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Biological Effects of Microwaves and Mobile Telephony

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ABSTRACT

Many of the existing safety guidelines governing microwave/RF/ELF, controlled /uncontrolled exposure are based on intensity of exposure that produces heating of tissues due to energy absorption leading to temperature rise and manifested as thermal effects. On the other hand, though the human body could compensate for and handle the extra energy load through the thermoregulatory mechanisms without obvious increase in temperature, stress could still develop. The thermal effects are manifested in the living being as well as tissue preparations, cell lines etc. However, the frequency induced effects in the non thermal low intensity range, are unique to a living organism, where the "coherence "component of the electromagnetic waves is discerned by the living organism and the oscillatory similitude of such waves interferes with the biological endogenous rhythms of the organism, akin to the electromagnetic interference phenomena occurring while turning on a cell phone inside an aircraft. The review of existing literature, the standards, the biological effects are discussed.

KEYWORDS

Microwave Radiation, Safety Standards,Mobile Telephones,Base Stations

INTRODUCTION

Most of the existing safety guidelines governing exposure of the public or the occupationally exposed are inadequate as they regulate only the intensity of exposure that produces heating of the tissues due to absorption of energy. At the microwave frequencies such heating could be due to the electric field of microwaves and at ELF frequencies the magnetic field leads to induction of circulating currents in the body [1] The existing safety limits restrict the intensity of the exposure that manifests through temperature rise. On the other hand the human body could compensate and handle the extra energy load through the efficient thermoregulatory mechanisms and maintain homeostasis though certain amount of stress could still develop. Besides the intensity component induced effects (thermal effects) which are known to occur in living and non living organisms, the uniqueness of the living organisms is their ability [2] to respond to aspects of technologically produced radiation other than its intensity, like coherence, at intensities well below the limits of safety guidelines. Such high degree of coherence associated with technologically produced electromagnetic fields from the natural ones can be easily discerned by living organisms including humans and result in frequency

specific subtle, non thermal effects against which the existing safety guidelines do not yield any protection.

In the modern world, with the use of sophisticated microwave emitting devices for communications in the air surveillance system, industry, diagnostic and therapeutic purposes in medicine- the importance of electromagnetic pollution need not be over emphasized. Microwave communication equipments are in use in defence and commercial networking systems. The primary charter of duties of any oraganisation is to safe guard its personnel like radar workers and the personnel concerned with the manufacture of high power microwave equipment, working in the near field of the microwave generating sources. Many studies have been undertaken to alleviate fears in the minds of people regarding the deleterious effects, if any, of electromagnetic radiation, which has been off late added to the already existing list of environmental pollutants. Starting from the radar worker in the defence setting to the housewife using the microwave oven - all are exposed to the potential microwave hazards. There are many reports pouring on in the literature indicating adverse health effects of cell phones which emit electromagnetic radiation, with maximum value of 50% of their energy being deposited when held close to the head. Hence there is a need to explore the biological effects of electromagnetic radiation in different frequency ranges.

MICROWAVE BIOEFFECTS

The microwave frequency spectrum ranges from 300 MHz-300 GHz and RF Radiation from 0.5MHz - 300 MHz. The sources of microwave and RF radiation are Air Traffic Control Systems, Police and Military Radar, Earth to Satellite Television Broadcast Systems, Long Distance Telephone Equipment ,Medical Diathermy Devices, Cancer Diagnostic & Therapeutic (Hyperthermia) Equipment, Microwave Ovens, Industrial Applications and Microwave Generators. The standards that limit microwave exposure were set at 0.4 W/kg SAR for occupational and 0.08W/Kg for public exposure (ANSI 1992). The averaging time for determination of SAR was 6 minutes (NRPB 1993). The mechanisms of interaction have been described as thermal effects, with rise in body/tissue temperature of more than $1^{o}C$, non thermal effects, with no obvious increase in body temperature and microthermal with thermoelastic expansion in the brain giving rise to microwave hearing effect. Microwaves produce thermal effects on biological systems at high power levels .The energy absorption at high power levels probably leads to nonspecific stimulation of hypothalamic-hypophyseal-adrenal axis with liberation of corticosterone that causes sequestration of cells, an effect induced by any known stressor. Some of the thermal effects reported include cataract formation, foetal abnormalities, decreased thyroid function (through hypothalamic-hypophyseal-thyroid axis inhibition), suppression of behavioural responses, gonadal function and natural killer cell activity, increase in the number of complement receptor positive cells and increased phagocytic activity of peritoneal macrophages. At non thermal levels ($<0.5^{o}C$ rise in rectal temperature) stimulation of thyroid, increased susceptibility of the organism to bacterial infections, decline in neutrophil and complement activity, increased lymphoblastoid transformation of lymphocytes, abnormalities in the erythrocyte/lymphocyte precursors in bone marrow are some of the reported effects. The various review articles describe the microwave effects in detail[3,4,5,6]

A number of effects such as increased endogenous opioid activity [7], increase in the concentration of benzodiazepine receptors, after an acute (45 min) exposure to 2450-MHz RFR (average whole body SAR 0.6 W/kg) in the cerebral cortex of the rat, with no significant effect in the hippocampus and cerebellum and adaptation of the response of the cerebral cortex to repeated RFR exposure (ten 45 min sessions) were reported by Lai etal[8].They also noted that exposure to RFR resulted in decrease in high affinity cholinergic uptake in frontal cortex and hippocampus in rats exposed to 0.6 W/Kg , 2.45 GHz microwaves for 45 mins.Further study showed that the response depended on the duration of exposure. Shorter exposure time (20 min) actually increased, rather than decreasing the activity.They stated that different brain areas have different sensitivities to RFR with respect to cholinergic responses. In addition, repeated exposure could lead to some rather long lasting changes in the system, the number of acetylcholine receptors increasing or decreasing after repeated exposure to RFR for 45 min or 20 min sessions respectively[9,10].Increase in single and double strand breaks in DNA have also been reported by them[11,12].Changes in blood brain barrier, neurotransmitter functions, cellular metabolism, calcium efflux and altered sensitivity to microwaves on treatment with certain drugs [4] and Alzheimers disease in electrical workers [13] are some of the effects.

Experiments were conducted by us [14] to elucidate the effects of chronic low power-level microwave radiation on the immunological systems of rabbits. Fourteen male Belgian white rabbits were exposed to microwave radiation at 5 mW/cm^2, 2.1 GHz, 3 h daily, 6 days/wk for 3 months in two batches of 7 each in specially designed miniature anechoic chambers using the design of Guy etal. Seven rabbits were subjected to sham exposure for identical duration. The microwave energy was provided through S band standard gain horns connected to a 4K3SJ2 Klystron power amplifier. The first batch of animals were assessed for T lymphocyte-mediated cellular immune response mechanisms and the second batch of animals for B lymphocyte-mediated humoral immune response mechanisms. The peripheral blood samples collected monthly during microwave/sham exposure and during follow-up (5/14 days after termination of exposures, in the second batch animals only) were analysed for T lymphocyte numbers and their mitogen responsiveness to ConA and PHA. Significant suppression of T lymphocyte numbers was noted in the microwave group at 2 months ($P<0.01$, ? % 21.5%) and during follow-up ($P<0.01$, ? % 30.2%). The first batch animals were initially sensitized with BCG and challenged with tuberculin (0.03 ml) at the termination of microwave irradiation/sham exposure and the increase in foot pad thickness (? mm), which is a measure of T cell-mediated immunity (delayed type hypersensitivity response, DTH) was noted in both the groups. The microwave groups revealed a better response than the control group (? %+12.4 vs.+7.54). The animals were sacrificed and the tissue T lymphocyte counts (spleen and lymph node) were analysed.

From these results it was speculated that the T lymphocytes are sequestered to various lymphoid organs under the influence of microwaves. A sub-population of T cells known as T helper cells (mediating DTH response) are probably not affected by microwave radiation. It is clear from our experiments that although chronic microwave radiation at 5 mW/cm^2 leads to suppression of peripheral T lymphocyte numbers, there is no concomitant functional impairment of these cells as evidenced by functional assays in both the groups. The results of our chronic studies also revealed cataract (2 rabbits,Fig.2), recurrent infections (7animals), lymphoid cell depletion in the lymph node, spleen, and appendix and increase in complement

receptor positive cells in the immunized popliteal lymph nodes in the chronic group. Cataracts have not so far been reported at such low power level as 5 mW/cm^2.

Fig. 1 Microwave Exposure Facility

Fig. 2 Cataract in Microwave Exposed Rabbit

We conducted experiments on another group of rabbits which were subjected to 100 mW/cm^2 45 minutes acute microwave exposures and the control group was subjected to heat exposure for identical duration. A comprehensive evaluation of the immunological systems was done. The results suggested decline in the T lymphocyte counts and enhanced response to mitogen PHA.

Our earlier studies [15,16] were carried out on 13 conscious rabbits (1.2-1.8 kg), of which 8 rabbits were exposed to microwave radiation (CW) at 5 mW/cm^2, 2.1 GHz, 3 h/day, 6 days/wk for 3 months in a polystyrene cage, using Ailtech microwave power signal source (M 126A, 10 W) as microwave energy source. The other 5 rabbits (control group) were submitted to sham exposures for 3 months. Blood samples collected at various time intervals (pre-irradiation, at 1, 2 and 3 months and follow up at 1 wk and 2 wk thereafter) in both the groups, were analysed for total and differential leucocyte counts, red blood cell count and absolute red cell indices. An increase of 50 percent in the TLC value at three months of microwave irradiation suggested a gradual low degree effect of microwaves on the leucocytes(Fig3). A three-fold increase in the large lymphocytes may be due to stimulation of lymphocyte production. The decline (15.4%) in the small lymphocytes is probably due to migration of these inactive forms away from the periphery. The observed neutropenia (2.4%) probably accounts for the redistribution of these cells among the various body pools(Fig.4). All the observed changes were, however, reversible. As the thermal effects are ruled out in our experiments, a specific cumulative effect of microwaves is suggested at low power levels.

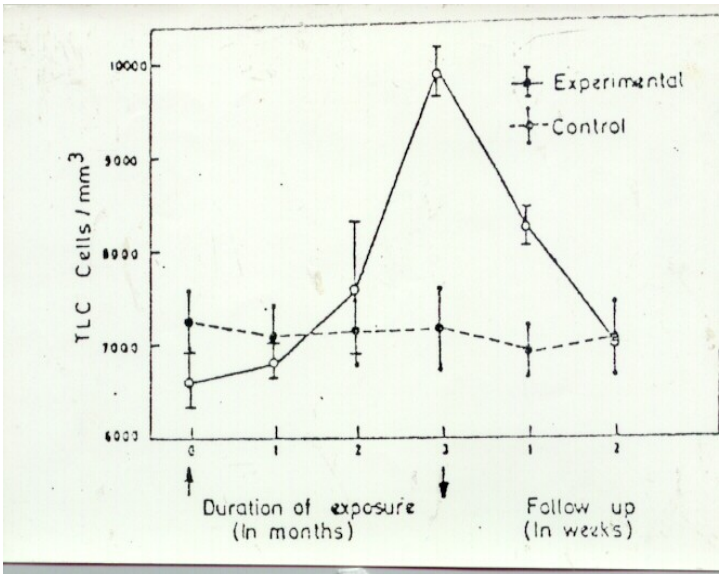

Fig.3: Effect of Microwave Radiation on the TLC of Rabbits

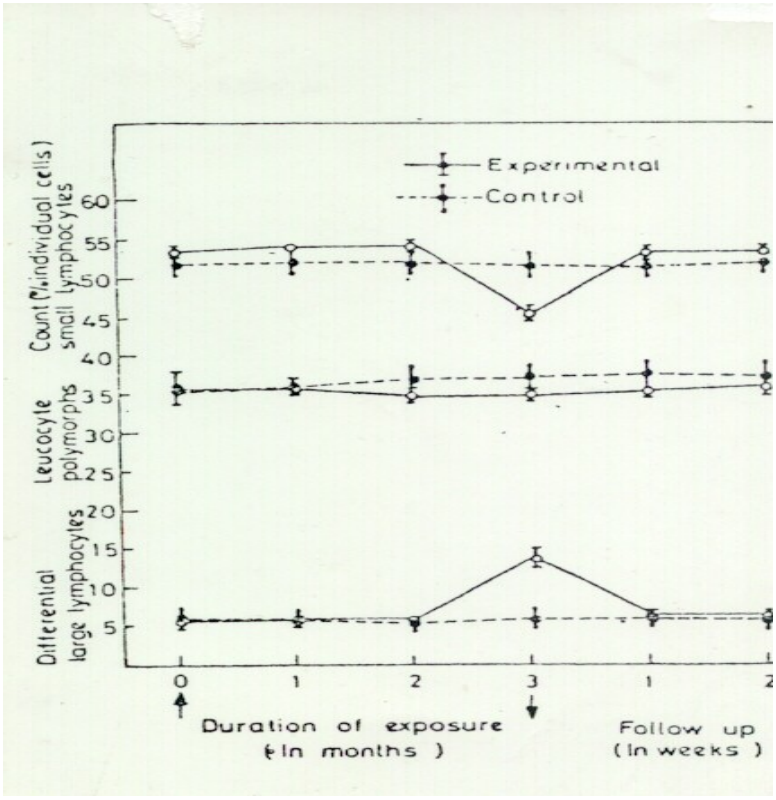

Fig.4 Effect of Microwave Radiation on the DLC of Rabbits

The progressive decline in the peripheral erythrocytes in the microwave irradiated rabbits[16] suggests the specific additive nature of microwave interaction with erythrocytes.However these effects seem to be compensated by increases in the mean corpuscular haemoglobin and mean corpuscular volume, which possibly maintain total surface area of red cells and available haemoglobin unaffected, thereby protecting the animal from untoward hypoxia.

Thus the results of our studies in rabbits on exposure to low power level microwave irradiation (5mW/cm^2, 2.1 GHz, 3 hr/day, 6 days/wk for 3 months) indicate significant leucocytosis, increase in the number of large lymphocytes, decrease in the number of small lymphocytes, T-lymphocytes, neutrophils and erythrocytes, increased susceptibility to bacterial infections, weight loss, increase in serum protein values and development of cataract. The power level used in the study resulted in an energy deposition of 0.83 W/kg (calculated SAR value in rabbits, 20% of their basal metabolic rate approximately). At high power levels (100 mW/cm^2, 2.1 GHz, 45 min. acute exposure) leucocytosis, lymphopenia, neutrophilia, declined T-lymphocyte count and enhanced response to mitogen PHA were observed. We concluded that there may be a delicate period during microwave irradiation at which time the animal may either get adapted or succumb to the adverse effects of microwave.

The experimental results of various researchers are to be interpreted,correlated and extrapolated into meaningful results after taking into consideration the variables such as intrinsic physical and physiological dissimilarities between species, heat distribution mechanisms, internal vascular anatomy, cognitive limits of the animal model, animal restraint, seasonal and circadian rhythms, uniformity of experimental design of various researchers, differentiation of reversible, compensatory phenomena from irreversible, harmful effects (Hazards) as suggested by many reviewers.

SAFETY STANDARDS

The various agencies concerned with setting national and International standards are ANSI/IEEE, NCRP, ICNIRP, FCC, SAA, NRPB. ANSI, ICNIRP and NCRP all agree that whole body exposure of the general public should be kept below a whole body SAR of 0.08 W/kg.As a result of differences between approaches and frequencies used,world-wide standards for the continuous exposure of the public to RF from base station antennas ranges from 0.2 to 1.2mW/cm.sq[17].

In 1974 , IRPA (International Radiation Protection Association) formed a working group on Non-ionizing radiation (NIR) which examined the safety aspects of various types of NIR. At the IRPA congress in 1977 this working group became the INIRC (International Non Ionizing Radiation Committee). In cooperation with the Environment Health Division of the World Health Organisation (WHO) the IRPA/INIRC developed a number of health criteria documents on NIR as a part of WHO s'Environmental Health Criteria Programme, sponsored by UNEPA. Each document includes an overview of the physical characteristics, measurement and instrumentation, sources and applications of NIR, through review of the literature on biological effects and an evaluation of the health risks of exposure to NIR.

At the 8th International congress of IRPA (Montreal 18-22 May 92) International Commission on Non Ionizing Radiation Protection (ICNIRP) was established as a successor to IRPA/INIRC with functions to investigate the hazards that may be associated with different forms of NIR, develop international guidelines on NIR exposure limits, deal with all aspects of NIR protection etc. Exposure to static and ELF electric and magnetic fields have been reviewed by UNEP/WHO/IRPA (1984, 1987), and UNEP/WHO/IRPA (1993)

MOBILE TELEPHONES

The cell phones operate at different frequencies and the safety standards that limit the RF exposure are different for each country. The ANSI/IEEE 1992 and NCRP (National Council on Radiation Protection and Measurements) set the standard for cellular phones as 0.57 mW/cm^2 and 1.2 mW/cm^2 for PCS phones. The ICNIRP, 1998 (International Commission for Non Ionizing Radiation Protection) set the standards as 0.4 mW/cm^2 for cell phones and 0.9 mW/cm^2 for PCS (Personal Communication Systems) phones. The ICNIRP guidelines are followed by SAA (Standards Association of Australia) and New Zealand. The FCC (Federal Communications Commission) 1996 recommends the standards as 0.57 mW/cm^2 for cell phones and 1.0 mW/cm^2 for PCS phones (followed by Canada also). The British Standards

were 0.57 mW/cm^2 at 900 MHz and 1 mW/cm^2 at 1800 MHz earlier. U.K stopped using its own standard for mobile phones and mobile phone base stations in mid 2000 and adopted the ICNIRP standard which is followed by many countries[17].

The cell phones operate at 860-900 MHz and the PCS phones at 1800-2200 MHz. With the GSM phones with the latest digital technologies, the TDMA and CDMA, the human brain ,the eyes, and the auditory apparatus (which are the most exposed due to the location of the phone) are sensitive to the microwave carrier frequency as well as the pulses at different frequencies especially of 8.34Hz and 2 Hz, which are within the alpha and delta frequency range of the brain s'endogenous rhythm. It is the coherence component of the pulses that is recognized by the brain and interferes with the body rhythms[18].

Repeated use of mobile phones leads to repeated irradiation of a fixed amount of body tissue with deposition of large amount of RF energy in the head. Added on to this is the fixed position of the telephone, often held very close to the head, leading to short term repeated irradiation of fixed amount of brain tissue generating "hot spots." Sometimes the SAR values in these hot sports could be to the tune of 2-8 W/Kg/W output of the instrument (peak output of the instrument could be 1-2W)[18]. Such hot spots can create thermoelastic expansion of the brain tissue (brain is contained in a bony cage i.e. cranium) or the energy so gained may be carried away through blood vessels to other areas of the brain. The brain has various vital centers and the thermoregulatory apparatus. Such dissipation of energy may affect it s' performance adversely though elsewhere in the body such additional energy load could easily be compensated for without breaking the homeostatic mechanisms of the body. Brain is concerned with perception, cognition, intellectual function and also initiation, control and coordination of motor activity and emotions. One could imagine, with such energy deposition rates of 2-8 W/Kg/W output power of the instrument, the signal processing mechanisms going on in the brain can go haywire. Functional derangement occurs much before the pathological damage to the tissue. Even transient interference with information processing in the neuronal circuitary in the brain can lead to gross errors in the ongoing signal processing at the nerve cell membrane adversely affecting the receptor-ligand interactions and the neurotransmitter release.

Mobile telephony is based on two way radio communication between portable handset and nearest base station . The microwave frequencies utilized are at 900 or 1800 MHz. A base station antenna radiates around 60W and handset between 1-2 W(peak). The stations also have subsidiary beams called side lobes. At 150-200m, the power density in the main beam near ground level is in tenths of uW/cm^2 [18].

Fort he Global System for Mobile communication (GSM) with digital modulations like TDMA (time division multiple access), the system used for simultaneous communication of more people, each channel is divided into 8 time slots, with peak values of 0.125 W-0.25W transmitted in 576ms bursts. The eight slots define a frame of 217 Hz frequency. The additional low frequency pulsing of the "multi-frames" formed by the handset and base station at 8.34Hz and the pulsing at 2 Hz of the DTX energy saving transmission mode correspond to the electrical frequencies of alpha and delta waves of the EEG of human brain and hence these rhythms may be subjected to interference. The reported in vivo non thermal effects include headache, (underlying mechanism of action being through dopamine-opiate

system of brain and increased permeability of blood- brain barrier), memory problems,(target region of microwaves in the brain being hippocampul region), increase in frequency of seizures in children ,decrease in duration of REM sleep and inhibition of secretion of melatonin.. The effects have been stated to be variable from person to person depending upon the level of stress and on the strength of the immune system [18,19].

With the advent of third Generation mobile phones that utilize CDMA (Coded Division Multiple Access) in place of TDMA, though the sensitivity to microwave carrier may remain, the pulsing used is irregular, hence does not enjoy the oscillatory similitude with the human brain activity [2].

The health council of Netherlands, Radiofrequency Radiation Committee recommends that certain levels of current density, SAR and power density should not be exceeded in order to prevent adverse health effects. These health based exposure limits are termed as basic restrictions [20]. It has been stated that in the frequency range upto 10 MHz, biological effects result from induced current, therefore, current density (J) Am^{-2} should be restricted. In the intermediate range of frequency from 100 KHz to 10 GHz the effects were mentioned to be dependent on generation of heat and hence the SAR is important as the basic restriction and is proposed as 0.4 W/kg for controlled exposure and 0.08 W/kg for uncontrolled exposure. A safety factor of 10 has been incorporated based on the available report of biological effects at 4 W/kg. In all cases the averaging time for determination of whole body SAR should be 6 minutes which has been considered to be reasonable equivalent of thermal equilibrium time. The proposed guidelines are also in tune with the National Radiological Protection Board, 1993 recommendations and the International Standards with minor deviations. In the frequency range of 10 GHz, higher surface absorption dominates and the committee recommends use of incident power density as a basic restriction ,which is directly proportional to the surface absorption. A value of 100 W /m^{-2} is proposed for workers and 20 W/m^{-2} for general public. As measuring of SAR or induced current in human beings is not feasible,. the committee recommends to use more readily measurable quantities like electric and magnetic field strengths. The electric field limits in the lower frequency range have been stated as 5 KV/mfor exposure of the general public and 10 KV/mfor exposure of workers.

Extremely low frequency fields (ELF) range from the frequency 30-300 Hz. The sources are power distribution networks, public transportation systems, electrical appliances, motors, electrical beds, blankets etc. The reported effects are increased incidence of childhood leukaemia, increased incidence of nervous system, brain, skin, eye and throat cancers, changes in Ca^{2+} movement through membrane, enhanced fracture repair, changes in circadian rhythm of melatonin, changes in behavioural responses etc. The fields in power stations are 1-5 kVm^{-1} for electric fields and 0.02-20 uT for magnetic fields[21]. The electric fields can be several kVm^{-1} near electrical blankets or heated water beds. The background 50Hz magnetic fields in typical homes have been measured as 0.01 1uT and the appliances generate 0.1-100 uT. The radio frequency radiation, pulse /amplitude modulated at extremely low frequencies (ELF) has been reported to cause increased calcium efflux at 450 MHz (16 Hz modulation) in chick cerebral hemisphere.,Decreased activity of protein kinases and increased activity of Ornithine decarboxylase at 835 MHz are some of the effects described. . The mechanisms of action could be through oxidative stress,changes in calcium ion homeostasis, increase in Ornithine decarboxylase decrease in nocturnal melatonin secretion

and tumor promotion[6]. The shortcomings of some of the studies were described by some reviewers as diverse cancer end points, imprecisely known & diverse exposure conditions (home, work place etc.), inconsistent and non reproducible results, improper dose-response relationship, transient effects, artifacts and nonconsideration of confounding factors by various researchers .

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REFERENCES

[1] *Potential Adverse Health Impacts of Mobile Telephony*, Memorandum, G.J. Hyland. 2000.Internet: http://www. emfguru.com/EMF/hyland/hyland.htm

[2] *The Physiological and Environmental Effects of Non-Ionising Electromagnetic Radiation*, European Parliament document, Directorate General for Research-Directorate A STOA-Scientific and Technological Options Assessment, Options Brief and Executive Summary. 2001

[3] Kalluri Sri Nageswari, 1988 A Review on immunological Effects of MicrowaveRadiation..*IETE Technical review(India),***5:**203-210

[4] Maria A. Stuchly 1995. Health Effects of Exposure to Electromagnetic Fields. *IEEE* 351-367

[5]K. Sri Nageswari. 1990. Biological Effects of Microwaves –A Review. *Ann Natl Acad Med Sci (India)* **26(1&2)**: 1-16

[6] William R. Hendee, John C. Boteler. 1994. The Question of Health Effects From Exposure to Electromagnetic Fields. *Health Physics* **66**: 127-136

[7] Lai H, Horita A., etal. 1984C. Microwave-Induced Postexposure Hyperthermia : Involvement of Endogenous Opioids and Serotonin. *IEEE Tran.* **MTT-32**: 882-887

[8] Lai H.,Carino M.A., etal. 1992. Single vs Repeated Microwave Exposure : Effects on Benzodiazepine Receptors in the Brain of the Rat. *Bioelectromagnetics* **13**: 57-66

[9] Lai H., Carino M.A., etal. 1989a. Low-level Microwave Irradiation and Central Cholinergic Systems. *Pharmac. Biochem. Behav.* **33**: 131-138

[10] Lai H., Carino M.A. etal. 1989b. Acute Low-level Microwave Exposure and Central Cholinergic Activity : A Dose-Response Study. *Bioelectromagnetics* **10**: 203-209

[11] Lai H., Singh N.P. 1995. Acute low-Intensity Microwave Exposure Increases DNA Single strand Breaks in Rat Brain Cells. *Bioelectromagnetics* **16**: 207-210

[12] Lai H., Singh N.P. 1997. Melatonin and a Spin Trap Compound Blocked Radiofrequency Radiation – Induced DNA Strand Breaks in Rat Brain Cells. *Bioelectromagnetics* **18**: 446-454

[13] Eugene Sobel, Zoreh Davanipour, Raimo Sulkava, etal. 1995. Occupations with Exposure to Elecgtromagnetic Fields : A possible Risk Factor for Alzheimer s'Disease. *American Journal of Epidemiology* **142**: 515-522

[14] K. Sri Nageswari, K.R. Sarma, etal. 1991. Effect of Chronic Microwave Radiation on T Cell-Mediated Immunity in the Rabbit. *Int. J. Biometeorology* **35**: 92-97

[15] Kalluri Sri Nageswari, etal. 1982. Effect of prolonged Low Power Microwave Radiation on Peripheral Leucocyte Counts in Rabbits. *Indian J. Med. Res.* **75**: 453-459

[16] Kalluri Sri Nageswari, etal. 1982. Effect of Chronic Microwave Radiation on Rabbit Erythrocytes. *Indian Journal of Experimental Biology* **20**: 13-15

[17] *Electromagnetic fields and Human Health*. 1999. Internet: http://www.mcw.edu/gcrc/cop/cell-phone-health-FAQ/toc.html

[18] G.J. Hyland. 2000. Physics and Biology of Mobile Telephony. *The Lancet* **356**: 1833-1836

[19] *Mobile Phone Mast Radiation Health.* 2000. Internet: http://fader.exit.mytoday.de/Health/Reports/Dr_Hyland/dr_hyland.html

[20] *Radio Frequency Electromagnetic Fields (300 Hz –300 GHz) Summary of an Advisory Report*, Health Council of the Netherlands : Radiofrequency Radiation Committee. 1998. *Health Physics* **75**: 51-55

[21] Larry E. Anderson. 1991. ELF : Exposure Levels, Bioeffects and Epidemiology. *Health Physics* **61**: 41-46