HEALTH EFFECTS OF ELECTRIC AND MAGNETIC FIELDS: PROGRESS AND NEW DIRECTIONS

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ABSTRACT

For decades there has been a scientific interest in interactions of electric, magnetic and electromagnetic fields with biological systems. Most of research and interest in the last few years have been in the area of extremely low frequency fields. Research of biological effects of electromagnetic fields is complex, comprising many areas, and it usually requires an interdisciplinary approach. Two distinctive, if sometimes overlapping, streams of studies have been conducted; one concerned with effects that may detrimentally affect human health, and the other exploring properties of electromagnetic fields for medical purposes, in either diagnostic or therapeutic applications. A brief overview is given here of the main directions in this field, progress and unresolved problems, and current directions of the research.

INTRODUCTION

Areas of research can be broadly divided into four categories, as illustrated in Figure 1. Measurements and dosimetry, and interaction mechanisms, provide an integral support in both the assessment of health effects and medical applications. The appreciation of the role of measurements and dosimetry in biological experimentation during the last two decades has brought a remarkable progress in quantification of biological effects and in development of exposure standards at radiofrequencies (RF) [1,2]. Dosimetry and interaction mechanisms provide important links between studies performed on various levels of organization of biological systems and the ultimate goal of determination of risks to the human health or therapeutic medical treatment, as illustrated in Figure 2. The importance of such an integrated approach has become particularly apparent in the research of biological effects of fields at extremely low frequencies, ELF, (1-300 Hz).

In contrast to early studies in bioelectromagnetics, which were mostly of exploratory nature, frequently only qualitative in assessment and often subject to artifacts, current studies are in many cases conducted by interdisciplinary teams. These studies include a careful characterization of exposure conditions, dosimetric evaluation where possible, and a meticulous control of artifacts. Many of the studies are aimed at testing and extending specific hypotheses [3]. Starting in the eighties the main research effort has been at ELF. Research activities and knowledge in bioelectromagnetics are too vast and diverse for a comprehensive overview, therefore, the remarks that follow are only a selected glimpse at some of the areas.

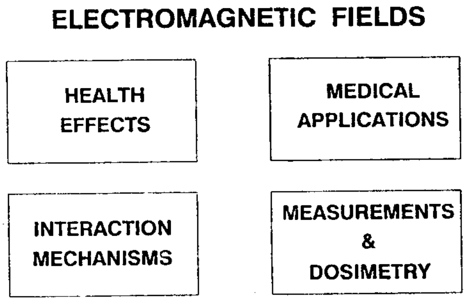

Figure 1

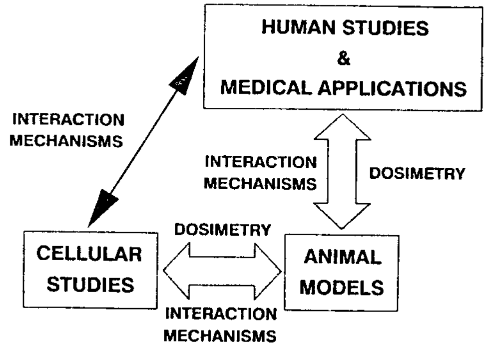

Figure 2

EXPOSURE ASSESSMENT

Measurements of electromagnetic exposure fields are of fundamental importance in many aspects of bioelectromagnetics. In experiments with cell preparations, animals and human volunteers, it is very important that exposure fields are comprehensively and accurately determined. Similarly, in medical applications, where it is important that either the exposure field or the electric field induced in the treated tissue have well defined specific characteristics, accurate measurements of fields are essential. Epidemiological studies have only a limited value, unless they include exposure assessment through actual measurements or other well-based quantitative methods. Finally, only through reliable measurements or estimation of exposure fields can compliance with exposure standards be ensured and protection against over-exposures implemented.

Exposure assessment at ELF and in particular at power line frequencies (50 or 60 Hz) is an area of a currently active pursuit. This is particularly important in support of epidemiological studies. A number of sophisticated personal dosimeters have been developed for this purpose [4]. One of the problems in this area is that the existing biological data do not clearly indicate what dosimetric parameters are of importance in eliciting interactions. Some studies suggest that the waveform, or perhaps transients or changes are important, which would indicate that measurements extending beyond the amplitudes of the electric and magnetic fields might be required.

Measurements of transient fields and pulsed electric and magnetic fields have recently become of growing interest, as there is a need to assess exposures associated with the electromagnetic pulse (EMP), as well as many other exposure situations such as large switching current at switchyards and transformer stations, arc-welding, induction heating, and RF heating. Several novel active and electro-optical sensors and measurement techniques have been recently developed [5,6].

DOSIMETRY

For ELF electric and magnetic fields dosimetric measures have not yet been established. Although induced current densities from exposure to these fields have been calculated and can be measured [7,8], at present there is no compelling evidence that the current density in tissue is the critical dosimetric measure. Perhaps, calculations of current densities and induced potentials on the microscopic (subcellular) level will prove useful when used in conjunction with biophysical models of interactions.

HEALTH EFFECTS

Most of the studies conducted with ELF fields, are at the power line frequencies (50 and 60 Hz) [9]. A number of studies are motivated by beneficial effects of exposure rather than a potential hazard. These studies often utilize complex waveforms with energy contained below 1000 Hz. Magnetic fields are more often used rather than electric fields. The on-going investigations can be divided into three groups: (1) human studies, (2) animal studies, and (3) in vitro studies.

On-going human studies are mostly epidemiological and concerned with cancer [10]. Environmental exposures of children to electric and magnetic fields at 50 or 60 Hz are being scrutinized for a possible association with childhood cancers, particularly leukaemia and brain cancer. Epidemiological assessment is also underway for various occupational groups that are more exposed to electromagnetic fields than workers in other occupational groups. What distinguishes these studies from a number of already published studies is that actual measurements of exposure are performed, if only on the sample basis. In these studies, personal dosimeters are used for a certain period of time (e.g. 48 h) to determine an average exposure of the studied cohorts to electric and magnetic fields. Usually, current studies also have more statistical power than the previous studies, and some are prospective rather than retrospective. A very interesting human study with volunteers looks at effects on cardiovascular and nervous system responses [11]. This study is characterized by careful dosimetry, as well as elimination of artifacts.

To elucidate the question of a possible association between exposure to ELF fields and cancer, a number of animal studies have been undertaken. Long-term chronic studies which encompass an animal lifespan are presently underway and include lymphoma development in mice, brain cancer in rats, liver cancer in mice and skin cancer in mice. In some of these studies, a specific cancer is initiated (with a chemical agent or ionizing radiation) and the investigations are aimed at determining whether the field acts as a promoter. Also short-term studies looking at specific interaction mechanisms (e.g. melatonin suppression, or copromotion) have been undertaken.

The number of cellular in-vitro studies in progress is relatively large, many of them focused on a biological interaction mechanism. There appears to be a better convergence among the studies undertaken by researchers concerned mostly with potential hazards from environmental, occupational or medical exposures and those who are primarily interested in beneficial uses of ELF fields.

Conclusions

Interactions of electromagnetic fields with biological systems have been a subject of scientific inquiry for quite a long time. There are many common features of studies of potentially hazardous health effects and of studies of medical applications. At present there appears to be better appreciation of this fact and considerable cross-fertilization. Another positive characteristic of many investigations today is that they are aimed not only at the identification of an effect, but that they explore testable hypotheses in search of interaction mechanisms.

REFERENCES

[1] Biological Effects and Exposure Criteria for Radiofrequency Electromagnetic Fields. National Council on Radiation Protection and Measurements, Report No. 86, Bethesda, MD, U.S.A. (1986).

[2] Stuchly, M.A., 1987, Proposed Revision of the Canadian Recommendations on Radiofrequency Exposure Protection, Health Physics, 53, 649-665.

[3] Adey, A.W., 1988, Cell Membranes: the Electromagnetic Environment and Cancer Promotion, Neurochem. Res., 13, 671-677.

[4] Renew, D.C., Male, J.C. and Maddock, B.G., 1990, Power-Frequency Magnetic Fields: Measurement and Exposure Assessment. CIGRE Congress Record, Publ. No. 36-105.

[5] Thansandote, A., Stuchly, S.S. and Stuchly, M.A., 1991, Broadband Active E-Field Sensors for Measurement of Transients, IEEE Trans. Instrum. Meas., 40, 465-468.

[6] Stuchly, M.A., LePocher, H., Gibbons, D. and Thansandote, A., 1991, Active Magnetic Field Sensor for Measurements of Transients, IEEE Trans. Electromagn. Compat., in press.

[7] Kaune, W.T. and Gillis, M.F., 1981, General Properties of Interaction Between Animals and ELF Electric Fields, Bioelectromagnetics 2, 1-11.

[8] Tenforde, T.S. and Kaune, W.T., 1987, Interaction of Extremely Low Frequency Electric and Magnetic Fields with Humans, Health Physics, 53, 585-606.

[9] Nair, I., Morgan, M.G. and Florig, H.K., 1989, Biological Effects of Power Frequency Electric and Magnetic Fields, U.S. Congress, Office of Technology Assessment, OTA-BP-E-59.

[10] Savitz, D., Pearce, N.E. and Poole, C., 1989, Methodological Issues in Epidemiology of Electromagnetic Fields and Cancer, Epidem. Rev., 11, 59-64.

[11] Graham, C., Cohen, H.D. and Cook, M.R., 1990, Immunological and Biochemical Effects of 60-Hz Electric and Magnetic Fields in Humans, Midwest Research Institute Report No. RA-338-C.