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Evaluation of the Potential Carcinogenic Effects of Electromagnetic Fields(EMF) on Tissue and Organs

Vahdettin Bayazit, PhD

Muş Alparslan University, Faculty of Arts and Sciences, Department of Biology, 49100, Muş, Turkey

Abstract: The purpose of this study is evaluate the likelihood that exposure to nonionizing electromagnetic radiation (NIEMR) poses a risk or is a risk factor for the development of cancer in humans. This investigation provides evidence that exposure to EM fields and the thundering results related various cancers, most notably leukemia, lymphoma, and brain cancer caused of EM fields

Key words: Cancer and tumor risk, electromagnetic radiation,

INTRODUCTION

Modern industrial development has resulted in people being increasingly exposed to a complex miz of electric ana magnetic fields ana radiation that cover a wide frequency range.Major sources of exposure to electromagnetic fields (EMFs) arise from electrical power generation, transmission and use in residental and occupational situations, anf from telecommunications, security ana process control have proliferated in industrial plants, in offices, homes, cars and in the environment. People are exposed to electric and magnetic fields (EWFs) arising from a wide variety of sources which use electrical energy at various frequencies the term radiation is appropriate at high frequencies, it is preferable to think in terms of the individual electric and magnetic field components at frequencies where there is only a slow variation with time such as 50/60 Hz used for power generation and distribution. (Ahlbom *et al.* 2000; Ahlbom, 2001; Ahlbom *et al.,* 2004; Al-Glaib *et al.,* 2007; Anane *et al.,* 2003a; Anane *et al.,* 2003b; Anderson *et al.,* 1999; Anderson *et al.,* 2000; Anderson *et al.,* 2004; Auvinen *et al.,* 2002; Bartsch *et al.,* 2002). The wavelength at 50 Hz is 6000 km - consequently people are exposed to fields from sources at distances very much less than a wavelength where the electric and magnetic field components are dissociated. Electric fields are associated with voltage and the electric field strength has the unit volt per metre (V m"[1]); electric fields do not require current to flow. Magnetic fields are associated with current flow and magnetic field strength has the unit ampere per metre (Am^{-1}). Magnetic fields can be described also by the use of the quantity magnetic flux density. The latter depends on the permeability of the medium in which the measurement takes place and has the unit tesla (T). Man-made sources dominate exposure to time-varying fields and radiation. Over that part of the frequency spectrum used for electrical power, man-made fields are many thousands of times greater than natural fields arising from either the Sun or the Earth. Naturally occurring time-varying magnetic fields are associated with changes in ionospheric currents which are most affected by the Sun's activity. Magnetic flux densities of 0.5 JJT at frequencies of a few hertz can be generated at times of intense solar activity, but normal daily variations from pulses of less than 0.1 Hz are about 0.03 ^T. This may be compared to the Earth's static magnetic flux density which is in the range 30-70 uT and around 50 jxT in the UK. Lightning strikes can generate a wide range of frequencies up to the megahertz region, the peak intensity occurring at frequencies of a few kilohertz but under normal circumstances the magnetic flux density decreases from 10^{-5} \xT at several hertz to 10"[8] uT at a few kilohertz. Atmospheric time-varying electric fields up to 1 kHz are less than 0.5 Vm"[1] and decrease with increasing frequency. Many of the effects of exposure can be related to the response to electric fields and currents induced in tissues. Dosimetric concepts have been developed which provide a basis for linking external electric and magnetic fields to the electric field strength. induced current density and the energy absorption rate in tissues. The exposures to extremely low-frequency magnetic fields (ELFMF) in our environment have dramatically increased, which includes both occupational exposure and general exposure to sources, such as

Corresponding Author: Vahdettin Bayazit, PhD, MuşAlparslan University, Faculty of Arts and Sciences, Department of Biology, 49100, Muş, Turkey,
Phone: +05362869456,
E-mail: bvahdettin@yahoo.com

power lines, household electrical wiring and medical devices. This produced a social alarm on the possible adverse effects of magnetic fields on human health and stimulated a number of investigations on the biological effects of ELFMF on living organisms. Some reports show that ELFMF may interfere on the activity of the brain and, generate behavioral and cognitive disturbances, increase the risk of neurodegenerative diseases in humans and produce deficits in attention, perception and spatial learning in rats. Furthermore, the developing central nervous system (CNS) exhibits even higher sensitivity to ELFMF. Prenatal or perinatal exposure to ELFMF decreases the density of neurons in the medial preoptic nucleus, affects some sexually dimorphic structures, and impairs scent marking and inter-male fighting behaviors during adulthood (Batanjac and Boorman *et al.,* 1999; Baum *et al.,* 1995; Pauncu, 2003; Berg *et al.,* 2005; Bonhomme-Faiver *et al.,* 1999; Capri *et al.,* 2004; Caraglia *et al.,* 2005; Che *et al.,* 2007; Chernoff *et al.,* 1992; Christ and Kuster, 2005; Christensen *et al.,* 2005).

Physical Properties of Electric and Magnetic Fields:

Although electric and magnetic fields are used widely in modern technology, most persons outside of the scientific and engineering community have few reference points with which to understand them. The most common experiences include static electric fields produced indoors in dry climates and static magnetic fields around permanent magnets. Electromagnetic radiation, or at least the effect of it, is familiar to almost everyone in the form of visible light, radio transmission, and x-rays. The purpose of this section is to provide a brief description of the properties of electric and magnetic fields and of how they interact with matter. This knowledge has been applied to human exposures to electric and magnetic fields for several decades, and many of the details of interaction at certain levels are now understood. Specific knowledge of how these interactions affect living organisms, on the other hand, is very limited and the subject of much investigation. Electric fields occur when electric charges are present. The matter we experience commonly consists of almost equal numbers of positively charged and negatively charged particles, so even though intense electric fields are occurring on a microscopic or atomic level, the matter is practically neutral on the macroscopic scale of which we are aware. When some of the positive and negative charges are separated over distances on our scale, we may experience obvious effects of an electric field. The large separation of charges as one moves across a room can produce a substantial static electric field. This field may cause the hair on the hands or arms to stand up as the subject moves near a grounded conductive object and result in a physical sensation. If the conductor is physically contacted, a shock may occur as electric current flows, returning the separated electric charges to a more neutral condition. If a conducting path is provided between areas of separated charge, the charges, usually in the form of electrons or ions (atoms with an unequal number of positive and negative electric charges), will flow between the two regions. This flow of charge is called electric current and is measured in units of amperes (A). Electric charge is measured in coulombs (C). Current is simply the number of coulombs of charge that flow through a given region per second. In reactive fields, no fixed relationship exists between the electric and magnetic field components for all cases. The parallel plate system described earlier, for example, will produce a ratio of electric to magnetic field strength much greater than 377 ohms at low frequencies. A calculation of power density in this exposure field would show very low values, This result is misleading because a dielectric or conductive object placed in the field will absorb more power (energy/time) than is predicted to be incident on the object by the power density calculation. In such cases, the object is absorbing stored energy from the electric field as the movement of charged particles or polarization of the dielectric produces thermal motion in the object. Similarly, a conductor or magnetic material will absorb energy from a pure magnetic field. Eddy currents in conductor and polarization effects in magnetic materials result in heating (D'Andrea *et al.,* 2003; Dawe *et al.,* 2006; Diem *et al.,* 2005; Feychting, 2005; Greenland *et al.,* 2000; Gurney *et al.,* 1997; Hardell *et al,* 1999; Hardell *et al.,* 2002; Health 1996; Heikkinen *et al.,* 2003; Hepworth *et al.,* 2006; Kato *et al.,* 1991; Koivisto *et al.,* 2000a; Koivisto *et al.,* 2000b; Koivisto *et al.,* 2001; Kwan-Hoong 2003; Lai and Singh, 1997; Loomis *et al.,* 1994; Marinelli *et al.,* 2004; Miller *et al.,* 1996; Miyakoshi *et al.,* 2005; Monfrecola *et al.,* 2003; Monselise *et al.,* 2003; NRPB, 1993; NRPB, 1994a; NRPB, 1994b; ORAU, 1992; Otto and Muhlendahl, 2007; Poole, 1996; Preston *et al.,* 1996; Radon *et al.,* 2001; Regoli *et al.,* 2005; Renew *et al.,* 1990).

Coupling of Electric and Magnetic Fields with the Body:

The interaction of electric and magnetic fields with the body can be divided into macroscopic and microscopic aspects. Macroscopic interactions are those occurring as a result of introducing a large dielectric object into the field. Viewed in this way, the body may be thought of as an antenna that absorbs energy from the field. Microscopic interactions are those occurring on the cellular or sub-cellular level, such as induced

membrane potentials, changes in ion transport, etc. Although the organism as a whole is exposed to the external fields, the tissues and cells experience a substantially different set of exposure parameters. Many details of macroscopic interactions are presently understood, including total energy absorption, induced surface charges, total currents, and others. Interaction mechanism theories generally address microscopic problems, assuming that local exposure conditions (at the tissue or cell level) have already been defined by evaluation of the macroscopic coupling effects. Biological substances, with a few rare exceptions, are nonmagnetic, meaning that the magnetic properties are similar to those of air or a vacuum. Consequently, ELF magnetic fields are practically the same inside the body as out, and the presence of the body does not significantly affect the magnitude or direction of the magnetic field. This fact simplifies the development of interaction mechanism theories based on magnetic field exposures because the magnetic field strengths at the tissue or cell level are known (Repacholi and Greenebaum, 1999; Rezaei *et al.,* 2009; Röschke *et al.,* 1997; Salem, 2005; Salford *et al.,* 1994; Savitz *et al.,* 1993; Savitz and Loomis, 1995; Schoemaker *et al.,* 2005; Simkó *et al.,* 2004; Simkó *et al.,* 2006; Sobel, 1995).

Epidemiologic Studies of Electromagnetic Fields and Cancer:

Concern extends not just to radiofrequency (RF) radiation but also to exposure from electrical power transmission and usage. The studies generally fall into one of three categories: occupational, environmental, and residential exposures. Results have been reported for different geographic regions, countries, age groups, industries, and occupational classifications. Many of the studies focus on 50- or 60-hertz (Hz) fields, the frequencies used for power transmission. There have been studies on cancer in children and cancer in adults. Childhood cancer studies have involved exposure to magnetic fields in the home, either measured or estimated by power line wiring configurations. The results of these studies bear directly on the risk of cancer in exposed persons. Studies of children and adults are evaluated separately. The presumed frequency of exposure is relevant. Studies that examined populations with exposure to RF radiation are evaluated separately from studies of 50 or 60 Hz, the frequencies of electrical power transmission. Many of the occupational studies use job titles or employment in industries or occupations with potential exposure to electromagnetic (EM) radiation, a surrogate of exposure. There were 344 cancer cases who met the study selection criteria. Of these, birth address information was lacking for 72 cases or the birth occurred prior to 1946, and death address information was lacking for 16 cases. As a result, analyses of birth address were made for 272 cases and their controls and of death address were made for 328 cases and their controls. Maps were made of the electrical wires and transformers in the vicinity of birth and death addresses for cases and controls. Primary [13-kilovolt (kV)] wires were classified as “large-gauge” or “thin.” Large-gauge wires are designed to carry high currents. Homes were classified as having either a “high-current configuration (HCC)” or “low-current configuration (LCC).” HCC homes were (1) less than 40 meters from large-gauge primaries or an array of six or more thin primaries, (2) less than 20 meters from arrays of 3-5 thin primaries or high tension (50-230 kV) wires, (3) and less than 15 meters from first-span secondary wires (240 volts) defined as secondaries issuing directly from the transformer without any loss in current through a service drop beyond the pole. The distribution of cases and controls by HCC and LCC residence at birth and at death was presented for leukemias, lymphomas, nervous system tumors, and all other cancer combined. For all cancer sites combined and for both types of addresses, the proportion of cases who resided in HCC homes was greater than the proportion of controls. There was no difference in the risk of all other cancer between cases and controls when consideration was given to death address alone. No statistical tests were performed nor odds ratios developed by the authors. Certain demographic factors that could relate to the development of cancer were examined to consider whether they could explain the observed association of excess cancer mortality in children who had resided in HCC homes. These factors were urban-suburban differences, socioeconomic class, family patterns of cancer, traffic congestion, and sex. There was a slight but nonsignificant excess of suburban addresses among controls. A trend, albeit not significant, toward higher socioeconomic class was seen in the cases. It is possible that certain site-specific cancers such as lymphoma and/or central nervous system cancer may present an onset period longer than that of leukemia and the net effect of lumping them all together as one group would be to mask individual differences in length of latency. The fact that children who have always lived at the same location have a higher risk of total cancer than those who have moved would seem to support this thesis. Differences in risk seen in “birth” residency cases separately from “death” residency cases may only be a reflection of the expression of different cancers, that is, lymphoma in “birth” residency cases and leukemia in “death” residency cases. In any event, this topic could have been more adequately discussed by the authors. When specific cancer

sites, that is, leukemia, lymphomas, nervous system, and/or other sites were analyzed, based upon case dwellings and control dwellings, only cancer of the nervous system is significant (Table 1) while that of lymphomas and/or other sites are nonsignificantly elevated. Leukemia is actually below expectation with a risk of 0.3. If persons were used as the units from which to calculate risk, all of these estimates would be elevated. It is likely that the risk of lymphoma and risk of cancer of other sites would be significant. However, although the risk of leukemia would be raised slightly, it would still fall below one. It should be noted that the rate of leukemia seems to be unusually low in this Swedish population, regardless of the EM fields issue. This may reflect some anomaly in the cancer registry. There is some evidence that leukemias may be underreported in the Swedish cancer registry (Baum *et al.,* 1995; Lai and Singh, 1997; Loomis *et al.,* 1994; Marinelli *et al.,* 2004; Miller *et al.,* 1996; Miyakoshi *et al.,* 2005; Monfrecola *et al.,* 2003; Monselise *et al.,* 2003; NRPB, 1993; NRPB, 1994a; NRPB, 1994b; ORAU , 1992; Otto and Muhlendahl, 2007; Poole, 1996; Preston *et al.,* 1996; Radon *et al.,* 2001; Regoli *et al.,* 2005; Renew *et al.,* 1990; Stenvens and Davis, 1996; Swanson, 1996; Swanson and Jeffers, 1999a; Swanson and Jeffers, 1999b; Tenforde *et al.,* 1996; Tomenius, 1986; UKCCS, 1999; UKCCS, 2000; Uloziene *et al.,* 2005).

Table 1: risk ratios for specific cancer sites and magnetic field level.

All Visible Structures[a]	≥0.3μT	<0.3μT
Sites:		
All	2.1[b]	1.0
Leukemia	0.3	1.0
Lymphomas	1.8	1.0
Nervous System	3.7[b]	1.0
Other sites	--	1.0
All Malignant Neoplasms	1.8	1.0
Benign Neoplasms	--	1.0

[a] Data for 200 kV wires and other visible structures, considered separately, were given in the paper but are not given here

[b] Per author, $p \leq 0.05$, chi-square test and only given if xpected numbers in each category were at least 5 and if adds ratios were different than 1.0.

Distance of residence from an overhead power line was grouped into intervals of 0-24, 25-49, 50-74, 74-99, and greater than 100 meters (Table 2, 3, 4). The latter grouping was taken as the reference group. For all cancers considered together, the odds ratios were greater than unity at all distances less than 100 meters, but there was no trend of increased risk with decreased distance. The largest ratio was 1.6 at 24-49 meters. No value was statistically significant. For analysis of lymphomas and leukemias, considered together, and of solid tumors, there was no clear pattern of increased risk with decreased distance. The risk ratios were generally elevated, but no increase was statistically significant. The highest risk ratio estimated for lymphomas and leukemias was 2.6 at 50-74 meters; statistical significance may be viewed as marginal with a p-value of 0.05.

As brain tumours in childhood and adult life are different in origin, arising from different types of cell, this evidence was considered to be less impressive than might appear. In the case of residential studies of childhood tumours there were problems with study designs; the positive results may have been artefacts of the method of enquiry. In the case of brain cancer observed in studies of workers involved in electrical occupations, it was impossible to decide whether the risk, if one existed, was due to exposure to electromagnetic fields or to some chemical associated with the work. There is an increasing interest in possible health effects of exposure to high frequency radiations arising from mobile phones and their base stations. The Advisory Group is also keeping under review relevant experimental and epidemiological studies related to exposure to radiofrequencies and will report on them in due course. The Advisory Group notes the publication by the Independent Expert Group on Mobile Phones (IEGMP. 2000) of the report on mobile phones and health. Cellular studies have played a vitally important part in the early identification of chemicals and other agents to which humans may be exposed and which have the potential to play a part in the causation of cancer. The major tumour types examined include leukaemias, lymphomas and chemically induced skin and mammary tumours. In addition, the evidence for possible inhibitory effects of power frequency electromagnetic fields on circulating levels of serum melatonin, implicated in the development of mammary and perhaps other tumours, is discussed. Finally, a possible role for electromagnetic field exposure effects on tumour development via compromised immune system function is explored (Baum *et al.,* 1995;NRPB, 1994b; ORAU , 1992; Otto and Muhlendahl, 2007; Poole, 1996; Preston *et al.,* 1996; Radon *et al.,* 2001; Regoli *et al.,* 2005; Renew *et al.,* 1990; UKCCS, 1999; UKCCS, 2000; Uloziene *et al.,* 2005).

Table 2: Distribution of cases and controls by distance from overhead power lines and by cancer.

	Distance[a]	Cases	Controls	RR[a]	95% CI[a]	p-values[b]
Lymphomas/	0-24	1	3	0.5	0.06-5.0	0.29
Leukemia	25-49	8	8	1.6	0.6-4.3	0.18
	50-74	9	6	2.4	09-6.6	0.05
	75-99	3	5	1.0	02-4.	0.48
	>100	169	269	1.0	---	--
Solid	0-24	3	3	1.6	03-8.1	0.27
Tumors	25-49	4	4	1.6	0.4-6.5	0.25
	50-74	5	10	0.8	0.3-2.4	0.26
	75-99	4	5	1.3	0.35-4.9	0.35
	>100	170	277	1.0	---	--
All	0-24	4	6	1.1	0.3-3.8	0.46
cancers	25-49	12	12	1.6	0.7-3.6	0.12
	50-74	14	16	1.4	0.7-2.9	0.13
	75-99	7	10	1.1	0.4-3.0	0.41
	>100	339	546	1.0	---	--

[a] Distance is in meters RR = risk ratio. Cl = confidence interval.
[b] Level of significance at 5%.

Table 3: Distribution of cases and controls by estimated magnetic field level in milligauss (mg) and by cancer type.

	Distance[a]	Cases	Controls	RR[a]	95% CI[a]	p-values[b]
Lymphomas/	<0.010	6	4	2.4	0.7-8.3	0.08
Leukemia	0.010-0.099	7	5	2.2	0.7-7.0	0.08
	0.10-0.99	4	8	0.8	0.2-2.7	0.36
	1.0-9.99	2	4	0.8	0.1-4.4	0.40
	>10.0	2	1	3.2	0.3-31.2	0.16
Solid	<0.010	3	4	1.2	0.3-5.5	0.38
Tumors	0.010-0.099	6	8	1.2	0.4-3.6	0.36
	0.10-0.99	5	7	1.2	0.4-2.2	0.40
	1.0-9.99	2	1	3.3	0.3-31.8	0.15
	>10.0	0	2	NA	NA	NA
All	<0.010	9	8	1.8	0.7-4.7	0.11
cancers	0.010-0.099	13	13	1.6	0.7-3.5	0.11
	0.10-0.99	9	15	1.0	0.4-2.2	0.47
	1.0-9.99	4	5	1.3	0.3-4.8	0.35
	>10.0	2	3	1.1	0.2-6.5	0.47

[a] RR = risk ratio. Cl = confidence interval, NA = not applicable
[b] Level of significance at 5%.

Table 4: Electromagnetic Fields and Their Sources

Freque	Wavelength		Description	Band	Sources
Ohz			Static	Earth's Magnets	field DC
30 Hz	10km	000	Sub-extremely low frequency	SEL	Electric power lines and cables
50 Hz	6 km	000	Extremely low frequency	ELF	Domestic and industrial appliances
300 Hz	1km	000	Voice frequency*	VF	Induction heaters
3 kHz	100 km		Very low frequency	VLF	Television sets Visual display units
30 kHz	10 km		Low frequency	LF	AM radio
300 kHz	1km		Medium frequency	MF	Induction heaters
3 MHz	100 m		High frequency	HF	RF heat sealers
30 MHz	10m		Very high frequency	VHF	FM radio
300 MHz	lm		Ultra high frequency	UHF	Mobile phones Television broadcast Microwave ovens
3 Ghz	10 cm		Super high frequency	SHF	Radar Satellite links Microwave communications
30 Ghz	1 cm				
300 Ghz	1 mm		Extra high frequency	EHF	Point-to-point links
			Infrared		

" Radiofrequencies equivalent to speech (sound) frequencies.
Note 1000 Hz = 1 kHz: 1000 kHz = 1 MHz: 1000 MHz = 1 GHz.

Magnetic Fields:

Magnetic field strength measurements are made using coils, which are designed to shield against the effect of any electric field component. The rate of change of magnetic flux through the area intercepted by the coil produces an induced electromotive force from which the magnetic flux density can be ascertained by using an appropriate voltmeter. Instruments have been designed with orthogonal loops to provide independence of

field orientation and, in contrast to electric field strength measurements, field perturbation causes minimal problems for measurements in practice. Accurate calibration of magnetic field strength instruments can be achieved by using Helmholtz coils which can be designed to provide a uniform magnetic field over the volume occupied by the measuring instrument.In this analysis, the risk of lymphomas/leukemia or "solid" tumors was not associated with increasing distance (in four strata) from 50-Hz overhead power lines. However, when the distances are collapsed to only two categories, i.e., <100 meters versus > 100 meters, then the risk ratios are 1.5, 1.2, and 1.4 for lymphomas/leukemias, solid tumors, and all cancer, respectively. These slightly elevated risk estimates suggest that there may be an association with "closeness" to power lines, but this association may be sharpened by utilization of actual measurements of the magnetic field intensity rather than a poor surrogate such as distance. The next analysis by the authors was to take only those cases and controls who resided within 100 meters from the overhead power lines and assign an estimated magnetic field strength in milligauss to each person and then estimate risks based upon intensity of the fields (Table 4). Although most of the risks were elevated, none were significant, and no dose-response relationship surfaced. Field values were grouped as less than 0.010, 0.010-0.099, 0.10-0.99, 1.00-9.99, and greater than 10.00 milligauss (mG). In units of microtesla, these grouped ranges are less than 0.001, 0.001-0.0099, 0.01-0.099, 0.1-0.999, ana greater than 1.0 μT. Again, subjects residing over 100 meters from a line were taken as the reference group. Obviously, it would have been more appropriate to classify everyone according to their respective magnetic field strengths and then analyse for dose-response relationships. It is likely that persons living beyond the 100-meter point were subject to magnetic field exposures from other sources. The character of these fields are probably not different from those produced by overhead power lines. Furthermore, the vast majority of the few cases and controls that did fall within 100 meters were subject to magnetic fields intensities that were very low, i.e., less than 1.0 mG (0.1 μT). These same data were used to evaluate site-specific cancer under low-power, high-power, and high-voltage conditions with measured values dichotomized, i.e., > 2.0 mG and <2.0 mG (Table 5). The main point to be gained from this analysis is that, there appears to be a modest increase in risk, up to 3.26, in several types of cancer in children who resided in homes where magnetic fields were > 2 mG. If 3.0 mG was used, similar to Tomenius, the authors noted an increase in site-specific odds ratios. No numbers are given, but they were stated to be imprecise. Stratified analyses for low-power use magnetic field data were made to examine potential confounding with maternal age, father's education, per capita income, maternal smoking during pregnancy, and traffic density (Gurney *et al.,* 1997; Hardell *et al,* 1999; Hardell *et al.,* 2002; Health 1996; Heikkinen *et al.,* 2003; Hepworth *et al.,* 2006; Kato *et al.,* 1991; Koivisto *et al.,* 2000a; Koivisto *et al.,* 2000b; Koivisto *et al.,* 2001; Kwan-Hoong 2003; Lai and Singh, 1997; Loomis *et al.,* 1994; Marinelli *et al.,* 2004; Miller *et al.,* 1996; Miyakoshi *et al.,* 2005; Monfrecola *et al.,* 2003; Monselise *et al.,* 2003; NRPB, 1993; NRPB, 1994a; NRPB, 1994b; ORAU , 1992; Otto and Muhlendahl, 2007; Poole , 1996; Preston *et al.,* 1996; Radon *et al.,* 2001; Regoli *et al.,* 2005; Renew *et al.,* 1990). Concerning the relationship between EM fields and adverse health effects are very The scientific issues complex and difficult to interpret. Epidemiologic data are limited and many results to date are based on small studies with methodological limitations. As a result, there are large differences in the way that these studies are evaluated and interpreted, both within the scientific community in general, and among scientists and Agencies within the Federal government in particular. This draft document on electromagnetic (EM) fields reviews and evaluates published information pertaining to the potential carcinogenicity of EM fields. The information includes epidemiology studies, chronic lifetime animal tests, and laboratory studies of biological phenomena related to carcinogenesis. The observed mortality was less in both male and female employees than expected, based on U.S. mortality rates (Table 5).

Table 5: Cancer risk (odds rat?os with 95% confidence intervals in parentheses) in relation to magnetic fields and electric fields, categorized into two exposure groups and measured under low- or h?gh-power use cond?t?ons, in residences occupied at diagnosis: denver standard metropolitan statistical area.

Site	Magnetic fields: low power (≥ 0.2μT)	Magnetic fields: high power (≥ 0.2μT)	Electric fields: high power
All Cancers	1.35 (0.63-2.90)	1.04 (0.56-1.95)	0.93 (0.53-1.61)
Leukemia	1.93 (0.67-5056)	1.41 (0.57-3.50)	0.75 (0.29-191)
Acute lymphocytic leukemia	1.56 (0.42-5.72)	1.05 (0.34-3.26)	0.67 (0.22-2.04)
Lymphoma	2.17 (0.46-10.31)	1.81 (0.48-6.88)	0.70 (0.15-3.27)
Brain	1.04 (0.22-4.82)	0.82 (0.23-2.93)	0.53 (0.15-1.81)
Soft tissue sarcomas	3.26 (0.88-12.07)	1.65 (0.44-6.20)	0.64 (0.14-2.96)
Other Canaers	0.31 (0.44-2.14)	0.49 (0.14-1.66)	(0.78-3.51)

[a]For magnetic fields, < 2.0 mG and 2.0+ mG. For electric fields, < 12.0 V/m and 12.0+ V/m.

The male employees had lower mortality than did female employees. Cancer was the predominant cause of death in both sexes. The risk of leukemia was elevated both at Moscow [standardized mortality ratio (SMR=2.5)] and at comparison posts (SMR=1.8). Neither SMR was statistically significant. Comparison post employees had a statistically significant excess risk (SMR=3.3) of nervous system tumors. In general, the Moscow and comparison groups did not differ appreciably in overall and specific mortality. However, the population was relatively young; it may have been too early to detect long-term mortality effects (Stenvens and Davis, 1996; Swanson, 1996; Swanson and Jeffers, 1999a; Swanson and Jeffers, 1999b; Tenforde *et al.,* 1996; Tomenius, 1986; UKCCS, 1999; UKCCS, 2000; Uloziene *et al.,* 2005).

Table 6: Observed and expected number of deaths, standardized mortality ratios (smr), and 95% conf?dence intervals (cl) by all causes of death, specified causes of death from cancer, and post for male and female state and nonstate department employees combined.

	Moscow			Other Posts		
	Number of Deaths		SMR	Number of Deaths		SMR
Cause of Daeth	Observed	Expected	(95% Cl)	Observed	Expected	(95% Cl)
All causes (0.5, 0.7)	49	105.3	0.47 (0.4-0.6)	132	223.7	0.59
Mallgnat neoplasms	17	19.0	0.89 (0.5-1.4)	47	41.1	1.1 (0.8-1.5)
Digestive organs	3	4.6	0.65 (0.4-1.9)	11	10.8	1.0 (0.5-1.8)
Brain tumors/CNS nroplasms	0	0.9	0.0	5	1.5	3.3 (1.1-7.7)
Pancreas	1	1.0	1.0 (0.0-5.6)	1	2.2	0.5 (0.0-2.5)
Lung	5	5.8	0.86 (0.3-2.0)	11	12.2	0.9 (0.4-1.6)
Leukemia	2	0.8	2.5 (0.3-9.0)	3	1.7	1.8 (0.4-5.3)
Hodgkin's disease	0	0.5	0.0	0	0.7	0.0
Breast	2	0.5	4.0 (0.5-14.4)	3	1.2	2.4 (0.5-7.0)
Uterus	1	0.2	5.0 (0.1-27.9)	0	0.0	0.0
Cervix	1	0.1	10.0 (0.3-55.7)	0	0.0	0.0

For the low-exposure groups, mortality ratios were only slightly elevated for diseases of the circulatory system (1.07); the cancer residual, other malignant neoplasms (1.19); and the total residual, other diseases (1.08). Cancers of the digestive tract (1.14), respiratory system (1.14), and lymphatic and hematopoietic systems (1.19) were elevated for the high-exposure group, but none of the increases was statistically significant. The differences in mortality from malignant neoplasms of the lymphatic and hematopoietic system, although elevated, were not statistically significant. Observed deaths (Table 7) were significantly lower than expected for all-cause mortality and for mortality from all malignant neoplasms combined, pancreatic cancer, cancer of the respiratory system, all circulatory diseases combined, all respiratory diseases combined, ana all accidents, SMRs were elevated for several cancer sites, and statistically significant excesses were found for specific sites in lymphatic and hematopoietic tissues, namely, acute myeloid leukemias (SMR=1.76) and multiple myelomas and other neoplasms of the lymphoid tissues, considered together (SMR=1.62). The latter rubric is the category for lymphomas other than lymphosarcomas and reticulum-cell sarcomas and Hodgkin's disease (NRPB, 1993; NRPB, 1994a; NRPB, 1994b; ORAU, 1992; Otto and Muhlendahl, 2007; Poole, 1996; Preston *et al.,* 1996; Radon *et al.,* 2001; Regoli *et al.,* 2005; Renew *et al.,* 1990). This is a study with a large population (67,829 licensees; 232,499 accumulated person-years; 2485 deaths). Excess risks are seen at several cancer sites but are especially concentrated at tissues of the lymphatic and hematopoietic system, where certain excess risks have been found. The risk of acute myeloid leukemia was significantly elevated. Leukemias generally predominate in younger ages. Chronic leukemias were low. Since licensing is required for amateur radio operators, enumeration of the population should be reasonably complete although licensing per se does not provide information on usage and exposure. Milham cites survey data that found that amateurs practice their hobby about 6 hours per week. It would seem that licensees would have exposure but the extent ana degree is not clear and is probably variable. However, the potential for exposure misclassification would tend to bias estimates towards the null (Monfrecola *et al.,* 2003; Monselise *et al.,* 2003; NRPB, 1993; NRPB, 1994a; NRPB, 1994b; ORAU , 1992; Otto and Muhlendahl, 2007; Poole , 1996; Preston *et al.,* 1996; Radon *et al.,* 2001; Regoli *et al.,* 2005; Renew *et al.,* 1990; UKCCS, 1999; UKCCS, 2000; Uloziene *et al.,* 2005).

Table 7: Mortality in Washington State and California: U.S. Federal Communications Commission (FCC) amateur radio operator licensees.

	Observed	Expected	SMR*
All causes	2485	3478.9	71*
All malignant neoplasms	741	836.9	89*
Esophagus	22	19.4	113
Stomach	30	29.6	102
Large intestine	88	79.0	111
Rectum	14	18.2	77
Liver	11	16.8	65
Pancreas	27	41.9	64*
Respiratory system	209	345.6	66
Prostate	78	67.6	114
Urinary bladder	16	24.1	66
Kidney	19	20.1	94
Brain	29	20.8	139
Lymphatic and hematopoietic tissue	89	72.1	123
Lymphosarooma/reticulosarooma	5	10.6	47
Hodgkin's disease	5	4.1	123
Leukemia	36	29.0	124
Lymphatic	9	8.7	103
Acute	3	2.5	120
Chronic	6	5.5	109
unspecified	0	0.8	0
Myeloid	18	12.9	140
Acute	15	8.5	176
Chronic	3	3.5	86
unspecified	0	0.9	0
Monooytic	0	0.6	0
Unspecified	9	6.7	134
Acute	6	3.4	176*
Unspecified	3	2.5	120
Other lymphatic tissues	43	26.6	162*
All circulatory diseases	1208	1731.7	70*
All respiratory diseases	127	252.5	50*
All accidents	105	164.5	64*

[a] SMR = standardized mortality ratio.

* $p < 0.05$.

Evaluation of the Potential Carcinogenicity of Electromagnetic Fields:

Although the entire NIEMR spectrum is of interest, the emphasis in this document is on time-varying electric ana magnetic fields in the extremely low frequency (ELF) range [approximately 3 to 3000 hertz (Hz)] and on radiofrequency (RF) radiation [approximately 0.003 to 30,000 megahertz (MHz)]. These two regions of the spectrum are emphasized because they are of regulatory concern to the Agency and because the preponderance of information is in these regions, The evaluation of the likelihood of human cancer risk is based on a judgment as to the overall weight of evidence that a carcinogenic response is causally related to specific levels or types of exposure. Since the establishment of causality is often difficult, the weight-of-evidence approach relies on the combination of empirical observations ana inferences founded in reasonable scientific judgment. Under this approach, the evidence from human studies is considered most important, with lesser importance being attached,respectively, to chronic lifetime animal studies and ancillary evidence, such as short-term tests of genetic toxicity, mechanistic studies, and evidence of carcinogenicity for chemical analogues to the agent under study. There are four essential elements in a risk assessment: hazard identification, dose-response assessment, exposure assessment, and risk characterization. This document deals largely with hazard identification, with a brief section devoted to exposure. Dose-response assessment is not attempted because the nature of the interaction between the body and electric and magnetic fields is not well enough understood to be able to specify the relevant aspects of exposure. In the absence of critical information about both exposure and dose-response, an overall risk characterization is not developed in this document.

In its entirety, this document represents an analysis of the state-of-the-science supporting a concern for the potential carcinogenic hazard of EM fields.The two basic sources of information that furnish evidence of the relationship between exposure to EM fields and cancer are human evidence and laboratory studies. Human evidence is observational in nature and cannot account for or control all of the potentially relevant factors. Laboratory studies with biological models of the human disease search for explanations of the human findings by evaluating the effects of the various controllable factors. A large number of human studies are available in which the relationship between human cancer incidence or mortality and exposure to EM fields has been

investigated. From these studies the strongest relative evidence that exposure to EM fields is causally related to human cancer comes from case-control studies of cancer in children. Seven of these have examined residential exposure from electric power transmission and distribution lines and two others have examined cancer in children in relation to father's occupation. These studies have consistently found modestly elevated risks (some statistically significant) of leukemia, cancer of the nervous system and, to a lesser extent, lymphomas. These findings are associated with magnetic fields in homes where children reside which were estimated after the diagnosis with both magnetic field measurements and with surrogate indicators of magnetic fields, i.e., wiring codes. Electric fields were not found to be a critical factor thus far. The studies of residential adult exposures to EM fields provide mixed evidence of a risk of leukemia, but due to a lack of statistical power and a lack of definite information on precise EM-field exposures, these findings are not as strong as those for childhood cancer. These studies cannot be interpreted as evidence either for or against a causal association between cancer and EM-field exposures. There have been very few lifetime animal carcinogenicity studies of EM fields, and none at power line frequencies. One study in mice of unmodulated 2450-MHz RF radiation at power levels low enough to cause only moderate body heating showed an enhancement of the growth rate of spontaneous mammary tumors and of skin tumors initiated by benzo[a]pyrene, a chemical carcinogen. One rat study of pulse-modulated 2450-MHz RF radiation designed to simulate human exposure to medium-range radar showed the induction of benign adrenal medulla tumors and an increased incidence of carcinomas at all tissue sites combined, with no increase at any one site; the latter finding was not accompanied by the induction of benign tumors.

ELF fields of relatively high intensity producing induced tissue currents on the order of 10 microamperes per square centimeter (μA/cm2) have enhanced DNA synthesis, altered the transcription of DNA into mRNA, altered the molecular weight distribution during protein synthesis, delayed the mitotic cell cycle, induced chromosome aberrations, blocked the action of parathyroid hormone at the site of its plasma membrane receptor, induced enzymes normally active during cell proliferation, inhibited differentiation and stimulated the growth of carcinoma cell lines, inhibited the cytotoxicity of T-lymphocytes (which indicates an impairment of the immune system) in vitro but not in vivo, inhibited the synthesis of melatonin (a hormone that suppresses the growth of several types of tumors), and caused alterations in the binding of calcium to brain tissues. Only three ELF effects have been induced at field strengths comparable to the low environmental exposures at which human cancer has putatively been caused: (1) the calcium efflux from brain tissue preparations using 16-Hz electric and magnetic fields that were perpendicular to each other; (2) calcium efflux from chick brain tissues after exposure of the developing embryo to electric fields; and (3) the inhibition of melatonin synthesis by the pineal gland when a static magnetic field of approximately the strength of the earth's magnetic field is changed through a small angle of rotation. The results of this first experiment are one of several phenomena that show a complex dependence of frequency, intensity, and orientation with respect to the earth's magnetic fields. In evaluating the potential for carcinogenicity of chemical agents, the U.S. EPA has developed an approach that attempts to integrate all of the available information into a summary classification of the weight of evidence that the agent is carcinogenic in humans. At this time, such a characterization regarding the link between cancer and exposure to EM fields is not appropriate because the basic nature of the interaction between EM fields and biological processes leading to cancer is not understood. For example, if induced electrical currents were the causative factor, then exposure to electric as well as magnetic fields would be important and the effect would be more severe as the frequency increases. But if the direct magnetic field interaction were the critical factor, then the ambient static magnetic field, as well as the alternating magnetic field, would be critical, and the effect may be confined to specific frequencies, resulting in an extremely complicated dose-response relationship. In addition, if they were shown to be causative agents, these fields probably exert their effects via other chemical and environmental factors rather than directly causing events known to be causally related to carcinogenic processes, as with genotoxic chemical agents (Kato *et al.,* 1991; Koivisto *et al.,* 2000a; Koivisto *et al.,* 2000b; Koivisto *et al.,* 2001; Kwan-Hoong 2003; Monfrecola *et al.,* 2003; Monselise *et al.,* 2003; NRPB, 1993; NRPB, 1994a; NRPB, 1994b; ORAU , 1992; Otto and Muhlendahl, 2007; Poole , 1996; Preston *et al.,* 1996; Radon *et al.,* 2001; Regoli *et al.,* 2005; Renew *et al.,* 1990).

Radio Frequency Fields (RF Fields):

The balance of epidemiologic evidence indicates that mobile phone use of less than 10 years does not pose any increased risk of brain tumour or acoustic neuroma. For long-term use, data are sparse, and the following conclusions are therefore uncertain and tentative. However, from the available data it does appear that there is no increased risk for brain tumours in long-term users, with the exception of acoustic neuroma for which there is some evidence of an association. For diseases other than cancer, very little epidemiologic data are

available. A particular consideration is mobile phone use by children. While no specific evidence exists, children or adolescents may be more sensitive to RF field exposure than adults. Children of today will also experience a much higher cumulative exposure than previous generations. To date no epidemiologic studies on children are available. Animal studies have not provided evidence that RF fields could induce cancer, enhance the effects of known carcinogens, or accelerate the development of transplanted tumours. The open questions include adequacy of the experimental models used and scarcity of data at high exposure levels (NRPB, 1993; NRPB, 1994a; NRPB, 1994b; ORAU , 1992).

***Extremely Low Frequency Fields (ELF Fields)*:**

The previous conclusion that ELF fields are possibly carcinogenic, chiefly based on childhood leukaemia results, is still valid. There is no known mechanism to explain how electromagnetic field exposure may induce leukaemia. The effects have not been replicated in animal studies. The calculations in the previous opinion of the possible proportion of childhood leukaemia cases that might be attributed to ELF fields still hold. For breast cancer and cardiovascular disease, recent research has indicated that an association is unlikely. For neurodegenerative diseases and brain tumours, the link to ELF fields remains uncertain. A relation between ELF fields ana symptoms (sometimes referred to as electrical hypersensitivity) has not been demonstrated (NRPB, 1993; NRPB, 1994a; NRPB, 1994b; ORAU , 1992).

Effects of Mobile Phone on Tissue:

Mobile phones and base stations send radio-frequency waves. Radio waves are non-ionising radiation. Contrary to ionising radiation, radio waves do not have enough energy to break any chemical bonds, or cause damage to human genotype, the DNA-molecule. Thus, radio waves cannot this way cause cancer. The exposure to RF radiation is given as a SAR (specific absorption rate) value that describes the wattage of the radio waves absorbed by human body or a part of it. The SAR value absorbed by head and body must not exceed 2 watts per kilo, and by arms and legs 4 watts per kilo (W/kg), respectively. The limit values are set by the Decree 294/2002 of the Ministry of Social Affairs and Health that controls the exposure of population to ionising radiation. The biological effects of radio waves have been studied for decades. The known direct health effects of RF radiation are due to absorption of energy from the radio waves into the body causing warmingup of tissues. Health hazards emerge if the human temperature regulation cannot eliminate the excess heat. RF exposures of this magnitude occur, however, only in exceptional working conditions, like in mast operations, radar mounting and industrial high-frequency heating. The effects of mobile phone radiation have been examined, for example, using cell studies. It has been observed that the RF radiation emitted by a mobile phone can temporarily change the activity of certain proteins in cell cultures and also in the human skin. The observed biological changes do not however indicate a health risk. When examining the exposure of children, the calculations demonstrate that a mobile phone held against the ear causes an exposure on the brain surface double of that for adults. The difference is due to children's thinner skull bone and more elastic earlobe. The exposure is however focused to such a small area that the warming-up of children's brain tissue is not any heavier than with adults. Approximately 20 general population studies concerning the causal relation of possible tumour risk and mobile phone use have been carried out. On the grounds of the studies to date, it is not possible to make such a conclusion that mobile phones would cause a health risk. Nevertheless, certain analyses that combine several earlier studies have reported an increased risk of brain tumour in people who have used a mobile phone for a long time (more than ten years). These studies however involve uncertainties. One source of error is a memory illusion related to the fact that mobile phone use and call durations that took place many years are ago are difficult to recall exactly. Since it takes years to develop a cancer and mobile phones have been in common use only for about ten years, the possibility, that a link between mobile phone use and cancer might be found in later population studies, cannot be ruled out. So far, the only known mechanism that mobile telephone radiation has had an effect on living tissue is heating. The rise in temperature on the surface of the brain caused by radio waves is 0.3 degrees at the most. This kind of temperature rise is not known to have biological significance. The temperature of the brain normally fluctuates by about one degree, and only after a five degree increase in temperature do cells become damaged. Experiments performed on cell cultures, also performed at STUK, have produced indicators that mobile telephone radiation could cause temporary changes in the functions of cells. These functions include the functions of genes, activation of proteins, and the internal chemical communication within cells. The trigger for these changes is unknown. It is only known that this phenomenon is not the result of excessive heating of tissue. Radio waves at the radiation level of mobile phones may increase the permeability of the so-called blood-brain barrier. The blood-brain barrier regulates the passing of material between the bloodstream and brain cells. Possible changes are, however, minimal and disappear quickly when the radiation stops. This could possibly be a case of a change

caused by microscopic heating. The occurrence falls within the realm of physiological fluctuation and is not known to be harmful. There is only scarce research evidence on children and mobile phones, and it is not easy to get more – in research ethical sense, children are a special group, which is why the intended study must be very well-founded. Research evidence is neither available on young people's using habits of mobile phones. Studies have been made with young test animals but these results are not directly applicable to humans. Children nevertheless have a special status as mobile phone users, among others, because brains continue to develop even up to 20 years of age. It should also be taken into account that children will have much more time to use mobile phones than adults today who started their regular mobile phone use only about ten years ago. The risk of long-term use of mobile phones cannot however be assessed with certainty until mobiles phones have been in use for several decades. Approximately 20 general population studies concerning the causal relation of possible tumour risk and mobile phone use have been carried out. On the grounds of the studies to date, it is not possible to make such a conclusion that mobile phones would cause a health risk. Nevertheless, certain analyses that combine several earlier studies have reported an increased risk of brain tumour in people who have used a mobile phone for a long time (more than ten years). These studies however involve uncertainties. One source of error is a memory illusion related to the fact that mobile phone use and call durations that took place many years are ago are difficult to recall exactly. A mobile phone with 1900 MHz frequency was placed over the ipsilateral ear of the rabbit for 25 minutes, and FN and surrounding tissues were exposed to a 1.5 watts pulse modulated (217 packets/s) electromagnetic field. During exposure to RFR, immediately after turning off the mobile phone, and 25 minutes after the exposure, temperature change in the surrounding tissue of the FN was recorded and compared to preexposure values. Additionally, another recording regarding the FN functions was done and the data were compared to preexposure values. The surrounding soft tissues were 0.7 degrees F higher in temperature than before cellphone exposure. The temperature returned to normal levels 25 minutes after the test. This is a statistically significant result. In addition: The amplitudes of FN CMAP after radiofrequency radiation exposure were significantly smaller than the preexposure amplitudes and the amplitudes were normal in the 25 minute measurement. Non-ionizing radiations (NIR) usually interact with tissue through the generation of heat. The hazards depend on the ability to penetrate the human body and the absorption characteristics of different tissues. Biological effects that resulted from heating of tissues by Radio Frequency (RF) and Macro Wave (MW) radiations are referred to as thermal effects. Generally the publications of NIR effects confirm the risks from RF and MW. Recently the world health organization (WHO) aids to raise awareness of the risks of NIRs. Because of high conductivity of skin and muscle, the electric field does not penetrate deeply in to these tissues. But the magnetic field component of field penetrates deeply in to the body. A mobile phone transmits RF radiations in all directions and proportion of it is directed to the body (Ahlbom *et al*. 2000; Ahlbom, 2001; Ahlbom *et al.,* 2004; Al-Glaib *et al.,* 2007; Anane *et al.,* 2003a; Anane *et al.,* 2003b; Anderson *et al.,* 1999; Anderson *et al.,* 2000; Anderson *et al.,* 2004; Auvinen *et al.,* 2002; Bartsch *et al.,* 2002; NRPB, 1993; NRPB, 1994a; NRPB, 1994b; ORAU , 1992). Technologic advances over the past three decades have resulted in increased development and use of electromagnetic emitting equipment. Today this equipment is used in medicine, industry, research, military systems, ana at home, for purposes as diverse as medical diathermy, communication, industrial processing, surveillance and reconnaissance. Not only is more and more equipment being produced, but also the power output is increasing. Current concern and emphasis of the environment, in addition to low-level effects reported in the literature from other countries, have also contributed to this renewed interest. The main apprehensions have concerned the risk of cancer, pregnancy disturbances, leukemia, brain tumors and a so-called electrical hypersensitivity. The examined group included 81 electric utility workers from Renel, Timisoara (Romania), professionally exposed to low frequency electromagnetic fields (50/60 Hz). The control group consisted of 50 workers who have never been exposed to electromagnetic fields at workplaces. Both groups were similar in structure according to age, sex and length of work history. The clinical examination before and after work in both groups included: anamnesis, physical examination, ECG, examination of visual functions, reaction time to visual and acoustic stimuli, measuring of blood pressure and skin temperature, and serum concentrations of adrenaline and noradrenaline. The workers of exposed group have had statistically significant more subjective troubles than the workers of control group (Table 8) (NRPB, 1993; NRPB, 1994a; NRPB, 1994b; ORAU, 1992; Stenvens and Davis, 1996; Swanson, 1996; Swanson and Jeffers, 1999a; Swanson and Jeffers, 1999b; Tenforde *et al.,* 1996; Tomenius, 1986; UKCCS, 1999; UKCCS, 2000; Uloziene *et al.,* 2005).

The mean values of hearth frequency, arterial tension, serum concentration of adrenaline and noradrenaline after the work in the examined group were statistically significant less than the values before the work (Table 9).

Table 8: Subjective troubles during the work at workers of exposed and control group.

	Exposed group		Control group		P
	Number	%	Number	%	
Eye's itch	25	30.8	3	6.0	<0.05
Tearful eyes	18	22.2	1	2.0	<0.05
Photophobia	23	28.4	2	4.0	<0.05
Aye's pam	17	20.9	1	2.0	<0.05
Glitter in visual field	15	18.5	1	2.0	<0.05
Sleepiness	59	72.8	5	10.0	<0.05
irritation	61	75.3	4	8.0	<0.05
Headaches	51	62.4	3	6.0	<0.05
Palpitation	34	41.9	4	8.0	<0.05
Bad memory	21	25.9	1	2.0	<0.05
Unconsciousness	15	18.5	1	2.0	<0.05
Depression	13	16.1	0	0.0	<0.05
Bad hearing	12	14.8	0	0.0	<0.05
Vomiting	13	16.1	1	2.0	<0.05

Table 9: Mean values of heart frequency, arterial tension, serum concentration of adrenaline and noradrenaline before and after the work in the examined group.

	Before the work	After the work	P
Heart beat	85.1± 10.2	69.1 ± 4.3	<0.01
Systolic tension	19.8 ± 5.3	16.4 ± 2.8	<0.01
Diastolic tension	11.9 ± 3.2	8.4 ± 1.8	<0.01
Adrenaline	15.1 ± 8.8	11.6 ± 5.7	<0.01
Noradrenaline	27.1 ± 7.1	20.1 ± 7.8	<0.01

These results indicate that electromagnetic fields can be a possible contributing factor in the development of cardiovascular, neurological and endocrine system, bring numerous subjective troubles, psychomotoric and visual weakness to exposed electric utility workers.

The medical preventive measures must be undertaken aiming to save the good health status of exposed electric utility workers.

Repeated exposure to the electromagnetic radiation (EMR) emitted from mobile phones is able to induce hepatic, renal and splenic tissue damage. The degree of damage increased with time of exposure to EMR. Previously similar tissue changes have been described using lower frequency EMR. In a study, It has been conmducted out the first to expose the mobile phone itself to the mice (Figure 1) (Al-Glaib *et al.,* 2007; Anane *et al.,* 2003a; Anane *et al.,* 2003b; Anderson *et al.,* 1999; Anderson *et al.,* 2000; Anderson *et al.,* 2004; Auvinen *et al.,* 2002; Bartsch *et al.,* 2002; Batanjac and Boorman *et al.,* 1999; Baum *et al.,* 1995; Pauncu, 2003; Berg *et al.,* 2005; Bonhomme-Faiver *et al.,* 1999; Capri *et al.,* 2004; Caraglia *et al.,* 2005; Che *et al.,* 2007; Chernoff *et al.,* 1992; Christ and Kuster, 2005; Christensen *et al.,* 2005).

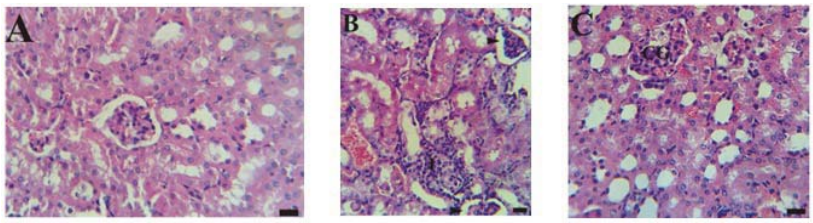

Fig. 1: Light micrograph of the kidney sections of mice. A Control kidney with normal glomeruli and renal tubules. B EMR exposed group for 1h with some atrophied glomeruli, leukocytic infiltrations between the kidney tubules and vacuolation of some tubules. C EMR exposed group for 12h with congested glomeruli and few leukocytic infiltrations. Sections stained with hematoxylin and eosin, Bar ¨T 20 µm

Discussion:

A multicellular organism such as a human being is not simply the sum of individual cells or tissues, but has an added value that derives among others from the availabilty of mechanisms that neutralize possible harmful influences and circumstances. These mechanisms maintain the socalled homeostasis, the primary liferegulating function of multicellular organisms. An effect on a biological system therefore does not necessarily have to lead to an adverse health effect. A health effect will only occur when homeostasis can no longer be maintained, that is, when a biological effect is potentially harmful and cannot or not sufficiently be

compensated. When a mobile phone is held against the head during a call, the brain is exposed to the electromagnetic fields emitted by the device, primarily in the part of the brain closest to the telephone. In recent years many studies have been performed into possible effects of this on the functioning of the brain. In some studies subtle changes in natural electrical processes in the brain have been observed as a result of exposure to the electromagnetic fields emitted by a mobile telephone. However, these are very minor effects without any health influence on health, according to prevailing knowledge. Studies into effects on cognitive functioning are equivocal: in some studies small and reversible effects have been observed, other studies found no effect. Auditory functioning and body balance do not seem to be influenced by signals from mobile telephones. In short: some effects on brain functions have been observed, but there are no indications that these indicate, or lead to, health effects.Electromagnetic (EM) fields with certain exposure parameters do affect biological systems, as demonstrated by the studies described in this report. These experimental findings raise a number of pressing questions. Primarily, how can the effects of an arbitrary EM-field exposure be predicted? In the present context, can environmental EM-field exposures be carcinogenic? Experimental data directly addressing the latter question are extremely limited. The biological effects described in this report have served mainly to indicate that present biological models are incomplete and to stimulate the development of new theories. Bioeffects have been found to result from induced currents far weaker than normal physiological currents, and at imparted energy levels a fraction of the average thermal energy (per particle). Only by identifying the mechanisms through which EM fields interact with biological systems can the larger questions, such as the potential for carcinogenicity, be fully addressed (Lai and Singh, 1997; Loomis *et al.,* 1994; Marinelli *et al.,* 2004; Miller *et al.,* 1996; Miyakoshi *et al.,* 2005; Monfrecola *et al.,* 2003; Monselise *et al.,* 2003; NRPB, 1993; NRPB, 1994a; NRPB, 1994b; ORAU , 1992; Otto and Muhlendahl, 2007; Poole , 1996; Preston *et al.,* 1996; Radon *et al.,* 2001; Regoli *et al.,* 2005; Renew *et al.,* 1990; Stenvens and Davis, 1996; Swanson, 1996; Swanson and Jeffers, 1999a; Swanson and Jeffers, 1999b; Tenforde *et al.,* 1996; Tomenius, 1986; UKCCS, 1999; UKCCS, 2000; Uloziene *et al.,* 2005). The EMR spectrum begins at low frequencies, lower than those released by power and telephone lines. The frequencies increO.-*ase for AM and FM radio waves Radio waves Electromagnetic energy of the frequency range corresponding to that used in radio communications, usually 10,000 cycles per second to 300 billion cycles per second. , television transmission, microwaves, and infrared radiation. The non-ionizing part of the electromagnetic spectrum electromagnetic spectrum Total range of frequencies or wavelengths of electromagnetic radiation. The spectrum ranges from waves of long wavelength (low frequency) to those of short wavelength (high frequency); it comprises, in order of increasing frequency (or decreasing , which this article addresses, is electrical energy in a form that passes through matter without dislodging electrons from atoms--hence, non-ionizing. The energy terminates once power to the source of the EMR is cut off. For example, a microwave oven can produce an enormous electromagnetic field electromagnetic field. Property of space caused by the motion of an electric charge. A stationary charge produces an electric field in the surrounding space. If the charge is moving, a magnetic field is also produced. Ionizing radiation may continue to produce potentially harmful energy for a few seconds or hundreds of thousands of years, depending on the material. These materials can only be "turned off" by the natural decay process. The best understood biological effect of electromagnetic fields is to cause dielectric heating. For example, touching or standing around an antenna while a high-power transmitter is in operation can cause severe burns. These are exactly the kind of burns that would be caused inside a microwave oven. This heating effect varies with the power and the frequency of the electromagnetic energy. A measure of the heating effect is the specific absorption rate or SAR, which has units of watts per kilogram (W/kg). The IEEE and many national governments have established safety limits for exposure to various frequencies of electromagnetic energy based on SAR, mainly based on ICNIRP Guidelines, which guard against thermal damage. There are publications which support the existence of complex biological effects of weaker *non-thermal* electromagnetic fields including weak ELF magnetic field and modulated RF and microwave fields. Fundamental mechanisms of the interaction between biological material and electromagnetic fields at non-thermal levels are not fully understood. The definite existence and possible extent of non-thermal effects is not fully established. The chairman of the United Kingdom's Health Protection Agency (HPA), Sir William Stewart, has said that "evidence of potentially harmful effects of microwave radiation had become more persuasive over the past five years." His report said that while there was a lack of hard information of damage to health, the approach should be precautionary. The HPA, however, disagrees with his assessment, and claims that there is no risk and no need for precaution. The official stance of the Health Protection Agency is that there is currently no proven risk from RF communication devices. The preponderance of evidence suggests that the low-power, low-frequency, electromagnetic radiation associated with household current does not constitute a short or long term health hazard, and whilst some biophysical mechanisms for the promotion of cancer have been proposed, none have been substantiated. Nevertheless, some research has implicated exposure in a number of adverse health effects. These include, but are not limited to, childhood leukemia, adult leukemia, neurodegenerative diseases

(such as amyotrophic lateral sclerosis) miscarriage and clinical depression. Mobile phones use electromagnetic radiation in the microwave range, and some believe this may be harmful to human health. These concerns have induced a large body of research (both epidemiological and experimental, in non-human animals as well as in humans). Concerns about effects on health have also been raised regarding other digital wireless systems, such as data communication networks (D'Andrea *et al.,* 2003; Dawe *et al.,* 2006; Diem *et al.,* 2005; Feychting, 2005; Greenland *et al.,* 2000; Gurney *et al.,* 1997; Hardell *et al,* 1999; Hardell *et al.,* 2002; Health 1996; Heikkinen *et al.,* 2003; Hepworth *et al.,* 2006; Kato *et al.,* 1991; Koivisto *et al.,* 2000a; Koivisto *et al.,* 2000b; Koivisto *et al.,* 2001; Kwan-Hoong 2003; Lai and Singh, 1997; Loomis *et al.,* 1994; Marinelli *et al.,* 2004; Miller *et al.,* 1996; Miyakoshi *et al.,* 2005; Monfrecola *et al.,* 2003; Monselise *et al.,* 2003; NRPB, 1993; NRPB, 1994a; NRPB, 1994b; ORAU , 1992; Otto and Muhlendahl, 2007; Poole , 1996; Preston *et al.,* 1996; Radon *et al.,* 2001; Regoli *et al.,* 2005; Renew *et al.,* 1990; Repacholi and Greenebaum, 1999; Rezaei *et al.,* 2009; Röschke *et al.,* 1997; Salem, 2005; Salford *et al.,* 1994; Savitz *et al.,* 1993; Savitz and Loomis, 1995; Schoemaker *et al.,* 2005; Simkó *et al.,* 2004; Simkó *et al.,* 2006; Sobel, 1995; Stenvens and Davis, 1996; Swanson, 1996; Swanson and Jeffers, 1999a; Swanson and Jeffers, 1999b; Tenforde *et al.,* 1996; Tomenius, 1986; UKCCS, 1999; UKCCS, 2000; Uloziene *et al.,* 2005).

REFERENCES

Al-Glaib, B., M. Al-Dardfi, A. Al-Tuhami, A. Elgenaidi and M. Dkhil, 2007. A Technical Report on the Effect of Electromagnetic Radiation from a Mobile Phone on Mice Organs. Libyan Journal of Medicine, pp: 8-9.

Ahlbom, A., N. Day, M. Feychting, E. Roman, J. Skinner, J. Dockerty, M. Linet, M. McBride, J. Michaelis, J.H. Olsen, T. Tynes, P.K. Verkasalo, 2000. A pooled analysis of magnetic fields and childhood leukaemia. British Journal of Cancer, 83: 692-698.

Ahlbom, A., A. Green, L. Kheifets, D. Savitz, A. Swerdlow, 2004. Epidemiology of health effects of radiofrequency exposure. Environ Health Perspect, 112: 1741-1754.

Ahlbom, A., 2001. Neurodegenerative diseases, suicide and depressive symptoms in relation to EMF. Bioelectromagnetics, l(5): S132-S143.

Anane, R., P.E. Dulou, M. Taxile, M. Geffard, F.L. Crespeau, B. Veyret, 2003a. Effects of GSM-900 microwaves on DMBA-induced mammary gland tumors in female Sprague-Dawley rats. Radiat Res., 160: 492-497.

Anane, R., M. Geffard, M. Taxile, D. Bodet, B. Billaudel, P.E. Dulou and B. Veyret, 2003b. Effects of GSM-900 microwaves on the experimental allergic encephalomyelitis (EAE) rat model of multiple sclerosis. Bioelectromagnetics, 24: 211-213.

Anderson, L.E., G.A. Boorman, J.E. Morris, L.B. Sasser, P.C. Mann, S.L. Grumbein, J.R. Hailey, A. McNally, R.C. Sills, J.K. Haseman, 1999. Effect of 13 week magnetic field exposures on DMBA-initiated mammary gland carcinomas in female Sprague-Dawley rats. Carcinogenesis, 20: 1615-1620.

Anderson, L.E., J.E. Morris, L.B. Sasser, W. Loscher, 2000. Effects of 50- or 60-hertz, 100 microT magnetic field exposure in the DMBA mammary cancer model in Sprague-Dawley rats: possible explanations for different results from two laboratories. Environ Health Perspect, 108: 797-802.

Anderson, L.E., D.M. Sheen, B.W. Wilson, S.L. Grumbein, J.A. Creim, L.B. Sasser, 2004. Two-year chronic bioassay study of rats exposed to a 1.6 GHz radiofrequency signal. Radiat Res., 162: 201-210.

Ahlbom, A., 2001. Neurodegenerative diseases, suicide and depressive syntoms in relation to emf.bioelectromagnetics supplement. Stockolm, Sweden, 5: 132-143.

Auvinen, A., M. Hietanen, R. Luukkonen, R.S. Koskela, 2002. Brain tumours and salivary gland cancers among cellular telephone users. Epidemiology, 13: 356-359.

Baum, A., M. Mevissen, K. Kamino, U. Mohr, W. Loscher, 1995. A histopathological study on alterations in DMBA-induced mammary carcinogenesis in rats with 50 Hz, 100 muT magnetic field exposure. Carcinogenesis, 16: 119-125.

Bartsch, H., C. Bartsch, E. Seebald, F. Deerberg, K. Dietz, L. Vollrath, D. Mecke, 2002. Chronic exposure to a GSM-like signal (mobile phone) does not stimulate the development of DMBA-induced mammary tumors in rats: results of three consecutive studies. Radiat Res., 157: 183-190.

Batanjac, J. and E.A. Pauncu, 2003. Risk OF 50/60 Hertz Electromagnetic Fields in Electric Utılıty Workers Medicine and Biology, 10(2): 99 – 100.

Berg, G., J. Schüz, F. Samkange-Zeeb, M. Blettner, 2005. Assessment of radiofrequency exposure from cellular telephone daily use in an epidemiological study: German Validation study of the international casecontrol study of cancers of the brain--Interphone-Study. J Expo Anal Environ Epidemiol, 15: 217-224.

Bonhomme-Faiver, L., A. Mace, Y. Bezie, S. Marion, G. Bindoula, A.M. Szekely, N. Frenois, H. Auclair, O.S. Arbouys and E. Bizi, 1998. Alterations of biological parameters in mice chronically exposed to low-frequency (50 Hz) electromagnetic fields. Life Sci., 62: 1271-1280.

Boorman, G.A., L.E. Anderson, J.E. Morris, L.B. Sasser, P.C. Mann, S.L. Grumbein, J.R. Hailey, A. McNally, R.C. Sills, J.K. Haseman, 1999. Effect of 26 week magnetic field exposures in a DMBA initiation-promotion mammary gland model in Sprague-Dawley rats. Carcinogenesis, 20: 899-904.

Capri, M., E. Scarcella, E. Bianchi, C. Fumelli, P. Mesirca, C. Agostini, D. Remondini, J. Schuderer, N. Kuster, C. Franceschi, F. Bersani, 2004. 1800 MHz radiofrequency (mobile phones, different Global System for Mobile communication modulations) does not affect apoptosis and heat shock protein 70 level in peripheral blood mononuclear cells from young and old donors. Int J Radiat Biol., 80: 389-397.

Caraglia, M., M. Marra, F. Mancinelli, G. D'Ambrosio, R. Massa, A. Giordano, A. Budillon, A. Abbruzzese, E. Bismuto, 2005. Electromagnetic fields at mobile phone frequency induce apoptosis and inactivation of the multi-chaperone complex in human epidermoid cancer cells. J Cell Physiol, 204: 539-548.

Chernoff, N., J.M. Rogersm and R. Kavet, 1992.A review of the literature on potential reproductive ana developmental toxicity of electric and magnetic fields. Toxicology, 74: 91-126.

Che, Y., S. Huaying, C. Yonghua, Zhou D.and Y. Ma, 2007. Effects of exposure to 50 Hz magnetic field of 1 mT on the performance of detour learning task by chicks. Brain Research Bulletin, 74(1-3): 178-182.

Christ, A. and N. Kuster, 2005. Differences in RF energy absorption in the heads of adults and children, Bioelectromagnetics, l(7): S31-S44.

Christensen, H.C., J. Schüz, M. Kosteljanetz, H.S. Poulsen, J.D. Boice, J.K. McLaughlin, C. Johansen, 2005. Cellular telephones and risk for brain tumours: a population-based, incident case-control study. Neurology, 64: 1189-1195.

D'Andrea, J.A., C.K. Chou, S.A. Johnston, E.R. Adair, 2003. Microwave effects on the nervous system, Bioelectromagnetics, l(6): S107-S147.

Dawe, A.S., B. Smith, D.W. Thomas, S. Greedy, N. Vasic, A. Gregory, B. Loader, D.I. Pomerai, 2006. A small temperature rise may contribute towards the apparent induction by microwaves of heat-shock gene expression in the nematode Caenorhabditis Elegans. Bioelectromagnetics, 27: 88-97.

Diem, E., C. Schwarz, F. Adlkofer, O. Jahn, H. Rudiger, 2005. Non-thermal DNA breakage by mobile-phone radiation (1800 MHz) in human fibroblasts and in transformed GFSH-R17 rat granulosa cells in vitro. Mutat Res., 583: 178-183.

Feychting, M., 2005a. Non-cancer EMF effects related to children. *Bioelectromagnetics*, Suppl 7, S69-S74. Renew, D.C., J.C. Male and B.J. Maddock, 1990. Power-frequency magnetic fields: measurement and exposure assessment. Paris. Cigre., pp: 36-105.

Feychting, M., 2005. Health effects of static magnetic fields – a review of the epidemiological evidence. Prog Biophys Mol Biol., 87: 241-246.

Greenland, S., A.R. Sheppard, W.T. Kaune, C. Poole, M.A. Kelsh, 2000. A pooled analysis of magnetic fields, wire codes, and childhood leukemia. Epidemiology, 11: 624-634.

Gurney, J., B.A. Mueller, S. Davis, S. Schwartz, R. Stefens, K. Kopecky, 1996. Childhood brain tumor occurrence in relation to residential power line configurations. Am. J. Epidemiol., 143(2): 120-128.

Hardell, L., A. Hallquist, K.H. Mild, M. Carlberg, A. Pahlson, A. Lilja, 2002. Cellular and cordless telephones ana the risk for brain tumours. Eur J Cancer Prev, 11: 377-386.

Hardell, L., A. Nasman, A. Pahlson, A. Hallquist, M.K. Hansson, 1999. Use of cellular telephones and the risk for brain tumours: A case-control study. Int J Oncol, 15: 113-116.

Heikkinen, P., V.M. Kosma, L. Alhonen, H. Huuskonen, H. Komulainen, T. Kumlin, J.T. Laitinen, S. Lang, L. Puranen, J. Juutilainen, 2003. Effects of mobile phone radiation on UV-induced skin tumourigenesis in ornithine decarboxylase transgenic and non-transgenic mice. Int J Radiat Biol., 79: 221-233.

Hepworth, S.J., M.J. Schoemaker, K.R. Muir, A.J. Swerdlow, M.J.Tongeren, P.A. McKinney, 2006. Mobile phone use and risk of glioma in adults: case-control study. BMJ., 332: 883-887.

Health, C.W., 1996. Electromagnetic field exposure and cancer: a review of epidemiological evidence. Cancer J. Clin., 46: 29-44.

Kato, M., K.I. Homna, T. Shigemitsu and Y. Shiga , 1991. Effects of exposure to a circularly polarized, 50 Hz magnetic fields on melatonin levels in rats. Bioelectromagnetics, 14: 97-106.

Koivisto, M., C. Haarala, C.M. Krause, A. Revonsuo, M. Laine,H. Hämäläinen, 2001. GSM phone signals does not produce subjective symtoms. Biolelectromagnetics, 22: 212-215.

Koivisto, M., C.M. Krause, A. Revonsuo, M. Laine, H. Hamalainen, 2000a. The effects of electromagnetic field emitted by GSM phones on working memory. Neuroreport, 11: 1641-1643.

Koivisto, M., A. Revonsuo, C. Krause, C. Haarala, L. Sillanmaki, M. Laine, H. Hamalainen, 2000b. Effects of 902 MHz electromagnetic field emitted by cellular telephones on response times in humans. Neuroreport, 11: 413-415.

Kwan-Hoong, N.g., 2003. Non-Ionizing Radiations – Sources, Biological Effects, Emissions and Exposures" Proceedings of the International Conference on Non-Ionizing Radiation at UNITEN (ICNIR2003) Electromagnetic Fields and Our Health.

Lai, H. and N.P. Singh, 1997. Melatonin and a spintrap compound blocked radiofrequency, radiation induced DNA strand breaks in rat brain cells. Bioelectromagnetics, 18: 446-454.

Loomis, D.P., D.A. Savitz and C.V. Ananth, 1994. Breast cancer mortality among female electrical workers in the United States. J. Natl. Cancer Inst., 86: 885-886.

Marinelli, F., D. Sala, G. Cicciotti, L. Cattini, C. Trimarchi, S. Putti, A. Zamparelli, L. Giuliani, G. Tomassetti, C. Cinti, 2004. Exposure to 900 MHz electromagnetic field induces an unbalance between pro-apoptotic and pro-survival signals in T-lymphoblastoid leukaemia CCRF-CEM cells. J Cell Physiol, 198: 324-332.

Miller, A.B., T. Teresa, A. David, C. Wall, L. Green, 1996. Leukemia following occupational exposure to 60 hz electric and magnetic fields among Ontario electric utility workers. Am. J. Epidemiol., 144(2): 150-160.

Miyakoshi, J., K. Takemasa, Y. Takashima, G.R. Ding,H. Hirose, S. Koyama, 2005. Effects of exposure to a 1950 MHz radio frequency field on expression of Hsp70 and Hsp27 in human glioma cells. Bioelectromagnetics, 26: 251-257.

Monfrecola, G., G. Moffa, E.M. Procaccini, 2003. Non-ionizing electromagnetic radiations, emitted by a cellular phone, modify cutaneous blood flow. Dermatology, 207: 10-14.

Monselise, E.B, A.H. Parola, D. Kost, 2003. Low frequency electromagnetic fields induce a stress effect upon higher plants, as evident by the universal stress indicator, alanine. Biochem Biophys Acta, 302: 427-434.

NRPB (National Radiological Protection Board), 1993. Electromagnetic fields and the risk of cancer. Supplementary report by the Advisory Group on Non-ionising Radiation (May 1993). NRPB. 4(5): 65-9. *www*.nrpb.org/

NRPB, 1994a. Electromagnetic fields and the risk of cancer. Supplementary report by the Advisory Group on non-ionising Radiation (12 April 1994). NRPB. 5(2), 77-81. www.nrpb.org/

NRPB,1994b. Health effects related to the use of visual display units. Report of an Advisory Group on Non-ionising Radiation. NRPB. 5(2): 1-75. www.nrpb.org/

Otto, M. and K.E. Muhlendahl, 2007. Electromagnetic fields (EMF): Do they play a role in childern's environmental health (CEH)? Int. J. Hyg. Environ. Health, 210: 635- 644.

ORAU (The Oxford Radiocarbon Accelerator Unit),1992. Health effects of low frequency electric and magnetic fields. Oak Ridge Associated Universities, Doc NRPB., 6(2): 7-190.

Preston, S.M., W. Navidi, D. Thomas, P.J. Lee, J. Bowman, J. Pogoda, 1996. Los Angeles study of residential magnetic field and childhood brain tumors. Am. J. Epidemiol., 143(2): 105-120.

Poole, C., 1996. Evolution of epidemiological evidence on magnetic fields and childhood cancers. Am. J. Epidemiol., 143(2): 129-132.

Radon, K., D. Parera, D.M. Rose, D. Jung and L. Vollrath , 2001. No effects of pulsed radio frequency electromagnetic fields on melatonin, cortisol ana selected markers of the Immune system in man. Bioelectromagnetics, 22: 280-287.

Regoli, F., S. Gorbi, N. Machella, S. Tedesco, M. Benedetti, R. Bocchetti, A.Notti, D. Fattorini, F. Piva, G. Principato,2005. Pro-oxidant effects of extremely low frequency electromagnetic fields in the land snail helix aspersa. Free Radic Biol Med., 39: 1620-1628.

Repacholi, M.H. and B. Greenebaum, 1999. Interaction of static and extremely low frequency electric and magnetic fields with living systems: Health effects and research needs. Bioelectromagnetics, 20: 133-160.

Rezaei Ochbelagh D., A. Borhanifar1, A. Asadi. 2009. Thermal Effects of Mobile Phone on Tissue. Asian J. Exp. Sci., 23(1): 351-356.

Röschke, J. and K. Mann, 1997. No short-term effects of digital mobile radio telephone on the awake human electroencephalogram. Bioelectromagnetics, 18: 172-176.

Salem, N.M., 2005. Thermal effects of photonphonon interaction on a simple tissue". The Environmentalist, 25: 241–246.

Salford, L.G., A. Brun, K. Sturesson, J.L. Eberhardt, B.R. Persson, 1994. Permeability of the blood-brain barrier induced by 915 MHz electromagnetic radiation, continuous wave and modulated at 8, 16, 50, and 200 Hz. Microsc Res Tech., 27: 535-542.

Savitz, D.A., 1993. Overview of epidemiological research on electric and magnetic fields and cancer. Am. Ind. Hyg. Ass. J., 54: 197-204.

Savitz, D.A and D.P. Loomis, 1995. Magnetic field exposure in relation to leukaemia and brain cancer mortality among electrical utility workers. Am J Epidemiol., 141: 123-34.

Schoemaker, M.J, A.J. Swerdlow, A. Ahlbom, A. Auvinen, K.G. Blaasaas, E. Cardis, H.C. Christensen, M. Feychting, S.J. Hepworth, C. Johansen, L. Klaeboe, S. Lonn, P.A. McKinney, K. Muir, J. Raitanen, T. Salminen, J. Thomsen, T. Tynes, 2005. Mobile phone use and risk of acoustic neuroma: results of the Interphone case-control study in five North European countries. Br J Cancer, 93: 842-848.

Simkó, M., C. Hartwig, M. Lantow, M. Lupke, M.O. Mattsson, Q. Rahman, J. Rollwitz , 2006. Hsp 70 expression and free radical release after exposure to non-thermal radio-frequency electromagnetic fields and ultrafine particles in human Mono Mac 6 cells. Toxicol Lett, 161: 73-82.

Simkó, M. and M.O. Mattsson, 2004. Extremely low frequency electromagnetic fields as effectors of cellular responses in vitro: Possible immune cell activation. J Cell Biochem, 93: 83-92.

Sobel, E., Z. Davanipour and R. Sulkava, 1995. Occupations with exposures to electromagnetic fields: a possible risk factor for Alzheimer's disease. Am J Epidemiol., 142(5): 515-24.

Stenvens, R.G. and S. Davis, 1996. The melatonin hypotheses: electric power and breast cancer. Environ. Health Persp., 104: 135-140.

Swanson, J., 1996. Long-term variation in the exposure of the population of England and Wales to power-frequency magnetic fields. J Radiol Prot., 16(4): 287-301.

Swanson, J. and D. Jeffers, 1999a. Possible mechanisms by which electric fields from power lines might affect airborne particles harmful to health. J Radiol Prot., 19(3): 213-29.

Swanson, J. and W.T. Kaune, 1999b. Comparison of residential power-frequency magnetic fields away from appliances in different countries. Bioelectromagnetics., 20: 244-54.

Tenforde, T.S., 1996. Interaction of ELF Magnetic Fields with Living System. In: Polk, C. and Postow, E., Eds. Biological Effects of Electromagnetic Fields. Boca Raton, FL: CRC Press, pp: 185-230.

Tomenius, L., 1986. 50 Hz electromagnetic environment and the incidence of childhood tumors in Stockholm Country. Bioelectomagnetics, 7: 141-207.

UKCCS (United Kingdom Childhood Cancer Study), 1999. Exposure to power-frequency magnetic fields and the risk of childhood cancer. Lancet., 354. ORAU92/F8: 1925-31. www.ukccs.org

UKCCS (United Kingdom Childhood Cancer Study), 2000. Childhood cancer and residential proximity to power lines. Br J Cancer., 83: 1573-80. www.ukccs.org

Uloziene, I., V. Uloza, E. Gradauskiene, V. Saferis, 2005. Assessment of potential effects of the electromagnetic fields of mobile phones on hearing - BMC Public Health, 5: 39-39.