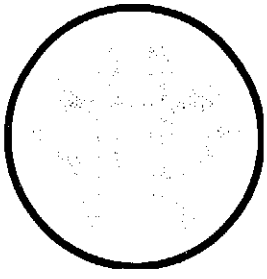
NON-THERMAL EFFECTS AND MECHANISMS OF INTERACTION BETWEEN ELECTROMAGNETIC FIELDS AND LIVING MATTER

An ICEMS Monograph



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Preface

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Electromagnetic fields are waves that transport energy through space. They are characterized by wavelength and frequency, the two of which are inversely correlated. The shorter the wavelength, the greater the frequency.

Electromagnetic fields include the following (in order of decreasing wavelength and increasing frequency): electromagnetic fields of extremely low frequency (from electric sources), electromagnetic fields of low frequency, electromagnetic fields of radiofrequency and microwaves (from mobile telephones, television antennas etc), ultrasounds, infrared rays, ultraviolet rays, X rays and gamma rays. Gamma rays, given their energy charge, are also defined as ionizing radiation, and are capable of altering genetic cellular material. Indeed, the carcinogenic effects of ionizing radiation have been known for decades.

Scientific data regarding the long-term effects, in particular carcinogenic risk,of the exposure to non-ionizing electromagnetic fields were not reported in the literature until the 1970s. In 1979 two American researchers, Wertheimer e Leeper, published for the first time the results of an epidemiological study that demonstrated an increased carcinogenic risk, specifically leukemic, in children residing in close proximity to electric installations and therefore exposed to non-ionizing electromagnetic fields from electrical current at extremely low frequency.

As was to be expected, concern about the possible carcinogenic risks of non-ionizing radiation has now expanded beyond electricity to include other types of non-ionizing radiation, such as electromagnetic fields of radiofrequency and microwaves from cellular telephones and other wireless technologies such as cordless telephones, computers etc.

The expansion of mobile telephone technologies in the last 10 years is without precedent. In 1996 the number of cellular telephones in Italy was circa 4 million, today this figure is estimated to be 40 million. In the US, cellular telephones in the 1990s numbered 9 million, today more than 150 million Americans use cell phones, including children. It is estimated than more than 2 billion people use cell phones worldwide. In addition, many citizens are exposed to electromagnetic fields originating from the antennas of radio base stations that transmit cellular signals. Indeed, exposure to electromagnetic fields of radiofrequency and microwave, in both the work and general environment, has never before experienced this type of growth. For this reason it is fundamentally important to address the issue of safety, using all available tools to evaluate the potential risks of exposure. These tools include both epidemiological and experimental laboratory studies, as well as basic research.

This book provide updated information concerning mechanism of interaction between non ionising radiation fields and living matter, with particular reference to potential non-thermal toxic effects.

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The scientific knowledge available today regarding electromagnetic fields remains limited. Nevertheless, on the basis of recent epidemiological studies, and while awaiting new experimental data, it is advisable to limit exposure to electromagnetic fields as much as possible. This is especially true for children and adolescents, the most vulnerable segments of the population, and has been recommended by both the Swedish and UK health authorities.

Why investigate the non thermal mechanisms and effects of electromagnetic fields on living systems? An introduction

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A Fairy Tale

Protection against Non Ionizing Radiation is based on a paradigmatic assumption:

"*We know very well the interaction between electromagnetic fields and living organisms: it is a* thermal *interaction; thus the standards internationally accepted are adequate to protect people and workers*"[1].

This is a fairy tale.

Since the 1970s the *non thermal* effects of electromagnetic fields on living organisms have been well known and also the *non thermal* mechanisms have been investigated[2,3]. Nevertheless, until today, we have been condemned to listen to representatives from international institutions repeating the old refrain above. Furthermore when scientists participating in the ICEMS agreed to edit a monograph – the present one - with the aim of illustrating the non thermal mechanisms and effects due to the electromagnetic interaction with living organisms - mechanisms that are well known today - some of us withdrew their contribution because they did not share the locution "*non thermal*" in the title. The following discussion, which many ICEMS scientists and the coauthors of this monograph took part in, focused on some basic points, maybe obvious but not infrequently forgotten.

To be able to speak about a thermal effect on a *system*, we must first observe a variation in the *temperature* of the *system*.

Temperature

In order to define the temperature of a system it is necessary to include the philosophical concept of ensemble: in extension a collection of independent and indistinguishable particles each having a well defined velocity. In such a picture the temperature will emerge as an average property of the system as the average kinetic energy defined on the ensemble. In the case of a biochemical system made up of many *non*-independent particles the very basic concept of temperature has to be defined through an oversimplification of the system description (useful in most applications): we assume that each molecule can be labelled with a mean velocity energy which, in turn, defines an average energy associated with each degree of freedom of the molecule itself. In such

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a picture a perturbation is termed "thermal" if it is able to change the average kinetic energy associated to each degree of freedom, in such a way that the average of the energies on the ensemble is changed.

The rotating motion of water molecules induced by microwaves is the most evident achievement of such a thermal effect, but we need not think it is unique. In our monograph we focus on an effect – the coupling of RF/MW with cancerous tissues – discovered by E.H. Frick and S. Morse (1924) and re-discovered by C. Vedruccio, as reported in this monograph.

The Energy transfer mechanism described by the classical or semi-classical model of biological matter is based on "hopping" along discrete energy levels. However, as is widely known in the literature, such a model cannot account for the energy transfer process in biological systems such as photo-synthesis, where the light-absorbing molecules can funnel energy with a near-unit quantum efficiency across mesoscopic distances. Such a conundrum implies a deeper re-thinking of the molecular biology model based upon independent and indistinguishable particles. The solution implies a high degree of correlation among a great number of molecules and the entry in play of quantum phenomena. Quantum mechanics teaches us that energy transfer can happen in a quantum-correlated system without entailing kinetic knocks.

Non Thermal effects

In such a picture it is paramount to distinguish between "thermal" and "non-thermal" effects. In fact, the existence of the latter implies a model of biological matter well beyond the classical or semi-classical representation. Hence the deep meaning of the thermal-non thermal *querelle* : to minimize this distinction could lead us to underestimate what is probably the watershed of modern biology.

However, because we are concerned with biology or biophysics - not atomic physics - we may be focused on much more complex systems than atoms and we may fail to monitor the variation of energy of single electrons or single atoms. Even an aqueous solution of aminoacids, in a quantity such as in the electrolytic cell of Zhadin described in this monograph, has millions of billions of billions of molecules, as Avogadro taught us. Thus we should not be deceived by the fact that a certain molecule receives energy during a reaction into concluding that this reaction is based on a thermal mechanism of interaction. We must look at the temperature of the system. We must observe the system and the average of the energies of all components involved.

For instance, in the aqueous solution of the Zhadin experiment, we witnesss an ion current peak - that can be detected in the order of 10-100 nA - when we apply a suitable combination of DC-AC magnetic fields. But the AC field is very weak: in the order of 10nT! And the DC field is like the geomagnetic one: there is no transfer of energy able to induce an alteration in the system temperature. It is not only a non thermal effect; it is an *athermal* effect!

Thermal/Non thermal in EMF risk assessment

Lastly, let us consider the current meaning of 'thermal effects' in RF/MW risk assessment. According to ANSI (1981), interactions inducing a temperature increase lower

than 0.5 °C in the human body are commonly accepted, even by the WHO. The corresponding value in terms of of WHOLE BODY AVERAGE SPECIFIC ABSORBTION RATE (WBASAR) is 4 W/kg. Furthermore, the absorption of 0.4 W/kg – corresponding to a temperature increase equal to a 0.05°C in the body – is considered negligible for workers and the absorption of 0.08 W/kg – corresponding to a 0.01 °C increase – seems to be negligible. WHO, IEEE and ICNIRP assure us that under such a threshold we can be protected against all health effects due to RF/MWs. On this view, biological non thermal effects are only to be considered as reversible effects. But non-reversible effects are detected under the same threshold by epidemiologists –see the assay by Lennart Hardell in this monograph -: such effects can be considered '*non thermal*' effects in this context. What about mechanisms inducing temperature increases lower than 0.001 °C (corresponding to 0.008 W/kg SAR)? They can be considered '*non thermal*' in the same context, in accordance with the usual convention that perturbation of a system, when the parameters are lower by three orders of magnitude than the corresponding parameters of the system, can be considered not related to such parameters.

Perhaps we should specify the meaning of the terms thermal/non thermal in the present monograph. With reference to the usual meaning adopted in the context of *protection against radiation*, we can consider as *non thermal* all mechanisms that are not able to induce an increase in temperature higher than 0.01°C, when we are considering a system like a living organism, or lower than 0.001 °C when a system like a cell is considered, or again lower than 0.0005 °C when a sub-cellular system is studied.

Several mechanisms and effects are considered in this monograph with the collaboration of many scientists who have joined this ICEMS initiative.

Our book does also include thermal mechanisms and effects as well as macroscopic phenomena (see the various sections of the book)

The point is, *protection against non ionizing radiation*, based on parameters adopted by international standards organizations, seems not to be adequate, despite the statement of Ms Van Deventer, nor able to protect people and workers. This is convincingly shown in the paper by Devra Davis, Om Ghandi and colleagues in this monograph.

Acknowledgment

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