The fact that the exercise is a collective one provides precious assistance but is not an absolute guarantee.

In contrast, 'decision-makers' must take into account the nature of the health effects in question, as well as the number of people exposed in the population (today and in the foreseeable future). It is also their responsibility to consider the availability and cost of solutions available to reduce exposure of the population. In a context where millions of people in France already use mobile telephones and the number is constantly increasing, and families see them as a means of staying in close contact with their children, the dilemma of 'the lesser evil' is particularly acute. It is necessary to assess the balance between the risks linked with developing a technology that may one day be found to have dangerous health effects, on the one hand, and the damage (including health considerations, as we are reminded by the European Union Council recommendation dated 12 July 1999) that could result from unjustified restrictions obstructing its development, on the other hand. One of the World Health Organization's working documents[2] thus warns the health authorities against taking measures which, although inspired by a legitimate desire to reassure public opinion and prevent hypothetical health hazards, would have no scientific foundation. Indeed, there is a great risk that varying levels of pressure from public opinion could lead governments to enact disparate 'safety standards' which could ruin all the efforts to achieve international harmonization. The confusion and fears of the public would only end up being artificially exaggerated, not to mention the fact that there would certainly be conflicts about 'arbitrary rulings and unfair competition or shackles on commercial exchanges'. The precaution principle cannot therefore justify measures without any rational foundation. The demonstration of hazardous biological effects, if there are any, would certainly require action to prevent the possible consequences, but that would not suffice to provide a rational basis for an efficient approach if the physical parameters requiring action were not yet fully understood. Exposure to RF, linked with the energy absorbed by the body, depends on a large number of factors, such as intensity of the field (which depends on the position of the device in relation to the base stations and on the position and type of aerial), field modulation – which makes it possible to transmit information – exposure duration (long when one is near a base station, but at very low intensity, intermittent yet more intense with the telephone itself and variable over time in both cases). For example, a precaution which appears to be 'common sense' (such as installing a physical protection around the aerial of the mobile telephone to 'protect' the head) is in fact counter-productive, for it causes the automatic power control of the telephone to increase field intensity to compensate for weaker reception. There are, therefore, many ways of reducing exposure to RF, but if the health risks were clearly established or strongly suspected, we would need to act specifically on the physical parameters responsible for the deterioration of the workings of the cells or tissues, which are not necessarily the same as those which enable communication between people.

In its text on the precaution principle[3], the European Commission proposed certain guidelines with the aim of "finding an adequate balance that makes it possible to make proportionate, non-discriminatory, transparent and coherent decisions – (through) – a decision-making process which is structured, based on detailed scientific data and other objective information". It reminds us that "the precaution principle which decision-makers use essentially in the context of risk management must not be confused with the element of caution applied by scientists to the evaluation of scientific data". One of these guidelines which is particularly relevant in this case is the desire to ensure that the measures implemented in accordance with the precaution principle are:

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[2] *Draft Fact Sheet for Final Review. Electromagnetic fields and public health cautionary policies. (6 July 2000); the document can be viewed on the site http://www.who.int/peh-emf/*

[3] *Communication from the Commission about recourse to the precaution principle, 2 February 2000*

- *proportionate* to the desired level of protection (and therefore to the level of risk to be avoided);
- *consistent* with similar measures already adopted in comparable fields;
- *based on an examination of the potential advantages and drawbacks* of acting or not acting,
- *re-examined periodically* in the light of new scientific data.

The group of experts was consulted about the existence of biological effects or health hazards resulting from exposure to RF associated with mobile telephones. This scientific body has no brief to decide on the *size of the safety margin* that would be required, if such effects were proved to exist today or were only seriously suspected, in the light of the current data, to achieve a level of risk which could be defined as 'acceptable'. This is a matter for political judgment legitimised by public debate on these issues. In contrast, the group of experts will determine whether the current state of our knowledge justifies a reduction in the exposure of mobile telephone users or people who frequent places within the field of base stations. In this case, they may make scientifically-founded recommendations concerning the ways of reducing exposure. Their report will indicate whether, despite any remaining uncertainties, the facts appear to be sufficiently well-founded and serious, in health terms, to adopt a precautionary approach. It will present the main lines of research required to eliminate these uncertainties. We can thus see that the relationship between the 'expert' and the 'decision-maker' is based on distinct, yet intertwined missions.

Although the precaution principle, used by public authorities for the prudent management of potential hazards as part of a wide range of more-or-less restrictive measures – e.g. regulatory, administrative, informative, etc. – is an element of public policy, various exposure-reduction measures can be taken by industry or even individual users. The "*prudent avoidance*" concept can be defined as the full set of voluntary measures which can be taken by private individuals to minimise any unnecessary and/or easily avoidable exposure. For example, telephoning under mediocre communication conditions (e.g. in certain closed spaces) leads to a substantial increase in the radiation received. If we are aware of this and have means available for acting on the information, it is then up to each individual to behave appropriately, in an enlightened, responsible manner. The group of experts thus considered a set of measures – compulsory, recommended, or voluntary – which would contribute to reducing personal exposure. Once they have explained their recommendations, they will indicate the measures they consider the most appropriate in the light of current knowledge of the risks.

**4- Selection criteria and analysis methods in recent reports and documents concerning mobile telephones and health**

There is a certain international consensus on the basic rules for 'good assessment practice' and this was adopted by the group of experts[4]. Any group conducting this type of assessment must represent a range of scientific specialities, given the complexity of the issue at stake, and members should also have expressed a variety of opinions on the subject. All the different points of view on the issue must be taken into account, including any divergences, either within the group of experts itself or through hearings or other forms of communication.
This plurality requirement, consolidated by transparency regarding any conflict of interests that may exist in the group[5], aims to ensure that the final opinion of the group is not biased.

[4] *See for example "Evaluation and use of epidemiological evidence for environmental health risk assessment", WHO-Euro, Copenhagen, 2000*

[5] *All the members of the group of experts filled out an information sheet on which, following the example of the experts assigned by other health safety agencies such as the AFSSAPS, they declared the scientific works carried out in conjunction with or financed by companies involved in the development of mobile telephony, as well as any business interests they might have in such companies.*

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The criteria governing the selection of the scientific materials to be reviewed must be explicit. The group of experts thus selected 5 summary reports written by committees of experts that met the following criteria:

- the expert committees included scientists from several disciplines concerned by RF, sometimes with specialists from disciplines not directly involved with RF, and produced their reports for national or international health authorities,

- the review of scientific evidence carried out by the committees of experts was based on publications in scientific journals with a reading committee ('peer-reviewed' cf. below) with the objective of being exhaustive at the date of the expertise,

- the committees' criteria for assessing the literature were explicit,

- these reports have been published since 1996 (date of the McKinlay report for the European Union), as it was considered that a sufficient amount of scientific data had been published on the biological and health effects of RF by that date.

The group of experts chose to accept only summary reports based on articles published or accepted for publication in scientific reviews with a peer-review committee, for this rule ensures that the work in question has been scrutinised by specialists in the same subject who were not a part of the project itself. Although this does not provide an absolute guarantee of quality and even less so of truth, this rule is widely accepted in various international assessment bodies and makes it possible to base the synopsis on information which meets minimum quality conditions, thus avoiding fanciful or purely anecdotal documents and limiting the amount of non-validated work. In our opinion, we cannot see how work refused for publication in the (many) scientific journals available could have any claim to being superior, nor could those whose authors considered it unnecessary to submit themselves to external scrutiny. Despite the delays which these 'peer review' procedures cause (sometimes as long as 1 year), the vast majority of subjects treated in this report have been studied for a sufficiently long time for the group of expert to obtain an adequate number of publications on the subjects under consideration. Except for recently published works, the group of experts considered that it was neither useful nor feasible, in the time it had to give its opinion, to go back over each of the hundreds of articles which had been analysed in detail in the summary reports it was studying. Some particularly innovative recent works may, however, be exempted from this rule. They were analysed on a case-by-case basis and their inclusion in this report was clearly explained. Each of the 'basic' summary reports was subject to detailed critical analysis by the group of experts, who then gave an opinion on the scientific relevance of each set of conclusions.

This report presents the critique of all the basic reports, following a single plan. In order to make it easier to read this synopsis, this plan systematically follows the various systems or morbid entities studied in the most recent summary report directed by William Stewart (May 2000). Whenever possible, the reader will find successively the studies concerning the nervous system and behaviour, those concerning cancer, reproduction and development, the cardiovascular system, the immune and blood systems, other miscellaneous disorders that may have been studied, interference with biomedical implants and, finally, the risks linked with driving a car when using a mobile telephone, with or without a hands-free system. For each theme, the conclusions of the authors of the summary report are cited in the introduction, in an identifiable manner, followed by a short presentation of the main work justifying these conclusions. The judgement expressed by the group of experts is mentioned at the end of each theme. A summary of the opinion of the group of experts is presented at the end of each chapter devoted to a given report.

Besides the 'basic reports', a certain number of 'additional documents' were also taken into consideration. They do not satisfy the criteria mentioned above but do provide other interesting

information (cf. list in the appendix). The points included in these documents which were inadequately or differently covered in the 'basic reports' have been highlighted.

The group of experts also collected all the scientific literature published after the most recent summary report. Besides the usual exercise of bibliographical monitoring via computerised databases, the group also contacted the main scientific publishers who were likely to receive articles on the subject (about forty journals were identified on the basis of the articles published in recent years), asking them to inform them of any article accepted for publication (and therefore positively reviewed by peers) and intended for publication by the end of the year 2000. Many editors responded (see list in the appendix of journals contacted and those which responded). These recent original articles were added to the list of additional documents studied with the ultimate aim of enabling the group of experts to give a global judgement of all the scientific material available.

Finally, the group interviewed a number of well-known people from scientific organisations, administrations, industry, associations, and politics, both to obtain further information on aspects not covered in scientific literature and identify society's concerns on this issue more fully.
The principle of transparency also applies to the criteria used by the group in forming their judgement on the state of knowledge, so that third parties would have an opportunity to criticise their choices and tools. The criteria chosen by the group of experts should be understood in light of the main question they were asked: "Do the recently published summary reports provide comprehensive, reliable information which the French health authorities can use as a basis for updating their principles and rules for managing the risks associated with the use of mobile telephones and base stations?" The group of experts considered that any response to this question would necessitate answering three logically connected questions:

- What are the demonstrated *biological effects* of RF?
- Among these biological effects, which can be considered reasonably predictive of a *health effect*, in the light of our current knowledge?
- Given what we know today, can we determine RF exposure levels and/or conditions which would reduce or eliminate these possible *hazardous biological effects*?

The guidelines adopted for preparing this "expert judgement" were those stipulated more than 30 years ago by the famous British epidemiologist Bradford Hill: "Is there any other way of explaining the set of facts before us, is there any other answer equally likely, or more likely, than cause and effect?"[6].

The main criteria selected by the group of experts for assessing the quality of the knowledge summaries were as follows: the exhaustive nature of the literature review (at the date of publication), the *relevance of the critique* of the articles upon which the opinion was based, the degree of *consistency* of the different results observed in the literature – which implies waiting for the replication of observations before pronouncing on their reality – and their *coherence* (these results must be part of a logical sequence covering a chain of mechanisms and/or be found in different animal species, including man). It should be noted that criteria relating to the intrinsic quality of the studies published (experimental or observation protocol, data analysis, and account taken of interfering factors, comparison with pre-existing scientific data) are not on this list, as they have already been taken into account, usually explicitly, in the summary reports on the literature that the group of experts analysed. These criteria were nonetheless applied to articles published too recently to be included in the summary reports.

[6] *Hill, AB. The environment and disease: association or causation. Proceedings of the Royal Society of Medicine, 1965, 58: 295-300*

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## ANALYSIS OF RECENT ARTICLES

**1- A critical review of epidemiological studies on radiofrequency exposure.**
*J.M. Elwood, Environ. Health Perspect. 1999, 107(supp1), 155-168*

*This article was submitted to the EHP journal in 1998; it makes a critical review of the epidemiological studies published between 1988 and 1998 on the risk of cancer associated with exposure to RF.*
The range of RF considered covers radar, radio and television waves in areas close to transmitters or occupational exposure in the electronics and telecommunications sectors. The first publications related to mobile telephones are concomitant. The interest of this article is therefore that it encompasses other professional or environmental exposure to RF besides that related to mobile phones.
*The author belongs to a university cancer research centre in New Zealand and carried out this review of the literature at the request of Telecom New Zealand. The EHP journal is one of the most prestigious in the field of environment and health sciences. It is a publication of the National Institute of Environmental Health Sciences (NIEHS) and reports on experimental or epidemiological scientific works.*
The authors divided the work analysed into four categories: investigations into clusters - 4 original publications; studies of the population in general exposed to radio and television transmissions and other similar fields (5); cohort studies concerning occupational exposure (5); and case-control studies (6). The articles considered were identified by searching on the Medline database or in previously published journals. After a description of each study, and particularly of the conditions for estimating the exposure of people or populations, the main results are presented in tables by category of work, thus facilitating comparison. Finally, Elwood takes all this information and subjects it to an interpretation grid inspired by B. Hill's causality criteria.

*1- Investigations into Clusters.*
From time to time, cases of rare diseases appear grouped in time and/or in space. These phenomena, often caused by chance, must be explored carefully in order to identify the characteristics common to the different cases. It is now accepted that these clusters can raise hypotheses concerning risk factors, although it is not possible to draw conclusions without implementing specific explanatory studies. Three reports have been published on cancer clusters near RF sources.
A case-control study was initiated when 12 children living near a radio transmitter in Hawaii were found to be suffering from acute leukaemia. Among the children living less than 4.2 km away, a (non-significant) excess of cancers was suggested, but the small number of cases led the authors to conclude that the cluster had no doubt occurred by chance. A similar situation was explored among 340 American policemen equipped with radar revolvers; the 6 cases of testicle cancer could not be linked with exposure. Another cluster was explored around a radio and television transmitter near Birmingham in Great Britain, covering all the cancer cases which occurred over 12 years within a radius of 10 kilometres around the suspected source. An excess of adult leukaemia was suggested in the inner circle, within a radius of 2 kilometres. This apparent trend was due to the lower-than-expected number of cases in the second circle, compared with the population as a whole. The authors concluded that it was not possible to attribute the cancers to the transmitter, but they did undertake a wider-ranging study covering 21 RF transmitters in the country.

*2- Living close to radio-television transmitters*
Five studies have been published on the incidence of cancer in populations living close to radio or television transmitters. The Birmingham cluster led to a comparative study of the incidence of cancers over 12 years, in a radius of 10 kilometres around 21 British transmitters (in the 430-890 MHz bands), including the transmitter which triggered the work in the first place. This study involved 3.39 million people. The initial observation of an excess of adult leukaemia was not confirmed: the number of cases in the first radius of 2 km around the 20 sites other than Birmingham was, on average, lower than expected, whereas the risk in the 10 kilometre-circle as a whole was slightly higher (+3%) than expected. However, the results varied depending on the type of cancer and from one site to another, and one large transmitter near London showed a trend in adult leukaemia which decreased with

distance. In total, the authors considered that their results gave, at best, only a very weak indication to support the initial cluster.
Another incidence study was conducted near three television transmitters (60 to 500 MHz) to the north of Sydney, Australia. The maximum power density estimated at a distance of 1 km was 80 $mW/m^2$ , and 2 $mW/m^2$ at 4 km. The comparison covered cases of child and adult cancer in the period 1972-1990, in relation to the distance from the transmitters (less than 4 km and from 4 to 15 km). An excess cancer risk was observed in adults (RR = 1.18 [0.98- 1.42]) and children (RR = 1.58 [1.1-2.3]) but not in brain cancers. These results therefore contrast with the British observations, despite the distinctly weaker field power. They show no gradient effect and the possibility of differences linked with socio-demographic structures of the populations cannot be excluded. This work was continued by another author who extended the area covered by the study to other nearby territorial units. Field measurements were taken, showing power densities varying from less than 2.5 W/m 2 to 1,000 W/m 2 at the foot of the transmitter. Although one of the three most-exposed zones showed, as in the initial study, an excess of child leukaemia compared with more distant zones, two others did not, thus suggesting the possible role of factors other than EM fields.
In the region of San Francisco, the incidence of leukaemia and lymphatic and brain cancer among subjects below the age of 21, between 1973 and 1988, was analysed in relation to the distance from a television transmitter tower, without showing up any excess risk in a first circle of 3.5 km (RR = 0.73). Another study pointed out by the author is reported in a review of studies carried out on the subject, but was not the subject of a referenced publication.

*3- Retrospective professional cohort studies*
Polish military staff were monitored from 1971 to 1985, using registers indicating possible exposure to RF (mainly pulsed emissions from 150 to 3,500 MHz, with a power density lower than 20 W/m 2). For all types of cancers, the excess risk was calculated for military personnel who had undergone exposure in relation to the others (RR = 2.1 [1.1- 3.6]); it was highest for leukaemia and lymphomas (RR = 6.3), but also for certain cancers of the digestive system (oesophagus, stomach, colon and rectum), an observation which has never been reported elsewhere. No excess was shown, however, for cancer of the bronchia. The exposure information may have been biased, according to Elwood, at the moment when the most careful exploration of the risk factors of cancer was carried out in the military hospitals that had taken in the patients.
An earlier study covered 20,000 radar transmissions personnel in the American navy, compared with 20,000 other sailors who had undergone lesser exposure, between 1950 and 1954; several exposure classes were defined in accordance with the definitions of the workstations. Cancer mortality was evaluated in 1974. It did not vary between the groups, nor between the particular categories of cancers of the digestive organs, leukaemia or lymphoma. However, lung cancer mortality was higher, with a gradient that followed the intensity of exposure.
A cohort of male radio enthusiasts from the States of California and Washington was studied, for various localisations of cancers that occurred between 1979 and 1984. For all types of cancers, mortality was lower than expected, but it was higher for one of the 9 forms of leukaemia studied: acute myeloid leukaemia, as well as for the 'other lymphatic cancers' category. Unfortunately, too little information was available about the exposure of the subjects who, in their activities or in their professions (often professions connected with electronics) could be subject to other chemical or physical exposure. It is therefore not possible to make a valid interpretation of this study.
A cohort of 2,600 radio and telegraph operators in the Norwegian merchant navy, active between 1920 and 1980, was studied for the incidence of cancers. A slight excess risk was observed for all types of cancer (RR = 1.2 [1.0-1.4]), as well as for malignant tumours of the breast (1.5 [1.1-2.0]) and uterus (1.9 [1.0-3.2]). Leukaemia, lymphoma and brain cancer were no more common in the reference population (non specified in the Elwood review). A case-control study was included in this cohort. The similarity of excess of cancers in the breast and uterus, in the absence of excess of other forms of cancer whose link with RF has sometimes been shown, suggests the role of reproductive factors, but this excess remained after the age of the women when their first child was born had been taken into account. Some EM field measurements carried out on vessels still equipped with old radio equipment showed magnetic field values (>8MHz) above professional exposure limits.

The last cohort studied, considered by the author to be the most valid from the methodological point of view, was composed of Canadian and French electricity company agents. In total, 2,679 incident cases of cancers of all types were recorded, thus making it possible to carry out an analysis of the case-control type in the cohort. Exposure was characterised using job-exposure matrices and by measuring the electrical field at the workstation of 1,300 workers over 1 week in 1991 and 1992.
The high-exposure classes corresponded to electric fields of more than 200 V/m in the 5-20 MHz band, but could also include fields of 150-300 MHz and RF (radio transmissions). An 'all cancers' excess risk was observed (RR = 1.39 [1.05-1.85]), as well as for bronchial cancer (after adjustment for tobacco addiction and a wide range of other risk factors). However, no link was demonstrated with cancers reported elsewhere with EM fields (leukaemia, lymphoma, brain cancer and melanoma). Elwood notes that the EM fields taken into consideration in this cohort are essentially a long way from the RF band.

4- *Case-control studies*
Specific mention of RF was found in 6 case-control studies. US-Air Force personnel employed from 1970 to 1989 who developed brain cancer were compared with 4 controls (same force, age, and ethnic category). Professional exposure was characterised using job-exposure matrices defined by a group. As well as a strong, unexplained association with rank, a discrete relation was observed with exposure to RF (RR = 1.39 [1.01-1.90]). One of the weaknesses of this study is the fact that agents who had left the army were not included, thus making a selection bias possible.
In three regions of the United States, fatal cases of brain cancer (white men over 30 years old) were compared with control groups (same age and zone of residence) who had died of affections other than cancer, epilepsy, cerebral vascular accident, or violent death. A close friend or relation was asked about professional exposure (varying response rate between the cases and the controls: 74% and 63%). The jobs were classified by potential exposure to RF. The risk of cancer was linked with the 'exposed' jobs (RR=1.6) only among the agents of the electrical and electronics industries, but not among those working in other professional branches (RR=1.0). This suggests that the risk factor could be due more to other aspects of the jobs than to RF (solvents, vapours etc.).
Testicle cancer risks were explored in 271 cases aged from 18 to 42 and in 259 controls, in three hospitals (including two military establishments). Job categories and subjects' statements were used to classify exposure to microwaves and other radio waves. The results were inconsistent, with excess risk when the subjects declared that they were subject to exposure, but not in relation to the job title - the jobs considered as being the most highly exposed to RF were associated with a low risk (RR = 0.8).
Risk factors in the incidence of breast cancer in men, a very rare disorder, were studied in 227 cases and 300 controls in 10 regions of the United States. The fact of having worked in a job involving RF defined exposure. Although the risks observed were higher among electricians, telephone line installation, and electricity production facility staff, it was not significantly higher among workers in the radio and telecommunications sectors (OR = 2.9 [0.8-10.0]; for 7 cases). The participation rates in the study were described as low by Elwood, who considered this work a preliminary study.
The risk factors in female mortality from breast cancer were the object of a case-control study covering a total of 33,000 cases and 117,000 controls in 24 States of the United States between 1984 and 1989. The only exposure data available was derived from the death certificates which were used to classify the women by a job-exposure matrix. Alongside various potential types of exposure to chemical substances (styrene, chlorine-containing solvents etc.), the probability of exposure to RF was estimated and categorised in four groups according to a gradient. Although exposure classes 1 and 3 suggested the existence of an effect, in relation to the non-exposed group (average OR = 1.14 and 1.15 respectively), the intermediate class showed no excess risk (OR = 0.95).
The authors concluded that 'the investigations showed no association with ionising or non-ionising radiation'.
The effect of RF on the risk of intraocular melanoma was studied in 221 white men in a San Francisco hospital and 447 controls from the same geographic area. Many professional exposure factors were explored, by job category. Only those that turned out to be associated with cancer were reported, thereby excluding an appreciation of the possibility of fortuitous associations. An association was demonstrated with exposure to microwaves and radar waves (OR = 2.1 [1.1-4.0] out of 21 exposed

cases). This result is not featured in the summary written by the authors who also point out the possibility of a memory bias in this type of survey.
Elwood reports other studies which could be of interest on the subject. One concerns the comparison of chromosome damage rates in 38 Telecom Australia employees - line technicians subject to exposure close to or below occupational limit values - at frequencies of 400 to 20,000 MHz, and 38 office workers who were not exposed.
The biological tests were carried out blind and showed no malfunctions in cell division among 200 metaphases for each subject examined (OR showing an aberration = 1.0 [0.8-1.3]). Two other types of data are mentioned, but in such an evasive manner that it is impossible to interpret them.
At the end of his review, the author recaps the observations and submits them to the Hill's causality criteria. This leads him to conclude that the individual studies are weak in terms of methodology, particularly when it come to the characterization of exposure, thus making it impossible to interpret them clearly in terms of a cause and effect relationship. "The major impression is that these studies are inconsistent. No type of cancer is linked consistently with exposure to RF".

Opinion of the group of experts on this article: *The studies considered in this review do not directly concern exposure to RF linked with mobile phones and their base stations. The frequency ranges and exposure conditions are distinctly different. However, these studies are, in principle, relevant, in that they may highlight categories of cancers that deserve particular attention in specific epidemiological studies on mobile telephones.*
*The information provided by Elwood to appreciate the quality of the original studies is very variable in terms of accuracy. There is sometimes a certain confusion between presentation and criticism of the studies, which does not facilitate 'objective' reading. Despite this, we can only agree that the message transmitted by this series of studies is far from convincing.*

**2- General articles and experimental work:**

***Non-thermal heat-shock response to microwaves***
*David de Pomerai, Clare Daniells, Helen David, Joanna Allan, Ian Duce, Mohammed Mutwakil, David Thomas, Phillip Sewell, John Tattersall, Don Jones, Peter Candido. Nature, 25 May 2000.*

A short article has recently been published in the prestigious journal, Nature, describing the results obtained by British and Canadian teams on small earthworms called nematodes, of the species Caenorhabditis elegans. These animals were exposed to low-level microwaves.
The aim of the study was to detect indirectly the expression of heat shock proteins (HSP:heat-shock proteins) caused by exposure. These proteins are produced when the organism is submitted to aggression such as heat or a toxic product. The proteins can be damaged in the cells and the HSP are there to act as chaperones for the proteins or to re-establish their three-dimensional structure.
The authors built transgenic nematodes in order to monitor HSP production experimentally. They thus prepared two strains bearing "reporter genes" (which express easily-detectable genes: those of the ß-galactosidase enzyme and of a green fluorescent protein). These reporter genes are regulated (expressed following the expression of hsp promoter genes).
During the night, the worms were exposed to microwaves CW at 750 MHz in a TEM[7] cell, one of the most commonly used exposure systems for cells in culture. In the course of several experiments carried out at increasing temperatures in a standard incubator, it was observed that the exposed worms reacted very differently to the control worms: the activity of the ß-galactosidase enzyme increased rapidly with the temperature of the incubator, as if they were heated by the microwaves. There was a difference of 3°C between the two batches (cf. appendix 3). The SAR was estimated at 1 mW/kg, which corresponds to a very small rise in temperature.

To explain their observations, the authors put forward three hypotheses:
- microwave acts on the bonds which maintain the proteins in their folding structure,

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[7] *transverse electromagnetic*

- species that react to oxygen are produced, and 3) signal[8] acts on the transduction processes.

In fact, none of these "explanations" is experimentally (or even theoretically) founded at present. Nevertheless, the authors are going to test them using this simple, quick model. Today, although these results are interesting, they cannot be extrapolated in terms of public health. However, the authors do not hesitate to suggest that exposure limits should be revised if such non-thermal biological effects exist, a bold short-cut from earthworm to man...

***Mobile-phone type electromagnetic fields do not influence genetic stability in yeast.***
Gos P., Heyer W.D., Kohli J., and Eicher B. (1999). In: *Proceedings of the Second World Congress for Electricity and Magnetism in Biology and Medicin*e, Bologna, Italy, June 1997, F. Bersani, Ed.

Formattato: Tedesco (Germania)

Following the work by the Grundler and Kielman group on the effects of millimetric waves on yeast[9], the Gos group in Bern unsuccessfully attempted to replicate these experiments[10]. More recently, a study financed by the FGF and Swiscom was carried out by the same group. The aim was to determine any possible effects on the same model of GSM-900 type microwaves. Cultures of *Saccharomyces cerevisiae* were therefore far-field exposed at 900 MHz

***Prenatal exposure to 900 MHz, cell-phone electromagnetic fields had no effect on operant-behaviour performances of adult rats.***
*Bornhausen M., Sheingraber H. Bioelectromagnetics, 2000, 21, 1-9.*

This article concerns the possible effects of the radiofrequency electromagnetic fields used in mobile telephone technology on brain development. To do this, gravid female Wistar rats were continually exposed during gestation. This exposure was carried out with radiation of 900 MHz, modulated at 217 Hz, which represents the exposure of the population most frequently observed in terms of exposure to the radiofrequencies used in mobile telephony. The total SAR (whole body) corresponding to this exposure was between 17.5 and 75 mW/Kg. The embryos subjected to these conditions were then tested to assess their cognitive faculties in terms of learning abilities (obtaining food). These tests are described as being particularly discriminatory for the two parameters that are the frequency of activation of the lever and the inter-response intervals. The results obtained in the course of these different tests by studying more particularly these two parameters showed that in-utero exposure induced no measurable effect on the cognition of the animals exposed to radiation compared with the performance of the control animals.

***Biological effects of electromagnetic fields - Mechanisms for the effects of pulsed microwave radiation on protein conformation***
*Laurence JA, French PW, Lindner RA, and McKenzie DR Journal of Theoretical Biology, 206: 291-298 (2000)*

In Australia, Laurence and coll. studied the effects of pulsed microwaves on the induction of heat shock proteins. The induction of HSP-70 was observed in mouse cells after exposure to bursts of microwaves at 2450 GHz, each lasting 6 minutes.

The amplitude of the effect increased with the dose (SAR from 12 to 58 W/kg). The authors claim to have shown that the average duration of 6 minutes recommended by the ICNIRP is inadequate. They

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[8] *propagation of messages from outside the cell to the cytoplasm and the nucleus*

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*(23°C, SAR of 0.13 and 13 W/kg). The tests carried out were those of reverse and direct mutation in response to canavanine. No effect was detected*

[9] *Grundler W, Keilman F, Putterlik V, Strube D (1982): Resonant-like dependence of yeast growth rate on microwave frequencies. Br J Cancer 45:206-208.*

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[10] *Gos P, Eicher B, Kohli J, Heyer W-D (1997): Extremely high frequency electromagnetic fields at low power density do not affect the division of exponential phase Saccharomyces cerevisiae cells. Bioelectromagnetics 18:142-155.*

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also carried out simulations of the basic mechanism of this effect. The main hypothesis was that the synthesis of heat shock proteins is triggered by the transitory warming of proteins without the macroscopic temperature rising. They estimate that the time required for a protein with a diameter of 10 nm to reach thermal equilibrium with its environment after absorbing microwaves is 1 nanosecond, whereas the time required for the unfolding of the protein is 50 nanoseconds.
Commentaries of the group of experts: several hypotheses put forward in this article are somewhat unreasonable, notably that the temperature of the water bonded with the proteins is high after absorption of the microwaves without there being a change in the temperature of the bath. In fact, the equilibrium between the two forms of water (free and bonded) is established almost instantaneously. Likewise, the explanation of the existence of power "windows" is not supported by the experimental observations nor by theoretical considerations (incomplete triggering of the response to the heat shock). It is probable that a defective dosimeter is the source of the observations made in this article and that the effects are in fact likely to be thermal in nature.

***Exposure to pulsed high-frequency electromagnetic field during waking affects human sleep EEG***
*R Huber, T Graft, KA Cote et al (NeuroReport, 2000, 11, 3321-3325)*

Formattato: Tedesco (Germania)

Volunteers were subjected to the field of mobile telephones emitted by a planar antenna on one side of the head or the other. After a short night limited to just 4 hours of sleep, the volunteers were exposed for half an hour early in the morning, in a seated position, before going back to sleep. A GSM signal was emitted with modulation at the various frequencies encountered in actual telephones: 2, 8, 217 and 1736 Hz, with a pulse duty factor of 87.5%. The maximum local SAR on 10 g was calculated as being 1 W/kg, corresponding to an average SAR on the hemisphere of the exposed side of 0.28 W/kg. The sleep parameters (latencies, durations, efficiency etc.) presented no significant differences. A difference of 10 to 12% in the density of the spectral power was significant in the frequency bands 9.75-11.25 Hz and 12.25-13.25 Hz in the first 30 minutes of non-REM sleep. This effect did not dominate on the exposed side.
Commentaries of the group of experts: *the exposure conditions are not at all physiological. An effect under these conditions has no significance that can be related to a real situation. The authors justify their protocol, among other things, by arguing that daytime sleep was favoured by the fact that the subjects were deprived of night-time sleep immediately before. Generally, it takes just a few nights for volunteers to get used to an unusual environment and sleep correctly. The main interest in this study is that it shows a delayed effect after exposure, thus suggesting the possibility of an accumulative effect. This hypothesis remains to be demonstrated in more physiological conditions, e.g. exposure in the evening before going to sleep.*

***Exposure to electromagnetic fields by using cellular telephones and its influence on the brain.***
*M. Petrides, Neuroreport, 11 (15), F15, 20 octobre 2000*

Formattato: Francese (Francia)

This editorial in the Neuroreport journal was initiated by the article by Huber et al, published in the same issue (cf. the critique of this article presented above). It places this study in perspective by referring to 6 other articles published since 1998 on the effects of brief exposure to RF on the physiology of the brain on certain cognitive functions.
The mechanisms of these effects remain uncertain, but it has been proposed that that a microthermal effect on synaptic transmissions could play a facilitating role in cognitive functions. The editorial underlines the fact that the effects shown by Huber et al are no longer visible after a 3-hour period of sleep and thus draws the conclusion that, in the light of our current knowledge, it is not possible for these short-term manifestations to be predictive of long-term consequences after repeated exposure. New work is required to answer this question.

***Radiofreqencies and genotoxicity FDA programme***

A joint call for tender by the Food and Drug Administration and the American telephone industry (CTIA) has just been issued for the replication and extension of two recent studies (submitted for

publication) showing the induction of micronuclei (genotoxicity test) after exposure of mammal cells to the radiofrequency signals used in mobile telephony.
The conditions under which this effect was demonstrated were, nevertheless, unusual and call for caution when it comes to interpreting this data.

***Investigation of DNA damage and micronuclei induction in cultured human blood cells***
*Hook G.J., Donner M., McRee D.I., Guy A.W., Tice R.R (article accepted by Bioelectromagnetics )*

The mobile telephony signals studied have a carrier frequency of about 837 MHz (Analogue, CDMA and TDMA) or 1900 MHz (PCS) and are modulated or otherwise by the voice.
Cultures of circulating human lymphocytes (2 donors) were exposed to SAR of 1 ; 2.5 ; 5 and 10 W/kg for 3 and 24 hours.
The two parameters studied were (i) DNA damage induction (single strand breaks, sites sensitive to alkalis) assessed by the comet test: this test identifies damage to individual cells after electrophoresis. A deteriorated cell takes the shape of a "comet" with the intact DNA forming the head, while the fragmented DNA which has migrated makes up the tail. (ii) micronuclei induction (MN, chromosome fragments or whole chromosomes which do not migrate correctly on division of the cell) assessed by the cytokinesis-blocked micronucleus assay. Only those cells which underwent cell division after treatment (bi-nuclear cells) were considered, which increased the sensitivity of the test (M. Fenech, The *in vitro* micronucleus test, Mutation Research, 2000).
In this study, the comet test revealed no DNA damage induction whatever the exposure conditions. The MN test was negative for all the signals after 3 hours of exposure. It is worth noting that only 2 experiments were carried out in most cases. The signals tested at 5 W/kg and 24 hours (TDMA and analogue) inducted MN in the lymphocytes ($p<0.001$, *only one experiment*). Finally, all the signals (modulated or not) showed an ability to induce MN after 24 hours' exposure ($p<0.001$, *two experiments per conditio*n).
According to the authors, this effect could be due to the cells heating, as the SAR range of the samples was very wide (7 to 31 W/kg - Guy *et a*l., 1999, Bioelectromagnetics, 20, 21-39). However, no hypothesis was formulated by the authors to explain the fact that the comet test was negative under certain conditions although a significant increase in MN had been detected.

***The effect of radiofrequency radiation with modulation relevant to cellular phone communication (835.62 MHz FDMA and 847.74 MHz CDMA) on the induction of micronuclei in C3H 10T1/2 cells***
Bisht K., Moros E.G., Straube W.L., Roti-Roti J.L (results presented to the Annual BEMS Meeting (Munich, June 2000) and submitted to Radiation Research)

The study concerns the search for the induction of micronuclei (MN) in C3H 10T1/2 cells (mouse fibroblast cell lines) exposed to the radiofrequency signals used in mobile telephony in the USA. Cells were exposed to the FDMA signal (carrier frequency: 835,62 MHz) at SAR of 3.2 and 5.1 W/kg or to the CDMA signal (carrier frequency: 847.74 MHz) at SAR of 3.2 and 4.8 W/kg. The exposure was isothermal (37 ± 0.3°C) and exposure times were 3, 8, 16 and 24 hours for the cells in the exponential growth phase or in the plateau phase (G0 phase of the cell cycle). Gamma ionising radiation (137 Cs) was used as a positive control. The test used was the so-called "cytokinesis-blocked micronucleus test" in which only the bi-nuclear cells, whose division is chemically blocked, are taken into consideration.
Under the experimental conditions of this study, this test proved to be capable of detecting the inducted MN from 0.6 Gy gamma photons.
The results showed that there was no increase in micronuclei when the cells were exposed to the FDMA signal, whatever the exposure conditions. Exposure of less than 24 hours to the CDMA signal was also without effect whatever the exposure level and the cell growth phase.
In contrast, an increase was noted in the number of MN (bi-nuclear cells with micronuclei and number of MN for 100 bi-nuclear cells) in the C3H cells in the plateau phase exposed at the highest level (5.1 W/kg) for 24 hours. The increase was around 20% and was significant ($p<0.05$, Student t with $n=6$). It

should be noted that in cells in the plateau phase, the 50% increase in MN observed after a dose of 0.3 Gy of 137 Cs was not found to be significant (n=3).

***Physics and biology of mobile telephony***
G.J. Hyland , The Lancet , 2000, 356:1833-1836.

Professor Hyland of Warwick University puts forward, in this article, a theory concerning the non-thermal effects of mobile telephones. It gives a brief reminder of the basic data about mobile telephony and its thermal effects. He then touches on the non-thermal effects, presenting his basic hypothesis, which is that the organism reacts to modulated waves as the latter can interfere with the oscillations of certain biological processes. A comparison is made with the interference phenomena encountered in electromagnetic compatibility. There then follows a list of examples of observed effects, such as: epileptic activity in rat brain sections, observed by Tattersall (however, the effect was observed at 700 MHz GSM as well as in non-modulated). The effects of millimetric waves on the growth of *Saccharomyces cerevisia*e were reported by Grundler in 1992, but Gos' team were unable to replicate these results (2000).
In all the results selected, except those of Repacholi, the amplitude of the biological effects was low and did not correspond to foreseeable health effects.
Commentary of the group of experts: *The demonstration is undermined by the selective choice of articles from the literature, since the negative experiments, in particular in replication, are not quoted and the examples are taken from the ELF, RF and millimetric bands without this being explicit. Furthermore, certain quoted references relate to unpublished works. Thus, in the second table, the work of the group of M. Bastide is quoted although it has not been published and concerns ELF.*
*Faced with the impossibility of reproducing certain results, the authors invoke the "non-linear" character of the phenomena (chaos, "butterfly effect") to explain that the results depend so strongly on the initial conditions that it is not possible to reproduce them!*
*This is a scientifically unacceptable argument. The quotations of epidemiological data are also biased and the conclusion on the famous episode of the irradiation of the American Embassy in Moscow is quite off the subject, from the point of view of mobile telephony RF.*
*In conclusion, it is most surprising that such a scientific journal as The Lancet should have published this article which fails to comply with the elementary rules of scientific communication in terms of content and form.*

***Criticism of the health assessment in the ICNIRP guidelines for radiofrequency and microwave radiation (100 kHz–300 GHz)***
*Cherry N, 2000. http://www.emfguru.com/ CellPhone/cherry2/ICNIRP-2.htm*

Neil Cherry is a Climatology professor in New Zealand. For several years, he has been actively fighting for low RF exposure limits to be applied. N. Cherry has just published a severe critique of the ICNIRP recommendations[11] on the internet. The author's main argument is that the ICNIRP maintains, despite all the evidence, that the only established and conceivable biological effects are thermal in nature, whereas the non-thermal effects should also be taken into account when assessing health risks.
Despite the impressive length of this contribution (143 pages), which claims to cover all the biological and health aspects of the non-ionising electromagnetic spectrum, the presentation which follows is short, as it is for the other recent works reviewed by the group of experts. A few examples drawn from the report by N. Cherry highlight the methodological and theoretical weaknesses of his arguments:

- N. Cherry explains that the amplitude of the biological effects increases with the frequency over the whole of the electromagnetic spectrum ('EMR Spectrum Principle'). This hypothesis is not backed up either by knowledge of the mechanisms, which depend on the frequency, or by the biological results obtained in the various frequency bands.
- Studies of varying natures are bundled together by the author without discernment (thus, ELF and RF fields are all considered globally),

[11] International Commission on Non Ionising Radiation Protection

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- The results of experiments are not always taken into account (negative and positive).
- The report often features badly-summarized or over-interpreted results.
- In epidemiology, there is a real difficulty in estimating subjects' exposure to the fields, especially in retrospective studies. This is also true of the case-control studies or 'ecological'-type studies on which the author makes abundant comment. This may lead to an under-estimation of the risk. N. Cherry concludes that any indication of an excess risk, even non-significant, implies a causal relation. He thus makes a very unorthodox reading of the causality criteria proposed by B. Hill which are evoked at length in support of his thesis. Many studies analysed by the colleges of specialists as being 'non-suggestive' of an association or as suggesting a relation whose causality is subject to caution, are presented by N Cherry as being demonstrative[12].

*This thesis is a good illustration of the fragility of an isolated critical approach in a scientific field characterized by its great complexity. In its intermediate report, the group of experts insisted on the necessity, in such a context, of mobilizing skills in different disciplines, as well as different points of view on the subject. This need for contradictory scientific critique is clearly highlighted here.*

**3- Epidemiological Studies**

***Epidemiological evidence on health risks of cellular telephones***
*Rothman KJ. Lancet, 2000, 356 : 1837-1840*

Editor in Chief of the journal Epidemiology and himself a famous epidemiologist, K. Rothman reports, for "The Lancet", on the state of epidemiological knowledge of the risks associated with RF.
In a short introduction, he gives a brief reminder of certain distinctive features of exposure to RF in relation to very low frequency electromagnetic fields (ELF EMF), a domain which has been the object of a very large number of epidemiological studies. At least as far as mobile telephone users are concerned, this exposure is localised and concerns clearly-identified tissues, it has considerably increased in recent times, occurs over short periods (phone calls), and can be measured indirectly (via invoices) or directly (SAR). All of these conditions should make the work of epidemiologists much easier than has been the case for ELF EMF. However, the time-scale is too short to be able to give definitive answers for certain effects which may be delayed, especially given the fact that the technologies have evolved in recent years.
First of all, the journal examines cancer. The studies relating to the RF linked with radio and television antennae, and also with certain occupational environments (radar, the electronics sector) – 11 articles discussed – are instructive but have little value as far as mobile telephony is concerned. Exposure near base stations poses, for K. Rothman, "formidable problems" of method and he expects little in the way of conclusive results from such studies, given the interference of many factors. Three studies concerning mobiles are presented – including one by the author of the article – and are considered inconclusive (doubts are expressed about the interpretation of the results of the Hardell study). The results of 3 other studies are expected, two in the near future (completed case-control studies) and the last one in several years time (the CIRC Interphone project).
The effect which is the most clearly established by epidemiology (3 articles presented) is the risk of accident when driving a vehicle, with excess risk of over 100 %.
The conclusion of the author is that it is too early to pronounce a verdict on the risks associated with mobile telephones, notably with regard to cancer. But K Rothman, basing himself on the scale of the risks envisaged (for brain cancer) or demonstrated (for accidents), estimates that even if mobile telephones were proven to represent a health hazard, the number of cases expected would be much lower than those due to accident.

[12] "The studies cited by ICNIRP contain sufficient evidence to conclude cause and effect between RF/MW and cancer across many body organs, especially leukaemia and brain tumours, and at chronic lifetime exposures showing dose-response relationships pointing to a Level of No Observed Adverse Effects threshold of about 20 nW/cm$^2$ ."

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***Radiofrequency exposure and mortality from cancer of the brain and lymphatic/hematopoietic systems.***
*Morgan RW, Kelsh MA, Zhao K, Exuzides KA, Heringer S, Negrete W. Epidemiology, 2000, 11 : 118-127*

A professional cohort in the Motorola company, where the probability of exposure to RF is greater than in the population as a whole, was monitored from 1976 to 1996. The RF under study were related to the telecommunications device production process and were not specific to the use of mobile telephones. With 195,775 workers and 2.7 million person-years of observation, this cohort represents the largest series available to date in the study of RF and mortality. The health variable studied was mortality, by cause of death, paying particular attention to brain cancer, lymphoma and leukaemia, among 14 causes of death due to cancer.
A detailed analysis of the professional history of these employees, using company records, made it possible to categorise them by level of exposure (nil – that is to say equal to the general population – weak, moderate, and strong) and duration: a study was carried out to validate the job-exposure matrix developed for the study, comparing the classification obtained in this way with on-site measurements. Two mortality comparison systems were adopted: external, with the population at large of the 4 American states in which most of the plants studied were located (calculation of the SMR), and internal, the most valid system, by comparing the exposure categories within the cohort itself. The very elaborate statistical analysis made it possible to take into account different factors of latency and length of service in the company.
Overall, neither the external comparisons (a strong 'healthy worker effect' was observed, with an SMR 'all deaths' of 0.66 [IC95%=0.64-0.67)], nor the internal comparisons (by level, duration, mode – usual, maximum or accumulated value – seniority, or latency of exposure) suggested that RF exposure played a role, notably in the three causes of death which initiated the study.
Although this study provides no argument in favour of the existence of a risk linked with occupational exposure to RF in this population, the authors underline the modest proportion of people classed as being "moderately or strongly" exposed (about 9%), the small number of subjects who died (3.2 %), and the relative youth of Motorola staff and point out that, in their opinion, the possibility of long-term effects cannot be excluded.
In an Editorial in the same journal 32, RD Owen, the head of the Radiation Branch of the United States FDA, expressed his satisfaction with this study which he qualified as a 'beginning', pointing out that it is not possible, as things stand today, to extrapolate data from one RF band to another or to predict the existence or absence of long-term effects. He insisted on the need for further research, with focusing particularly on the conditions for estimating exposure, both in experiments and epidemiological studies.

***Case-control study on radiological work, medical X-ray investigations, and use of cellular telephones as risk factors for brain tumours.***
*Hardell L. Med Gen Med, May 2000.*

This was a population case-control study carried out in Sweden and concerning various risk factors for brain tumours. 209 subjects (men and women) with brain tumours (malignant or benign) and 425 controls were included in the analysis.
The cases, selected from the National Cancer Register, came from 2 different regions of Sweden between 1994 and 1996 (benign tumours were only considered in 1996) and the patients were alive at the time of their inclusion in the study. Anatomopathology reports were available for 197 cases (136 malignant tumours and 62 benign tumours).
The controls were matched by sex, age and region and were drawn at random from the National Population Register.
Exposure to risk factors was evaluated using a self-report questionnaire sent to the homes of the subjects (completed by a telephone interview if necessary). The collection and coding of the questionnaires and the additional telephone interviews were carried out blind with regard to case or control status. The risk factors concerned: professional factors (profession, exposure to ionising radiation for health workers, chemical exposure), radiological examinations, use of cellular phones.

***Possible health risks of radiofrequency exposure from mobile telephones.***
*Owen RD. Epidemiology, 2000, 11 : 99-100*

The results show some significant associations with certain professions and X-ray examinations of the head and neck (we will not comment on the results concerning these factors). As far as cellular-phone use was concerned, a significant association was observed (OR = 2.62 ; IC : 1.02 - 671), and confirmed after adjustment for all the risk factors, with the occurrence of tumours in the temporal or occipital zones and the temporo-parietal lobe on the side where the user habitually held the telephone (most exposed area of the brain). In contrast, no association was observed for tumours on the opposite side to the ear usually used or tumours in general, whatever their location. These results are based on 13 exposed cases (10 malignant tumours and 3 benign); 9 cases were exposed only to analogue telephones and 3 to analogue and GSM telephones.
Comments of the group of experts : *This high-quality study is extremely sound in various aspects: case and control recruitment in a population register, blind, standardised collection of data, inclusion of the main known or suspected risk factors in the brain.*
*The main arguments in favour of causality are a clear association, the fact that the main confusion factors were taken into account, the global quality of the study and, above all, the fact that the excess corresponds to the location at the greatest risk, in principle, and was not detected at locations further from the exposure, thus making the observed positive result biologically likely.*
*The principal limitations are the small number of exposed cases on which the results are based (although the study as a whole is of a good size). For this reason, it was impossible to take into account the analysis of exposure-effect relationships, nor the temporal aspects of exposure, nor the histological form of the tumours. The homolateral location of the cancer in relation to the declared use of the telephone is striking, but it is quite possible, given the conditions of the study, that this could be an artefact of the declaration.*
*In conclusion, this study provides arguments in favour of the causality hypothesis, but still remains too limited to go any further in this direction. In particular, it is not possible to exclude a potential bias in the statement of the usual side on which the telephone was used. The study is continuing and it will obviously be interesting to have more results and to compare them with the other studies published on the subject.*

***Handheld cellular telephone use and risk of brain cancer***
*JE Muscat, MG Malkin, S Thompson, RE Shore, SD Stellman, D McRee, AI Neugut, EL Wynder, JAMA, 284 (23), 3001-3007.*

This keenly-awaited article (it was presented in July 2000, by G. Carlo – who had contributed to its financing by the WTR - as "suggesting that there is a risk of brain cancer", in particular on the side on which the mobile is used[13], as the work of Hardell tended to show in 1999), was published in mid-December. It presents the results of a case-control study conducted between 1994 and 1998 in 5 university hospitals on the east coast of the United States, covering 469 subjects (aged from 18 to 80) suffering from brain cancer and 422 matched controls. Exposure to the waves associated with mobiles was characterised by a questionnaire and measured by the number of hours of monthly use and the number of years of use.
Compared to non-users, and after adjustment for confusion factors, the 'Odds Ratio' (OR: standard measurement for "excess risk") for cellular telephone use was 0.85 (IC95%: 0.6-1.2). The average length of use was 2.8 years for cancer sufferers, as compared to 2.7 years for controls. The ipso- or contra-lateral position of the cancer depended on the area of the brain that was affected. All histological types of cancer had an OR less than 1, except for one rare form: neuro-epithelioma (OR=2.1 [0.9-4.7]).

[13] *Scientific Progress - Wireless Phones and Brain Cancer: Current State of the Science. George L. Carlo, PhD, MS, JD, and Rebecca Steffens Jenrow, MPH, Wireless Technology Research, LLC Washington, DC, MedGenMed, July 31, 2000, Medscape.*

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The authors concluded from this work that there was no excess risk of brain cancer associated with the use of mobile telephones, but considered that further research was required, particularly to take longer periods of use into account.

***Cellular telephone use and brain tumors.***
*PD Inskip, RE Tarone, EE Atch, TC Wilkosky, WR Shapiro, RG Selker, HA Fine, PM Black, JS Loeffler, MS Linet. New England Journal of Medicine, 2001, 344: 79-86 (available on internet on December 19th 2000).*

This case-control study was carried out between 1994 and 1998, involving 782 patients with intracranial tumours (cancers of the brain, meningioma, and neurinoma of the acoustic nerve) and 799 matched controls (residence, age, and sex) with non-tumoral diseases, in three cities in the United States. This is the largest-scale study to date.
The cumulative use of a mobile telephone for at least 100 hours was not associated with the presence of a tumour (OR= 1.0 [IC95% = 0.6-1.5] when all forms of cancer were considered. This result varied depending on the type of cancer, but the relationship was never statistically significant, once the various confusion factors had been taken into account. The authors did not find any link between the presence of cancer and the intensity of use (over 60 minutes per day or over 5 years), or between mobile telephone use and the side the tumour was located.
As in the previous article, the authors concluded that, while their research did not show any link between mobile telephone use and brain tumours, it was not possible to come to a final conclusion concerning the consequences of long-term exposure (only 8 % of the patients had started using a mobile telephone before 1993).
In an editorial in the same journal, two leading specialists in cancer epidemiology expressed the opinion that this research should be considered reassuring as it confirmed other publications on the same topic, and was consistent with the weakness of empirical observations and the lack of a theoretical basis for carcinogenic effects unrelated to heat.

***Prevalence of headache among handheld cellular telephone users in Singapore: a community study.*** *Chia, S-E, Chia H-P, Tan J-S. Environ. Health Perspective, 2000, 108: 1059-1062*

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This cross-sectional, epidemiological study was carried out on a random sample of inhabitants in one part of Singapore, with the aim of comparing the prevalence of various subjective symptoms (headaches, dizziness, fatigue, loss of memory, etc.) with the subjects' use of mobile telephones (MT).
This population, consisting of 808 men and women between 12 and 70 years old, made very frequent use of mobile telephones (44.5 %). Special attention was paid to controlling bias in the selection and declaration of symptoms. Headaches were the only symptom significantly associated with the use of MT (OR = 1.31 [IC95%: 1.00-1.70]), with increasing prevalence in relation to the declared length of use (up to 1 hour per day). It was quite remarkable that MT users equipped with hands-free systems reported fewer headaches (41.7% if they used them all the time, 54.4 % for irregular users, and 65.4 for non-users). The authors envisage two etiological hypotheses: the effects of RF waves on the blood-brain barrier and on the dopamine-opioid system. In spite of the limitations of cross-sectional studies, particularly the difficulty of establishing the time sequence of the factors studied, this research indicates that RF may play a role in headaches in the general population. It remains to be determined whether, in view of the environment under study (electromagnetic radiation density, noise, atmospheric pollution, etc.), these results can be extrapolated to other situations. It should be noted that there is a high frequency of headaches in this population. For example, in the French GAZEL cohort (40-60 years old), the rate (prevalence over the previous 12 months) was on the order of 15-20 % in men and 33-38 % in women.

***The Possible Role of Radiofrequency Radiation in the Development of Uveal Melanoma.***
*Andreas Stang, Gerasimos Anastassiou, Wolfgang Ahrens, Katja Bromen, Norbert Bornfeld, and Karl-Heinz Jöckel. Epidemiology, Volume 12, Number 1, January 2001,*

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A very recent article published in the journal "Epidemiology", presenting the findings of a case-control study carried out by a German team, examined the relationship between professional exposure to various sources of EMC, including RF, and the occurrence of uveal melanoma, which affects eye tissue between the cornea and the crystalline lens. In a series of 118 cases and 475 controls, an excess risk associated with RF from mobile telephones was identified (OR = 4.2, IC95% = 1.2-14.5).
*Although this scientific journal has a good reputation, the group of experts could not asses this work as they only had access to the abstract, and not the full text of the article.*

General conclusion of the group of experts on recent research: *Recent literature does not make any clear departure from previously available information. Publications describing experimental work give further details concerning the effect of exposure on certain cognitive functions in both animals and man. Is this a 'microthermal' effect? Does it involve hormonal phenomena? It is difficult to say in the current state of knowledge, just as it is impossible as yet to conclude that prolonged and/or frequent exposure to these phenomena represents a real risk to human health. However, these results will certainly be considered in light of the epidemiological study in Singapore, which suggests quite convincingly that intensive use of mobile telephones may lead to headaches. As the protocol of this study was relatively unsophisticated, the findings should be confirmed and validated using other approaches, under different circumstances, before they are considered hard evidence.*

*Publications describing the appearance of micro-nuclei in cells exposed to RF should also be replicated. They were not the first to study the effects of relatively long-term exposure (24 hours continuously, or even several days), but the other studies produced negative results*[14]*. However, while such long-term uninterrupted exposure is not very realistic in comparison with everyday use, it does offer ways of investigating the effect of repeated exposure, as the cumulative effects are not very well known. Ongoing research is currently exploring this aspect.*

*The various epidemiological studies investigating the risk of brain tumours are in agreement and do not conclude that RF plays any role in the development of these forms of cancer, under present observation conditions, i.e. after relatively short induction periods (maximum: 5 to 6 years). While these results are reassuring, they do not exclude the possibility of long-term effects. They do not, however, give any indication that such effects exist.*

[14] *Particularly: Adey et al. (1999): Spontaneous and nitrosourea-induced primary tumors of the central nervous system in Fischer 344 rats chronically exposed to 836 MHz modulated microwaves. Radiat Res.152(3):293-302; and: (2000) Spontaneous and nitrosourea-induced primary tumors of the central nervous system in Fischer 344 rats exposed to frequency-modulated microwave fields. Cancer Res. 1;60(7):1857-63.*

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The report directed by W. Stewart recommended that children (under 16 years old) should be discouraged from using mobile telephones, unless it was absolutely necessary. This opinion was based on the following main arguments:

- the exposure dose received by a young child's brain is considered to be higher than that received by an adult, if the cellular telephone is emitting the same power,
- children are considered to be more sensitive to external agents than adults,
- children's cumulative exposure will eventually be greater than adults', as mobile telephones have only recently come into use.

The group of experts also studied this important issue.
No facts have yet been clearly established concerning the greater dose absorbed by children's heads due to their smaller size. Research by Gandhi's team (1996) at the University of Utah concluded that the SAD received by the brain of a 5 year-old child at a frequency of 835 MHz was 3.3 times higher than that received by an adult, while the ratio was 2.2 for a 10 year-old child, and there was no age-related difference at 1900 MHz. In 1998, Schönborn et al. carried out a new modelling and simulation study at the same frequencies, but using brain phantoms that were more representative of the children (3 and 7 years old, respectively). The findings contradicted those of Gandhi et al. Among their criticisms of the earlier research, these authors indicated that the models used were merely proportional reductions of adult brains, which do not really correspond to children's brains. Other authors (Kuster and Balzano [1992], Hombach et al. [1996], and Meier et al. [1997]) agreed with Schönborn et al. Another experiment that Stewart seems to have taken into account was carried out on rats of different ages (Peyman et al. 2000)[15]. It showed differences between the dielectric constants of the brain, salivary glands, and muscle mass of rats 10 and 20 days old, but there was no further reduction in conductivity in rats over 20 days old. It is very difficult to extrapolate these (unpublished) findings in animals to age differences in humans.
The other arguments presented by W Stewart et al. are discussed and explained below. The age at the time of the initial exposure can certainly affect the risk of developing a delayed pathology in the long term. The major risk is cancer, but any delayed effect may present the same characteristics. Cancer epidemiology offers arguments that the age at the time of initial exposure may affect the risk level for various reasons.

- *Greater sensitivity*: children may be more sensitive than adults to the carcinogenic effects of exposure for reasons related to development (developing tissue, etc.) and physiology (greater activity is accompanied by higher absorption, although the relevance of this parameter for RF radiation is not obvious). Perhaps the best-established example is that of tobacco: the younger a person starts smoking, the higher the risk of lung cancer, all other exposure conditions being equal (average quantity, cumulative dose, etc.). There are, however, also some counter-examples. In the case of asbestos, all the available findings show that age at the time of exposure probably has no effect, so the risk is the same whether the first exposure occurs during childhood or adulthood.

- "*Mechanical" effects of time:* whether or not there is any greater sensitivity during childhood, the "lifelong" risk of developing a cancer caused by exposure is increased if exposure takes place early in life. This is due to a combination of two phenomena that have a cumulative effect: *(*i) in general, the earlier the exposure, the higher the cumulative lifelong exposure will be (if exposure is continuous: this is obviously not true if exposure stops or decreases over time): the relevant parameter for quantifying cancer risk is generally cumulative exposure levels; *(*ii) the earlier the exposure the more time is "available" to develop an effect related to this exposure. This is all the truer if there is a long latency period between exposure and the occurrence of the effect. For

[15] Peyman, Rezazadeh and Gabriel, poster presented at the annual meeting of the BEMS (BioElectromagnetics Society), in Munich, 9-14 June 2000. "Changes in the dielectric properties of aging rat tissues".

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example, there is almost no risk of developing a mesothelioma of the pleura if even very intense exposure to asbestos occurs after the age of 80, as the average latency period is approximately 35 years and the person will probably have died before a mesothelioma has had time de develop. Inversely, if exposure occurs very early, the risk will be much higher, even though children do not seem to have any intrinsically increased sensitivity, as mentioned above.

These arguments should be tempered by the fact that the hypothesis on which they are based is that exposure will be continuous over time. It is, however, clear that, as radiocommunication technologies develop, unit radiation tends to decrease. In particular mobile telephones will soon cease to be in close proximity to users' heads (see paragraph on technological developments in chapter II), although the increasing number of radiation sources in our everyday surroundings may offset this positive trend.
**These data led the group of experts to recommend an attitude "of careful avoidance", although they did not consider that currently available scientific data justified any restrictive legislation.**

## CONCLUSIONS OF THE GROUP OF EXPERTS ON HEALTH HAZARDS AND RECOMMENDATIONS FOR REDUCING EXPOSURE OF THE POPULATION TO RF ELECTROMAGNETIC FIELDS

The group of experts' brief was to express an opinion on the available scientific data and make recommendations in the field of public health. This put the group in a situation that went beyond the usual role of scientific experts, whose expertise relates to risk assessment. The group of experts accepted this mission. Thus, in this chapter, the group of experts present their conclusions on health protection, based on all the information they obtained and analysed. This included several summary reports, as well as the most recent scientific research, and opinions expressed by the personalities they interviewed. The first paragraph sets out the salient points on which they based their rationale, and the remainder of the chapter consists of their recommendations.

**Salient points:**

- International regulations, inspired by the work of the International Commission on Non-Ionizing Radiation Protection (ICNIRP), are based solely on scientifically demonstrated biological effects corresponding to health hazards. In the RF range, these consist of **certain effects due to heating** generated by dielectric absorption. Starting with the lowest exposure levels that cause the most significant effect in animals, lapse factors – described as 'reduction factors' – have been applied to transpose these values to the human species, considering people exposed to this radiation in the course of their work as well as the general public. This is expressed in units of a suitable physical magnitude, the Specific Absorption Rate (SAR), which was used to define the 'basic restrictions' in the European Union recommendation dated July 12$^{th}$ 1999. These correspond to exposure levels for the public.

- Current scientific data, however, indicates that a variety of **biological effects** occur at energy levels that do not cause any rise in local temperature. In the current state of knowledge on these **non-thermal effects**, it is not yet possible to state whether they represent a health hazard.

- Is it possible to state that there are no health risks ? No: although few scientific arguments are available to back up this hypothesis, it is not possible to eliminate the possibility of **non-thermal health hazards** associated with low level RF fields on the basis of our current state of knowledge. Furthermore, some potentially serious effects (e.g. promotion of brain cancer) are currently the subject of large-scale, international, epidemiological research which will not produce conclusions for several years. Research is also continuing into other potential effects (e.g. damage to hearing or the nervous system, and headaches).

- If future research were to validate this hypothesis, i.e. demonstrate the existence of health hazards related to the usage of mobile phones, the probability, on an individual level, would certainly be very low. Indeed, it is reassuring to note that no risk has yet been demonstrated, in spite of the considerable amount of work done over the past several years. However, if there were a risk, the very high number of mobile telephone users could mean that, even if the individual risk were very low, the impact on public health could be substantial. In view of this, would it not be prudent to set new exposure 'standards' at lower values immediately, without waiting for the results of ongoing research ? The group of experts consider that measures of this type would be justified if they were really effective in reducing potential risks. This implies, firstly, that the medical effects resulting from exposure to RF fields could be identified and secondly, that new values could be defined that would guarantee reduction, or even elimination, of this risk. **This is not the case in the current state of knowledge**. There is not, at present, any reliable scientific information that could be used to adjust and scale such measures. Therefore, any new threshold limit exposure values proposed would be unscientific, arbitrary, misleading, and would probably differ from one manufacturer or country to another, thus adding to public confusion and concern.

- It has been conclusively established that using a mobile telephone while driving, whether with a hands-free kit or not, is a **real accident risk factor**. This risk is not associated with electromagnetic fields, but is due to the loss of concentration resulting from the telephone conversation. This is a major risk, in terms of both frequency and seriousness.

- Mobile telephony has also been identified as a factor in security and medical safety (by speeding up calls for help and, thus, the arrival of emergency services, etc.). This means of communication also has other advantages that were not covered by the group of experts' brief.

**Consequently, the group of experts make the following recommendations:**

1- They recommend adopting **an approach based on the precautionary principle** to manage any potential risks associated with mobile telephony. The precautionary principle is understood as described in chapter I of the report. The general overall objective should be to **reduce average exposure of the public to the lowest possible level compatible with service quality**. The following aspects should be taken into account in implementing this principle:

   a- More intensive research into the biological and medical effects of exposure to RF is required, to reduce the uncertainties and elucidate points on which information is lacking. Research priorities and organisational recommendations are presented in the following chapter.

   b- Users should adopt **prudent avoidance measures** - simple steps aimed at reducing superfluous exposure (e.g. minimise the use of mobile telephones when reception is poor, use an earpiece kit, and avoid carrying mobile phones close to potentially sensitive tissue – i.e. a pregnant women's abdomen or an adolescent's gonads).

   c- Manufacturers should continue their efforts to **reduce mobile telephone emissions to the lowest possible level** compatible with service quality.

   d- The objective of reducing public exposure to a minimum is particularly important for potentially sensitive populations, including children and sick people. For this reason, the group of experts recommend that **'sensitive' buildings** (hospitals, day care centers, and schools)**, located less than 100 metres from a base station, should not be directly in the path of the transmission beam**[16]. This recommendation is not incompatible with the installation of a base station antenna on the roofs of buildings in this category, as the incident beam has little or no effect on the area immediately below it ("fountain" effect). The group of experts feel that, if operators apply these measures, public fears, especially those of parents concerned by their children's exposure in school, will be allayed, especially keeping in mind that, in view of the exposure levels observed, the group of experts does not back the hypothesis that there is a health risk for populations living in the vicinity of base stations.

   e- Children are theoretically a high-risk population. In the current state of knowledge, it does not appear that the sensitive organs inside children's heads receive a higher dose of microwaves during a phone call than adults do. However, if they start using mobile telephones at an early age, the cumulative exposure over their lifetime will be higher than that of today's adults (however, the constant, rapid changes in technology may lead us to reconsider this reasoning). There is no scientific data establishing any risks due to long-term exposure in adults or children, but neither is it possible to eliminate that possibility, in the current state of knowledge. For this reason, the group of experts suggest that parents who feel it is necessary to equip their children with mobile phones should ensure that they make reasonable use of this

[16] The limit of the beam is reached when the field power has decreased by a factor of two. This beam is defined in the horizontal axis and in the vertical axis.

equipment. A recommendation to this effect should be included in the instructions for use supplied with all mobile telephones.

f- Exclusion areas in the immediate vicinity of base stations, where access is prohibited, must be clearly marked, with a system of logos applicable throughout Europe.

g- The group of experts do not support the proposal in the Stewart report concerning the installation of antennas run by different operators in the same area at a single base station. In keeping with the objective of reducing public exposure to the lowest possible level, the group noted that calculations have shown that, while concentrating or dispersing antennas does not affect **average exposure**, installing several in the same place would tend to **concentrate the electromagnetic fields in space**, and, therefore, lead to a more heterogeneous exposure for the population. The group is aware that this point of view may be in contradiction with concerns for landscape preservation, but feel that this problem can be solved by additional efforts to integrate (or hide) these antennas in the landscape, at a relatively moderate cost to operators.

The group of experts felt that consideration of the proposal in the Stewart report concerning a **mediation organisation** to monitor the installation of base stations was not part of their brief. They do not endorse the hypothesis that living in the vicinity of base stations poses a health risk. Furthermore, they felt that aesthetic or economic issues involving base stations were outside the scope of their mission.

*The group of experts emphasises that the prudent attitude they recommend, in the current state of knowledge and uncertainties, does not in any case constitute a validation of the health hazard hypothesis. It is, rather, a matter of advice based on common sense, justified by the existence of a "reasonable doubt", pending further scientific investigation.*

2- The public authorities should provide incentives for the implementation of these principles by all the stakeholders.

a- The European Commission's July 1999 recommendations should be applied in national legislation as soon as possible, to clarify the situation for all those involved.

b- Mobile telephone users should be able to find out the extent of their exposure[17]. This requires two types of measures:

- Information on the power of mobile telephone emissions and on the local SAR in users' heads, measured under standardised conditions, should be provided with every mobile telephone purchased. This will facilitate a comparison between mobile telephones, taking into account radiation efficiency, which affects local SAR.
- Telephone displays should inform users of the emission strength during conversations, expressed in a simple way (e.g. % of maximum power, averaged over the duration of the last telephone call). This would have an educational effect, showing users that making telephone calls under poor reception conditions increases the radiation they receive quite significantly.

c- The public should be able to find out the usual exposure in the vicinity of base stations. Several measures would be required to implement this principle:

- The 'Agence Nationale des Fréquences' (ANFR – National Frequencies Agency) should establish standardised rules for measuring electromagnetic fields in the vicinity of base stations (prepared in the context of European protocols), as soon as possible. These rules

[17] It is recalled that exact exposure cannot be directly measured and must be estimated according to some standardised parameters. True exposure varies considerably according to the environment and the antenna position. Estimation procedures are under standardisation.

should be adopted by all technical monitoring organisations authorised to carry out these measurements.

- An obligation to transmit the results of these measurements to the national monitoring authority, presently the ANFR, should be included in the specifications of all organisations authorised to carry out these measurements.
- Regular measurement campaigns carried out according to an annual, long-term programme, on the initiative of the ANFR, using a sampling schedule taking population density into account, in order to define maximum population exposure values (closest buildings in base station emission beams)[18].
- The ANFR should set up a register of results per site for all their own measurements and those carried out by authorised private organisations, in the form of a data base accessible to the public via Internet. The ANFR should publish an annual report summarising the field levels measured throughout the entire country.
- The 'Groupe interministériel RF' (Interdepartmental RF Group) should issue the set of technical specifications for the installation of base stations as soon as possible. This is currently in preparation at the CSTB and its application should be made compulsory. These national specifications should soon be replaced by a standardised European reference manual.

3- In view of the frequency and seriousness of accident risks, there should be more driver information on the danger of using mobile telephones while driving, with or without a hands-free kit, and traffic laws on this subject should be made stricter. A national information campaign on this theme should be launched in 2001.

4- The public should be given more extensive information on issues of legitimate concern.

a) The informative document currently being prepared by the 'Groupe interministériel RF' (Interdepartmental RF Group) to explain the physical and biological phenomena associated with mobile telephony should be completed and circulated to the general public as soon as possible. In particular, it is necessary to explain that exposure to the electromagnetic field of base stations is insignificant compared to that associated with mobile telephones themselves, even considering the exposure of the closest neighbours of the base stations under the most unfavourable emission conditions.

b) It is recommended that people who have electronic implants (pacemakers, insulin pumps, neurostimulators, etc.) carry their telephone at least 15 cm away from their implant and hold it to the ear on the opposite side when they call. If these measures are applied, the use of mobile telephones should not present any risks. The group of experts noted that technical research into electromagnetic compatibility is continuing, particularly to deal with new technological developments in RF, which will use different ranges of frequencies.

c) The group of experts do not recommend that users equip themselves with "anti-radiation protection" systems, which have by no means proved their effectiveness.

5- The group of experts were not asked to examine the issue of exposure to RF in occupational situations. However, they recommend that appropriate steps should be taken and their implementation monitored by the labour inspection department and CRAM specialists, to ensure that maintenance and repair operations at base stations are carried out only when the installation is shut down. This recommendation is consistent with the concern to reduce exposure of the population – including workers – to the lowest possible level compatible with service quality.
The Royal Society of Canada report recommended the reduction of local exposure limit thresholds for workers to the same values as those applicable for the public. The group of experts consider that this issue should be settled by *ad hoc* occupational risk management committees in France and the European Union. They are in favour of the recommendation in the British report that

[18] It follows from this sampling approach that average population exposure will be much lower than these values.

recordings should be kept for certain categories of highly-exposed workers, for epidemiological monitoring purposes.

6- In compliance with the rules recently laid down by the European Union governing the application of the precautionary principle, a report on all available scientific data should be prepared regularly by an *ad hoc* scientific body recognised by the Union, in order to examine whether there are grounds to modify legislation on the exposure of the general public and workers to electromagnetic fields associated with the radiofrequencies used by mobile telephones and base stations, and make appropriate recommendations to the political bodies responsible for these matters.

## RESEARCH RECOMMENDATIONS

The majority of the scientific work mentioned and analysed in this report is only indirectly linked with the use of mobile telephones. The other data is often contradictory, making comparative analysis of the results difficult, or even impossible, due to the diversity of protocols and equipment used. These factors mean that assessments of the potential health risks of mobile telephones can easily have a subjective bias.
It is also clear that some experts analyse the experimental findings through an implicit filter, assuming that the biological effects of GSM microwaves must be due solely to an increase in temperature in the tissues, whereas other analyses envisage the possibility that microwaves may have non-thermal effects, even if the precise mechanisms involved cannot be explained scientifically at present. Depending on the importance given to experiments aimed at demonstrating non-thermal effects, the main lines of research envisaged by the various groups of experts were quite different.

***In view of these prefatory remarks, the group of experts make three general recommendations concerning research to be started or completed, investigating the biological effects of GSM microwaves:***

- Experimental protocols and equipment should be standardised as soon as possible, following discussion on a national and international level. This will facilitate comparison of the findings of different studies (this is only partially being done in the context of the WHO's EMF programme);
- in view of the very slight heating of tissues observed with mobile telephones in normal use, special effort should be devoted to investigating effects that cannot be directly explained by the thermal activity of microwaves *(in vitro* and *in viv*o);
- to reduce the risk of error or imprecision in interpreting results, a comprehensive "monitoring" of the contingent physiological variables should be included in all new protocols (stress assessment in animals, checking the vigilance of subjects during EEG studies, etc.), particularly those for *in vivo* experiments on animals and humans. This is especially true of experiments designed to demonstrate or confirm non-thermal effects of microwaves (low- or very low-power exposure).

Furthermore, a review of all the available scientific literature shows that a number of research fields have received little or no attention. This is particularly the case of:

- a possible synergy between the effects of microwaves and certain pre-existing or concomitant chronic or acute pathologies (particularly skin and neurological conditions),
- the effect of microwaves on certain tissues that are directly exposed to varying degrees (meninges, blood vessels, skin, etc.) under prevalent conditions of use (telephone held to one ear), or probable future conditions related to the implementation of new technologies like Bluetooth (telephone attached to a belt or carried in a pocket, which leads to exposure of the skin, peritoneum, viscera, and sexual organs). Particular attention should be given to the potential impact of RF on certain resident immune cells active in a number of pathologies affecting the skin, aponeuroses, meninges, and viscera and involving inflammation and/or pain (mast cells), both *in vitro* and *in viv*o.
- the particular effect of GSM waves on growing organisms and tissues (embryos, foetuses, children, and adolescents);
- the possible effect of base stations during "full body" exposure at average or relatively strong intensities (installation and maintenance staff).

The group of experts felt that the major topics described in detail below should be given top priority.
Some of them require preliminary dosimetric studies. It is also important to keep up with new developments in this technology and start research now into the potential effects of the new frequency ranges that will be used in the near future (UMTS, Bluetooth, etc.).
Finally, the lack of epidemiological studies other than those targeting mobile phones as a possible cause of brain cancer indicates a need for different types of research aimed at identifying the possible

effects of GSM microwaves on other pathologies, particularly headaches, either in "ordinary" users or those with physiological conditions likely to make them more sensitive to such effects.

The group of experts also made several specific research recommendations.

**1- Studies of biophysical interactions**

The COST 244b report recommended that large-scale work modelling these interactions should be carried out prior to research in this field. It is obviously necessary to make a precise determination of the type of field on a molecular level in order to predict its macroscopic effects, which are based on the microscopic ion-ligand and membrane proteine interaction models.
This research may lead to an investigation into the cell mechanisms for detecting RF fields (this work should initially concentrate on cells in the nervous systems of certain vertebrates that are sensitive to magnetic fields).

**2- In vitro studies**

The biological effects of RF waves observed *in vitro* to date are of very small amplitude, which perhaps explains the difficulty of reproducing them experimentally. Furthermore, if these effects were confirmed, it would still be difficult to determine their possible health consequences.
By definition, *in vitro* studies observe isolated systems that do not take even the most elementary interactions between the organic element studied and the rest of the system into account.
However, *in vitro* research is useful for studying the action of microwaves on single-cell models (bacteria) and some cells isolated from animal and human organisms (starting with immune and germ cells). These are justified in three specific cases: 1) replication of earlier positive experiments, 2) observing organisms that are difficult to study in any other way, and 3) studying mechanisms that have not yet been investigated at all.

In these three categories, the following points should be highlighted:

- studies of the genotoxicity of microwaves (there are too few publications to form a definite opinion). Among the experiments that should be replicated, for example, is the "micro-nuclei" test where the frequency provides an evaluation of the number of damaged chromosomes. Another is the "comet" test, where fluorescence microscopy is used to identify fragmented DNA (although a recent replication of this test in a French laboratory produced negative results),
- the effect of microwaves on apoptosis or " programmed cell death" (no published work),
- gene expression (C-fos and C-jun) and nucleic acid synthesis. It is also important to replicate recent experiments on worms showing that radio-frequencies modify the expression of "heat shock" proteins without any increase in temperature using cultured human cells. In fact, these proteins react to all types of cell "stress",
- changes in the synthesis and/or storage of neurotransmitters (brain slices);
- the effect of microwaves on intercellular transmission (brain slices);
- phenotype and functional modifications in immune cells (cultured cells).

*In general, all of the above experiments should be repeated in the presence of chemical and physical (ionising radiation) mutagens to identify any interaction between these agents and radio-frequencies.*

*In vitro* studies of the effect of microwaves on the functional characteristics of inner ear hair cells are justified due to the difficulty in carrying out *in vivo* research (relative appreciation of the possible influence of microwaves on the various stages in the nervous system, from these cells to the primary auditory cortex, and effects of prolonged exposure on their survival).

**3- Animal studies**

*The difficulties in comparing the results of different experiments mentioned in the introduction to these recommendations are particularly acute in animal research. There may be considerable differences in experimental conditions (exposure system, whether or not the animal is anaesthetised, evaluation of the SAD, etc. ) and some of them had crucial gaps, such as not taking certain potentially important co-factors into account, including the stress of tightly-restrained animals and the effect on their humoral, circulatory, or neuro-physiologicqal condition. For this reason, a certain number of these investigations should be repeated using stricter experimental protocols and these physiological variables, or at least a good index for these variables, should be taken into account in analysing the results.*

It is also true that several particularly important fields have received little or no attention, although some are currently under investigation, e.g. in the French COMOBIO programme.

*Among the data requiring confirmation, the group of experts give priority to the following topics:*

- effect on induced tumours (at SAD levels corresponding to GSM). Some controversial, isolated experiments have shown that radio-frequencies may reinforce the effects of certain carcinogens or promote growth in transplanted tumours (cf. ICNIRP 1996, Repacholi 1998, Moulder and coll. 1999, Royal Society of Canada 1999);
- effect on DNA. Lai and Singh's work (1995), showing DNA damage in animals exposed to radar waves, requires validation;
- replication of experiments showing memory disorders in rodents, using behavioural tests better targeted to assess different types of memory;
- effect on synthesis of neurotransmitters and their receptors in the brain;
- effect on neuron excitability (EEG, use of C-fos and C-jun markers);
- replication of studies investigating the permeability of the blood-brain barrier (relatively large number of contradictory experiments at poorly-defined SAD levels, with no monitoring of circulatory functions, using a variety of techniques to measure extravasation, with differing levels of sensitivity that makes them difficult to compare);
- effect on the inner ear. Intense radio-frequency fields produce an auditory perception ("click") that is interpreted as being due to a temporary increase in temperature that produces a shock wave in the inner ear. No other effect has been shown to date and, to our knowledge, none of the published work investigated the effects of transmissions at power levels compatible with mobile telephones, although there is one ongoing study in France. In particular, it would be advisable to study the potential effects of these transmissions in conjunction with the "normal" acoustic stimulation involved in using a telephone, taking into account the increase in temperature due to holding it against one ear (independently of any thermal effect due to microwaves as such).
- long-term impact of repeated exposure on the appearance of cancerous tumours and immune and endocrine system functions.

*Fields that have received little or no attention to date:*

- synergy with other types of radiation (UV, ionising radiations, etc.) or chemicals with known teratogenic, carcinogenic, or immunosupressor effects;
- synergy with chronic or acute pathologies (particularly certain inflammatory conditions 55, neuro-degenerative diseases, epilepsy, and the effect of alcohol or drugs);

55 On this subject, we note that there have been no complaints from users suffering from chronic skin diseases, such as eczema or psoriasis, that affect the immune and nerve cells primarily involved in other inflammatory pathologies, such as migraine, where the occurrence of attacks can be exacerbated by GSM microwaves. If GSM microwaves are capable of acting on these deep cell systems (meninges), they should *a fortiori* have an even greater impact on these same cells located on the surface, as they are exposed to a much greater degree. In the same way, to our knowledge, there have

been no particular complaints from patients with vascular facial pain or characteristic neuralgia such as that caused by damage to the sensory nerves linked to the trigeminal gland.
- effect of RF on animals predisposed towards certain pathologies (cancer, high blood-pressure, immune deficiency, etc.) or those that have been genetically modified (knock-out for certain genes);
- effect on skin, paying special attention to melanocytes and resident immune cells, i.e. mast cells;
- effect on the meninges (especially the dura mater, described as the site of migraine diseases, also considered to be the lymphoid organ that protects the brain);
- long-term effect on the structure and functions of blood vessels in the skin, meninges, and brain (paying special attention to the endothelium);
- effect on digestive tissues, gonads, and germ cells, in view of the likelihood that GSM's will increasingly be worn on belts. For the same reason, research should be extended to include the effect on embryos and foetuses (exposure of pregnant women). It is particularly important to replicate the study by Magras and Xenos (1997) that demonstrated a decrease in female fertility following exposure to low-intensity signals;
- general application of these research fields to immature animals (more suitable for representing the susceptibility of children or adolescents).

**4- Human laboratory studies**

Any of the studies described below that are carried out in France will be required to comply with the 1996 law on Bioethics and obtain approval from a CCPPRB.
The proposed research should be carried out using both healthy volunteers and patients with a diagnosed pathology suspected of affecting the impact of GSM microwaves and other frequency ranges under development on health. In most cases, these experiments will be designed to answer questions raised by animal research using non-traumatic techniques available in laboratories or hospitals.

*Exposure of healthy volunteers:*

- EEG (EEG and magnetoencephalography);
- neurotransmitters (positron-emission tomography);
- immune and humoral systems (blood test);
- sleep;
- memory and cognitive tasks or tasks involving targeted associative brain regions;
- Immediate and delayed effects (repeated exposure) on sight and hearing;
- cardiovascular system. In particular, the experiment carried out by Braune and coll. (1998), showing that a 35-minute exposure (with the telephone on the right side of the head) caused a significant increase in arterial blood-pressure, accompanied by a decrease in heart rate and capillary perfusion in the hand (signs of an increase in autonomous sympathetic nerve activity), should be reproduced with a larger number of volunteers.

Part of this research should consist of non-invasive investigations, involving children and adolescents, as well as patients with mild pathologies that may be aggravated (or attacks may be caused) by the use of GSM, if this is ethically acceptable. These would focus particularly on migraine, rheumatism of the joints, and inflammatory skin diseases, such as eczema and psoriasis (which have not yet been studied, to the best of our knowledge). It is also important to study the effects of mobile phone use on patients with more serious pathologies: neurological syndromes (epilepsy, non-consolidated cerebral infarction, and chronic or acute cerebral circulation disorders), cardiovascular problems (high blood pressure), and ear or eye diseases (maculopathy, glaucoma, etc.). In this field, we emphasise that special attention should be given to the risk of epilepsy in children and young adolescents. If the use of mobile telephones were shown to increase the risk of epileptic seizure, the fact that the inhibiting mechanisms in young people's brains are not completely developed should be taken into account, as it further aggravates this risk.

The same studies should also be carried out with a group of people who consider themselves hypersensitive to radio-frequencies, although no specific pathology has been identified, as well as another group suffering from subjective symptoms (headaches, hot flushes, and attention or memory disorders) associated with the use of mobile telephones (see study reports from Scandinavia and Singapore). Double-blind studies could be carried out on these groups, with or without exposure to GSM waves, under otherwise identical experimental conditions.

The group of experts also recommend that research should be carried out to identify a possible nocebo effect, due to extensive media coverage of the potential dangers of mobile telephones. The specific arrangements and protocol for such a study have not yet been defined, but it could, for example, involve a group of healthy volunteers of the same sex and age group, identified by a survey as being convinced that GSMs are harmful or not. These volunteers would be exposed to microwaves and subjected to the analyses described above.

**5- Epidemiological studies**

Apart from the risk of traffic accidents related to the use of mobile telephones while driving, which is both clearly proven and serious, the other effects on human health are still only hypotheses, backed to varying degrees by scientific arguments. It is therefore necessary, as recommended by all the committees that have examined this issue, to develop further epidemiological research, especially as some of the effects envisaged are serious, due to their intrinsic severity and/or the high number of cases potentially attributable to the use of mobile telephones.
Recommendations for epidemiological research should distinguish between the different types of expected effects, particularly separating cancer from benign, short-term effects (headaches, migraines, sleep disorders, "radio-frequency syndrome", etc.). There are considerable differences between protocols for epidemiological studies, including methods, feasibility, and cost, depending on the effects to be studied.

*Benign, short-term effects*
The main priority should be given to studying exposure to mobile telephones, rather than the proximity of base stations, as the latter represent very low exposure levels.

A variety of protocols may be used: cross-sectional, case-control, and prospective cohort studies.
*Cross-sectional studies* are relatively easy to organise and may be completed in a short time at low cost, but they have severe limitations in terms of causal interpretation. They may lead to hypotheses, but never produce definite conclusions. Use data from operators for the same subjects would strengthen the validity of these studies. A cross-sectional study based on a sample where participants living close to base stations were clearly identified would be useful for generating hypotheses, or disproving effects that are currently described without any scientific basis.

*Case-control studies* are also difficult to interpret if they do not follow a particularly strict protocol to avoid biased information, because the subjects under consideration are more likely to attribute their disorders to the use of telephones at a time when the effects of telephones are under close media scrutiny.
*Prospective cohort studies* (contemporary) are the best suited, as they study highly varied effects, as well as the development over time of telephone technologies and methods of use – if the monitoring period is long enough. The suspected benign effects are frequent and short-term. Because of this, it is not necessary to set up very large cohort studies, and reliable results can be obtained quite quickly, especially if data about the actual use of mobile phones is available from operators. Existing prospective cohorts could be used, such as SUVIMAX or GAZEL, with the addition on specific studies of the effects of mobile phones. This would present several advantages (savings and speed), as they are already in place and some of them have already had data collected on these effects for several years. This methodological approach could easily and economically include studies on “well-being”, as recommended by the Stewart report.

Fragile or sensitive groups should be subject to specific studies, as should subjects who are highly exposed in their professional environment. Alongside general population studies, it would therefore be wise to propose studies focusing on children, adolescents, and migraine sufferers, as well as studies within suitably selected companies or professions.

*Traffic accidents*
Although the risk of accidents caused by the use of mobile phones while driving vehicles is both clear and high, the group of experts recommends new epidemiological research in France, for two reasons: *(*i) it would be useful to have epidemiological data comparing the risks involved in the use of hands-free telephones with those of conversation with a passenger, in order to confirm the results of experimental work on this point; and *(ii*) in terms of prevention, the results obtained in the national context would obviously have a greater impact on the public (and the public authorities), leading to a more effective implementation of the necessary measures.

*Cancer*
As far as the base stations are concerned, the available data gives no indication of a real risk. Nonetheless, owing to demand, the group of experts would recommend verifying this point, if possible. However, none of the epidemiological methods available (ecological, case-control, or cohort) are capable of producing valid information due to the infinitesimal nature of the risk, if it indeed exists, and the large number of potential confusion factors.
Several types of study can be carried out on mobile phones: ecological studies, population case-control studies, cohort studies, and registers of exposed subjects. *Ecological studies* do not seem to be appropriate in the current state of knowledge.

*Population case-control studies* are clearly the preferred protocol at present in attempting to provide rapid answers to questions about the carcinogenic effects of using mobile phones. As hands-free kits have only relatively come into use and we do not have sufficient hindsight, this retrospective approach can only concern tumours of the brain, acoustic nerve, and salivary glands. As the results of the huge, ongoing CIRC study (‘Interphone' project, a case-control study on tumours of the brain, acoustic nerve, and – although not in France – parotid gland) in 13 countries, with a number of cases guaranteeing excellent power, will be available in 3 or 4 years, it is unreasonable to propose developing new studies of this type in France, especially as a French team is taking part in this international CIRC study. The funding of the French part of this study should be carefully examined.
On the other hand, it is important to stress the importance of the large-scale *professional mortality cohort studies* being carried out in various countries. This type of study is relatively easy to set up in France, thanks to the many measures available for monitoring mortality.
The context is also theoretically favourable: many large companies have computerized personnel files including full professional histories, and a number of technical and research teams have good knowledge of exposure to radiofrequencies and other potential carcinogens. However, it will be necessary to implement measures to guarantee the methodological quality (no in-house epidemiological teams exist) and independence of the research. Certain categories of ‘highly exposed’ workers, as recommended in the Stewart report, could be recorded in parallel with the constitution of professional cohorts to form the base of a study, even though it would be wise to supplement them with other types of users. These registers should obviously be coupled with monitoring of mortality by cause.
The idea of a *population cohort* proposed by the Stewart report would seem difficult to implement in terms of the risks of cancer, owing to the enormous number of people that would have to be monitored over many years. In any case, this sort of effort is only conceivable on an international scale (it should be remembered that the CIRC, quite rightly, did not choose this protocol, preferring a case-control approach).
With a view to long-term monitoring, questions should also be asked about current and forthcoming technological developments, as well as changes in the methods of use of mobile phones, which are leading to exposure of other parts of the body. At the moment, although it is clearly premature to envisage case-control studies on other localizations of cancer, professional environment prospective cohort studies could be considered the best answer to this concern.

Other epidemiological research

Works aiming to gain a *better insight into exposure on a population level* (including "registers" of people who are 'more exposed', as indicated above) are necessary for various reasons: *(*i) owing to public concern about the possible effects of mobile phones, there is justification for giving reliable, independent information about exposure within the population; *(*ii) several of the epidemiological protocols envisaged here will be facilitated by the availability of population exposure data.

*This research could take several forms: individual dosimetry campaigns, and modelling using data on base stations and the use of mobile phones.*
*Research in social sciences* is necessary: quality studies of the psychological and sociological aspects of mobile phone use would be of considerable importance if a *"crisis situation"* were thought to be emerging.

Epidemiological monitoring

The group of experts' brief asked whether it would be advisable to set up a measure for monitoring the possible effects of exposure to RFs. The group of experts consider that, like future research in this area, priority should be given to the consequences mobile telephone use rather than the areas around base stations. The foremost purpose of this monitoring is to produce information for decision-making purposes. Therefore, one of the main criteria in considering the relevance of epidemiological monitoring programmes is scientific evidence, which must be sufficiently sound to show that an increase in the population's exposure to electric and magnetic fields resulting from the use of mobile telephones is accompanied by an actual increase in associated health hazards.
However, epidemiological monitoring could sometimes be envisaged in the absence of scientific evidence of such an association. Indeed, one of the other purposes of epidemiological monitoring is to produce information used to generate hypotheses which contribute to identifying disorder or pathology risk factors. In this context, epidemiological monitoring would be one of the tools of descriptive epidemiology. In this case, its decisional value is relatively low, but its relevance can be seen when the surveillance approach efficiently collects the information required for the purpose of hypothesis generation.
Finally, when a potential hazard is an issue of widespread social concern and scientific knowledge has failed to provide a satisfactory answer, epidemiological monitoring may also be envisaged to collect further data on this social issue.
In the last two cases, the feasibility and cost-effectiveness of monitoring should be compared with other approaches, including human or animal experimentation.

Does the issue of possible health effects associated with mobile phones fall into this category?
As far as the risk of cancer is concerned, some *départements* already have registers covering brain cancer. Cancer-related mortality is also covered by exhaustive records throughout France. Scientific evidence on the role of exposure to RFs associated with mobile phones is very limited, as mentioned above. It would thus seem preferable to wait for the results of the multi-centre case-control study coordinated by CIRC before deciding on any systematic monitoring of these pathologies using the national registry. The specific association between exposure to electromagnetic fields and the occurrence of cancers (or the percentage attributable to this exposure in the occurrence of these pathologies) takes on particular importance here, in that one of the main objectives of monitoring will be to assess spatial and temporal trends. Low specificity combined with rare morbidity (with an annual risk of 10 -5 ), would make the interpretation of these trends all the more difficult.

On the other hand, with regard to self-declared subjective disorders, which at present remain ill-defined (headaches, attention or memory disorders, heat sensations, etc.), epidemiological monitoring may be envisaged in order to:

- better characterize this phenomenon;

- measure and monitor changes in the scale of this problem over time;
- generate etio-pathogenic hypotheses

In this context, the first stage could be to set up a descriptive survey based on the active collection of self-declared events among mobile phone users via an active information system developed in conjunction with the operators. The results of this survey would make it possible to characterize the phenomenon more precisely and identify particular groups of users to include in later analytical-type epidemiological studies (case-control), or groups for targeted monitoring.
Should the phenomenon be confirmed, it would then be necessary to set up a cohort-type survey in order to study its predictive value from the point of view of various health problems, e.g. neurological disorders. At a later date, depending on the results obtained, this study could either be repeated over time or a register could be made for declaring these complaints. If scientific knowledge were to confirm the reality of this phenomenon, historical data would thus be available to facilitating the monitoring of trends over time. This would take into account future increases in prevalence and changes in the conditions of exposure to electromagnetic fields attributable to the use of mobile phones.

**6- Funding and organizing the research**

Funding for these studies should include a large contribution from companies operating in the mobile telephony sector. Both equipment manufacturers and operators profit from this industry, and it is therefore logical that they should contribute to research on mobile phones. Possible measures could consist of a tax, which would be regularly revised according to the number of subscribers and the financial needs of the research. This tax could either be imposed by the public authorities or based on voluntary contributions from the manufacturers and operators.
The group of experts recommends that a large part or even the majority of funding should be provided by the public authorities, who would thus keep control over the research. Research financed half by manufacturer/operators and half by public funds (major research bodies, Public Health departments European Commission) could therefore be envisaged.
Whatever the measures chosen, they must always guarantee the absolute independence of the programming and project-selection committees, as well as the research teams. For this reason, it is crucial that contributions from the manufacturers and operators do not interfere with the choice of research topics and follow-up. This implies that funding from manufacturers and operators should either be channelled through the State or a structure or "foundation" under state control.

For this reason, it seems important to form permanent "committees" of experts on a national and European level. These experts should be chosen from various scientific disciplines and governmental administrations concerned with the issue. In accordance with the rules already applied in other research programs, the experts involved in projects submitted to these authorities for funding should be excluded from discussions on those projects. On a national level, this committee could be made up of members appointed by the major scientific bodies (CNRS, INSERM) and the Public Health department. It would be responsible for several missions:

- writing up a regular public report on current knowledge;
- determining priority research themes, depending on the conclusions of the report;
- publishing calls for tender corresponding to these themes;
- allocating private funding in response to applications from research laboratories.

This type of allocation should ensure complete transparency with regard to the management, nature, operation, and progress of the research, as well as the content of the resulting scientific publications.
On an international level, the national committee would also play a role in proposing and coordinating research programs in liaison with any European committee(s) in this field.
The current level of funding for research in this field, which, including all public and private contributions, comes to 7 million French Francs (excluding salaries), should be continued for at least 5 years. Funding should be available not only for laboratory studies, but also for epidemiological research in this field, which does not yet have any specific funding.