

Can EMF Fields cause biological effects?

Back in the late 1980's after numerous complaints from soldiers operating radar devices about different health effects the Army wanted to test whether the source of these effects might be the EMF fields surrounding the radar system.

Research originated by the U.S. Army, Walter Reed Army Institute in 1986, initially performed by the Catholic University of America (CUA) in Washington D.C., and replicated by six other Universities in three different continents from 1993 to 2002.

The research was initially funded by the U.S. Army with a \$3.9million grant and performed by an interdisciplinary team of 15 physicists, biochemists, biologists and engineers facilitated at the Vitreous State Laboratory of the CUA.

After six years of comprehensive studies the CUA published at August 15th 1991 a scientific paper, titled:"Effect of Coherence time of the applied magnetic field on ODC activity", in the scientific journal: "Biochemical and Biophysical Research Communication".

In this paper CUA introduced the preliminary result that an exposure of mouse cells (L929 murine) to a **regular 60Hz electromagnetic field** doubled the activity in the cells of the critical enzyme, Ornithine Decarboxylase (ODC), which is involved in DNA and cell reproduction, i.e. **the 60 Hz EMF field was shown to cause biological effects.**

The 60 Hz EMF field used in these studies is within the so called extremely low frequency field (ELF) range (0 –1,000 Hertz), but further research done by CUA also showed that the whole spectrum up to visible light, i.e. ELF, Radio frequency (RF) (1,000 Hertz –0,8 Ghertz) and ELF Microwave, 0,8 Ghertz –1 Ghertz) cause the same effects.

These findings were later replicated by the CUA thousands of times on chicken embryos still showing a doubling in the activity of ODC and a similar and possible linked increase in abnormalities in the spinal cord (so called: spina bifida).

The results were scientifically significant enough to convince the scientists at CUA, that regular (constant) 60 Hz EMF fields used in the experiments were "bioeffective". i.e., able to cause biological effects in living cells.

The answer to the question, whether EMF Fields could cause biological effects was therefore: yes, the studies involved could only lead to that conclusion.

Later in 1992 the US Army's Walter Reed Institute stated to the U.S. Patent Authorities that the scientific work at the CUA was valid and would have lasting significance.

Further documentation for EMF fields causing biological effects:

Chromosomal damage in human blood cells. Maes et al., 1993, Nordenson et al., 1994 and 1996.

Chromosomal damage (micronuclei) in human cells. Dr. George Carlo, 2000, Maes et al., 1993, Garaj-Vhrovac et al., 1992.

Increased DNA strand breaks in animal and human cells. Dr. Lai et al., 1995, 1996, and 1997. Philips et al. 1998.

Changes in Gene expression in human cells. Professor Reba Goodman et al. 1995, 1997 and 1998. Tsurita et al., 1999. Harvey et al., 1999.

Change in Cell differentiation in human blood cells. Trosko et al., 2000. Change in Melatonin metabolism in electric utility workers. Burch et al., 1998.

Change in cellular repair mechanism. DiCarlo et al., Lin et al., 1997. Professor Goodmann et al., 1998. Tsurita et al., 1999.

These studies, along with those mentioned above, provide compelling evidence that biological effects can occur due to exposure to EMF fields.

The physical ability of an EMF field to establish biological effects (“bio-effects”) in living cells and tissues is based on three different elements, the Energy, the Intensity and the Structure. If one of these components actually can cause changes in the cellular system, the field is considered bio-effective.

The fourth dimension, the length of the exposure or the accumulated exposure over time is decisive for whether the biological effects are beneficial, neutral or adverse to the biological system. It is a matter of doses.

Studies have shown, that short term or few times exposure (up to half an hour in a couple of days) to EMF actually can stimulate the defense system of the cells and thereby constitute a beneficial effect, a principle known from hospital magnetotherapy.

On the other hand if the exposure is long term or repetitive (which is mostly the case in the use of electric equipment and cellphones) this effect might change from beneficial via neutral to adverse to the cellular system.

Thus as the three components: energy, intensity and structure are the key to whether biological effects occur or not, the time of the exposure is the decisive factor for whether the effects are adverse or not.

a) Energy: The element of the EMF field, which can promote the biological effect via direct cell damage.

The power of EMF fields carrying high energy (number of photons higher than visible light) can cause biological effects directly by breaking chemical bonds and damaging the cells, in which case the field is called ionizing.

Below visible light the fields carry a lower number of photons and thereby do not contain power enough to damage, in which case the fields are called non-ionizing; (Fields from electric household and office appliances and Cell Phones are such non-ionizing fields).

b) Intensity: The element of the EMF field, which can promote the biological effect via thermal damage.

EMF fields carrying a high intensity (number of waves) above 10 watts/kg SAR (Standard Absorption rate) can heat up and ultimately damage the cell by directly raising its temperature. This is the case inside a microwave oven dedicated to cooking tissues.

Most countries have set standards for the approved exposure of human beings to 2 watts/kg SAR, significantly below the 10 watts heating threshold. China has recently lowered the standard to 1 watt/kg SAR, which should bring the exposure out of the potential heating range. If the fields carry a low intensity below 10 watts/kg SAR and thereby not enough power to heat tissues it is called: non-thermal.

(Fields from electric household and office appliances and Cell Phones are all non-ionizing and non-thermal).

c) Structure: The element of the EMF field, which can promote all other biological effects than direct damage by energy and damage by heating.

EMF fields structured with a constant frequency, amplitude and waveform can cause biological effects even if the SAR intensity is lower than 10watts/kg and even though the intensity is too low to create any significant rise in temperature (probably only a millionth of a degree) in the exposed tissue. These fields are considered non-thermal, and it is the structure of these fields, which makes the field biologically active, without any heating involved. (Fields from electric household and office appliances and Cell Phones are non- ionizing, non-thermal and constant in pattern).

According to the laws of physics and biology, the structure of the EMF fields (frequency, amplitude and waveform) needs to be constant not only in time (intervals) but also in space (covering the exposed cells across the entire surface) in order for the field to act like a (digital information) signal, able to communicate and interact with the cellular system.

One of the important papers demonstrating that a non-ionizing, non-thermal and constant EMF field carrying low energy and low intensity still can create biological effects is: Professor Reba Goodman et al. "Electromagnetic field exposure induces rapid, transitory heat shock factor activation in human cells', 1997.

If the EMF field structure has no regular pattern or signal it is considered noise and not bio-effective; only if the structure is patterned in a constant way is the field able to trigger biological effects in the cell.

Thus the constant signal structure is the trigger of the non-thermal biological effects just as energy is the trigger of direct cell damage and intensity is the trigger of the heating-related effects on the cell.

As demonstrated, the non-ionizing, non-thermal EMF field carrying a constant signal is capable in transmitting a message into the cellular system of animals and human beings.

This signal is characterized as a warning message informing the cellular system about the EMF exposure, just as if it was exposed to a real threat such as potential damage due to ionizing radioactivity, x-ray, overheating, toxic chemicals, bacterial attacks etc.

Despite the fact that the non-thermal EMF field lacks the energy and intensity to harm the cellular system directly, the response on the biological level to this false alarm is still triggered,

which undesirably can exhaust the cell's defense system and makes it vulnerable to real attacks. However, a condition for triggering the cell's response is that the constancy of the EMF field is at least one second, as it takes that amount of time for the cellular system in humans and animals to respond to the exposures. Where the constancy of the EMF field exceeds one second, the EMF signal is able to trigger the sensors in the cell membranes, and thereby transmit the warning message into the cellular system, triggering a cascade of events in the cellular biological system.

Strong evidence for this sequence of events is provided by at least 50 studies showing that EMF exposure triggers the sensors at the cell membrane level. These studies are addressed in a 1996 paper, published by professor W.R. Adey and titled: "A growing scientific consensus on the cell and molecular biology mediating interactions with environmental electromagnetic fields".

Furthermore, research supporting the fact that EMF fields, by triggering the sensors in the cell membrane, actually can cause the activation of messenger enzymes like Tyrosine Kinase, has been published in different scientific papers, where the most important ones are three studies published by Loscher et al. in 1998, Harvey et al. in 1999, and Dibirdik et al. in 1998.

As demonstrated, the responding sensors transmit the warning message through the messenger enzymes in the cell to the nucleus, which hereafter in self-defense activates a variety of biological effects in the cell metabolism, such as changes in the activities of the genes, hormones, enzymes, and proteins, all putting the cell in a stress mode designed to protect the cell against interference from the environment.

The leading studies confirming this are: Lin et al. 1995, 1997, Goodman et al. 1998 and Trosko et al. 2000.

This mechanism is nature's emergency procedure and should be beneficial or protective, which seems to be the case at shorter exposures. However, if the exposure is repetitive for a longer accumulating period, generally being the case at EMF exposure, it can establish an almost permanent red alert state, which can involve an exhaustion of the cellular repair system, a condition that in the end can suppress the production of some of the most important repair enzymes and stress proteins and thereby down-regulate their ability to function.

This down-regulation of the cellular repair system is a serious condition, as the cells continually need to maintain efficient repair of their different biomolecules (among them the DNA molecule) constantly being bombarded and damaged (unfolded) by free radicals and other reactive species.

If the repair enzymes are stressed and thereby unable to repair (fold) the DNA molecules, the ultimate repair tool, the stress proteins, should be activated making the enzymes functional again.

Yet, if the stress protein is exhausted too due to repetitive exposure to the EMF field, this process will not be activated and the molecules will remain un-repaired.

In case of un-repaired DNA molecules, the dysfunctional molecule can either die or transform itself into an abnormal molecule with damaged chromosomes, a so-called micronuclei, in both cases constituting a possible health effect, such as Cancer, Alzheimer's and Parkinson's diseases.

If the abnormalities appears in the brain, cancer is most likely to happen in the areas, where the cells have the ability to multiply whereas the areas where the cells cannot reproduce Alzheimer's disease is a possible effect.

Several studies among them two studies done by the Catholic University demonstrate this down-regulation as a consequence of repeated EMF exposure: DiCarlo et al., Bio-electromagnetics circulation, 1999, "Myocardial protections conferred by electromagnetic fields" and DiCarlo et al. Bioelectrochemistry, "Electromagnetic field- induced protection of chick embryos against hypoxia exhibits characteristics of temporal sensing".

As shown non-ionizing, non-thermal EMF Fields are not able to damage the cellular system directly due to lack of sufficient energy or intensity, but the self created stress mode (down regulation) creates the only risk involved in the exposure to these powerless EMF field. It is the response to the exposure inside the cell system itself, which causes the biological effects and not the exposure as such.

However, because of the reaction mechanism in the cellular system, no matter the length of the exposure a certain constancy in the pattern of the field is still needed before the exposure of the sensors actually results in an effective message, detectable in a responsive form by the nucleus.

Studies suggesting a link between EMF exposure and health effects

It is a well-known fact that the EMF issue is still surrounded by controversy. Anyway a substantial number of epidemiological studies and scientific publications show a possible link between EMF exposure and biological and health effects.

More than fifty epidemiological studies:

Although the link between the recognized biological effects and the health effects is not scientifically proven yet, more than fifty important epidemiological studies suggest that EMF exposure is associated with an increased risk of diseases, most commonly Cancer, Alzheimer's and Parkinson's disease.

A considerable number of laboratory studies:

Also a considerable number of significant laboratory studies from universities and laboratories around the world show health effects due to EMF exposure.

The most prominent is the Royal Adelaide Hospital study in Australia, funded by Telstra, showing a doubling of tumors in EMF exposed mice and the paper published in 1966 by D. Jacobson from George Washington University showing chromosomal damage among 34 exposed employees at the US Embassy in Moscow.

Even research done by the Cell Phone Industry Association in US, found a link between EMF exposure and cancer. Dr. George Carlo: "Cell Phones –invisible hazards in the wireless Age".

Controversy:

However other studies, mostly sponsored by the cell phone industry (think tobacco!) show no effects at all, so the discussion is still ongoing and it is not possible based upon the existing

epidemiological and laboratory studies alone to make a clear, unconditional statement about the health issue at this point in time.

But since the majority of epidemiological and laboratory studies suggest a link between EMF exposure and Health effects, the only prudent response to the issue is to be careful and take whatever precaution is available to protect against the potential risk. Otherwise the explanation of the phenomenon and the final proof might be too late.

Public Statements about Possible Biological and health Effects

Based upon the existing epidemiological and laboratory studies the following public statements have been made to guide the users of electric equipment.

The Vienna Resolution: In 1968, at a scientific conference on biological and health effects of EMF exposure from cellular phones at the University of Vienna, the following solution was adopted: “The participants agreed that biological effects from low-intensity exposures are scientifically established.”

Sweden’s National Board of Industrial and Technical Development: (Date?) “We will proceed on the assumption that there is a connection between exposure to lower frequency magnetic fields and cancer, in particular, childhood cancer.”

European Parliament Resolution, 1992: “...according to an increasing number of epidemiological and experimental studies, even slight exposure to non-ionizing electromagnetic fields increases the risk of cancer...”

U.S. National Institute of Environmental Health Sciences (NIEHS), 1997: The vast majority of the members of the advisory panel voted for the following conclusion: “Extremely low frequency electromagnetic fields should be regarded as possible carcinogens.”

Wireless Technology Research (an independent group funded by the cell phone industry), Dr. George Carlo, former chairman: “WTR has found links between cellular phone use and cancer.”

Department of the Army, Walter Reed Institute of Research, Colonel Edward C. Elson, 1992: “As a major user of radio frequency and extremely low frequency energy in the field, the Army is closely following the epidemiological studies on health and the laboratory investigations, especially that of The Catholic University of America group, as the evidence accumulates, the Army will consider application of the Litovitz technique of ameliorating possible adverse effects of electromagnetic energy. I and others monitoring the research are persuaded that the phenomena described are valid and that the work will have lasting significance.”

Conclusion:

It is demonstrated in the majority of published scientific studies, that non-thermal EMF fields in the ELF, RF and microwave frequency area can cause biological effects, which can be, but not necessarily are, harmful to the exposed human or animal cellular system. Some of the effects are acknowledged promoters of cancer, Parkinson’s and Alzheimer’s diseases.

However it is not proven at this stage, that the first step actually results in a disease further down the line and it is still to be found whether the self-defense system ultimately manages to stop the development before the changes in the cellular system trigger the disease.

It will probably take a while before the link between EMF exposure and diseases is officially accepted but at that point it might be too late. Take action now.

For a prudent participant in this area, however, the fact that EMF Fields can cause fundamental biological effects should lead to a consideration of whatever precautions are available and the EMFSafeSwitch, which turns off these fields, is the only absolute solution to the EMF issue.

REFERENCES

1. "A Review of the Potential Health Risks of Radiofrequency Fields from Wireless Communication Devices", An Expert Panel Report prepared for the Royal Society of Canada for Health Canada, March 1999, ISBN 9200064-68-X.
- 2 Litovitz, T.A., and Penafiel, M., "How do transmission protocols determine potential bioeffects of cellular phone radiation?", Proceedings of the International Workshop on Possible Biological and Health Effects of RF Electromagnetic fields, 25-28 October 1998, University of Vienna.
- 3 Litovitz, T.A., Krause, D., Montrose, C.J., and Mullins, J.M., "Temporally incoherent magnetic fields mitigate the response of biological systems to temporally coherent electromagnetic fields." *Bioelectromagnetics* 15: 399-409 (1994).
- 4 Farrell, J.M., Barber, M., Krause, D., and Litovitz, T.A., "The superposition of a temporally incoherent magnetic field inhibits 60 Hz-induced changes in the ODC activity of developing chick embryos." *Bioelectromagnetics* 19: 53-56 (1998).
- 5 Litovitz, T.A., Montrose, C.J., Doinov, P., Brown, K.M., and Barber, M., "Superimposing spatially coherent electromagnetic noise inhibits field-induced abnormalities in developing chick embryos." *Bioelectromagnetics* 15: 105-113 (1994).
- 6 DiCarlo, A.L., Litovitz, T.A., "Myocardial protections conferred by electromagnetic fields." *Bioelectromagnetics Circulation* 99: 813-816.
- 7 DiCarlo, A.L., Mullins, J.M., Litovitz, T.A., "Electromagnetic field-induced protection of chick embryos against hypoxia exhibits characteristics of temporal sensing." *Bioelectrochemistry* 52(1): 17-20.
- 8 Martin, A.H., and Moses, G.C., "Effectiveness of noise in blocking electromagnetic effects on enzyme activity in the chick embryo." *Biochem. Mol. Biol. Int.* 36: 87-94 (1995).
- 9 Lin, H., and Goodman, R., "Electric and magnetic noise block the 60 Hz magnetic field enhancement of steady-state c-myc transcripts levels in human leukemia cells." *Bioelectrochemistry and Bioenergetics*, 36: 33-37 (1995).
- 10 Lin, H., Opler, M., Head, M., Blank, M., and Goodman, R., "Electromagnetic field exposure induces rapid, transitory heat shock factor activation in human cells." *J. Cell Biochem.*, 66: 482-488 (1997).
- 11 Opler, M., Cote, L., and Goodman, R., "Electromagnetic noise fields block bioeffects caused by 60 Hz fields in human leukemia cells and rat pheochromocytoma cells." *Annual Review of Research on Bioeffects on Electric and Magnetic Fields* 12 (1994).
- 12 Raskmark, P., and Kwee, S., "The minimizing effect of electromagnetic noise on the changes in cell proliferation caused by ELF magnetic fields." *Bioelectrochemistry and Bioenergetics*, 40: 193-196 (1998).
- 13 Penafiel, L.M., Litovitz, T.A., Krause, D., Mullins, J.M., "Role of modulation on the effect of microwaves on ornithine decarboxylase activity in L929 cells." *Bioelectromagnetics* 18: 132-141 (1997).
- 14 Litovitz, T.A., Penafiel, L.M., Farrell, J.M., Krause, D., Meister, R., Mullins, J.M., "Bioeffects induced by exposure to microwaves are mitigated by superposition on ELF noise." *Bioelectromagnetics* 18: 422-430 (1997).

- 15 Buch, J.B., Reif, J.S., Yost, M.G., Keefe, T.J., and Pitrat, C.A., "Nocturnal excretion of a urinary melatonin metabolite among electric utility workers." *Scandinavian Journal of Work, Environment and Health* 24: 183-189 (1998).
- 16 Carlo, G., and Schramm, M., "CELL PHONES –Invisible Hazards in the Wireless Age", Carroll & Graf Publishers, Inc., New York, ISBN 0-7867-0812-2.
- 17 Repacholi, M.H., Basten, A., Gebski, V., Noonan, D., Finnie, J., and Harris, A.W., "Lymphomas m-Pim1 Transgenic Mice Exposed to Pulsed 900 Hz Electromagnetic Fields", *Radiation Research* 147: 631-640 (1997).
- 18 Maes et al., "In vitro cytogenetic effects of 2450 MHz microwaves on human peripheral blood lymphocytes", *Bioelectromagnetics* 14: 495-501 (1993).
- 19 Nordenson et al., "Chromosomal aberrations in human amniotic cells after intermittent exposure to 50 Hz magnetic fields", *Bioelectromagnetics* 15: 293-301 (1994).
- 20 Nordenson et al., "Chromosomal aberrations in lymphocytes of engine drivers", *Bioelectromagnetics Society Meeting, Victoria, Canada, 1996. Poster P-64-B.*
- 21 Goldsmith, J.R., "Epidemiological Evidence Relevant to Radar (Microwave) Effects", *Environmental Health Perspectives* 105, Supplement 6 (December 1997).
- 22 Garaj-Vhrovac et al., "The correlation between the frequency of micronuclei and specific chromosome aberrations in human lymphocytes exposed to microwaves", *Mutation Research* 281: 181-186 (1992).
- 23 Lai, H., and Singh, N., "Acute low intensity microwave exposure increases DNA single-strand breaks in rat brain cells", *Bioelectromagnetics* 16: 207-210 (1995).
- 24 Lai, H., and Singh, N., "Single- and double-strand DNA breaks in rat brain cells after exposure to radiofrequency electromagnetic radiation", *The International Journal of Radiation Biology* 69-4: 513-521 (1996).
- 25 Lai, H., and Singh, N., "Acute exposure to a 60Hz magnetic field increases DNA strand breaks in rat brain cells", *Bioelectromagnetics* 18: 156-165 (1997).
- 26 Phillips et al., "DNA damage in Molt-4 T-lymphoblastoid cells exposed to cellular telephone Radiofrequency fields in vitro", *Bioelectrochemistry and Bioenergetics* 40: 193- 196 (1998).
- 27 Ahuja et al., "Comet assay to evaluate DNA damage caused by magnetic fields", *Proceedings International Conference on Electromagnetic Interference & Compatibility* (December 1997), Hyderabad, India.
- 28 Goodman, R., and Blank, M., "Magnetic field stress induces expression of hsp70", *Cell Stress & Chaperones* 3 (2): 79-88 (1998).
- 29 Tsurita, G., et al., "Effects of exposure to repetitive pulsed magnetic stimulation on cell proliferation and expression of heat shock protein 70 in normal and malignant cells", *Biochemical and Biophysical Research Communications* 261: 689-694 (1999).
- 30 Harvey, C., and French, P.W., "Effects on protein kinase C and gene expression in a human mast cell line, HMC-1, following microwave exposure", *Cell Biology International* 23 (11): 739-748 (1999).
- 31 Trosko, J., et al., *Environmental Health Perspectives*, October 2000.
- 32 Adey, W.R., "A growing scientific consensus on the cell and molecular biology mediating interactions with environmental electromagnetic fields", *Biological Effects of Magnetic and Electromagnetic Fields*, Ed. S. Ueno, Plenum Press, New York, 1996.
- 33 Loscher, W. et al., "Animal and cellular studies on carcinogenic effects of low frequency (50/60 Hz) magnetic fields", *Mutation Research* 410: 185-220 (1998).
- 34 Dibirdik, I., Kristupaitis, D., Kurosaki, T., Tuel-Ahlgren, L., Chu, A., Pond, D., Tuong, D., Luben, R., Uckun, F.M., "Stimulation of src family protein-tyrosine kinases as a proximal and mandatory step for syk kinase-dependent phospholipase C γ 2 activation in lymphoma B cells exposed to low energy electromagnetic fields", *The Journal of Biological Chemistry* 273 (7): 4035-4039 (1998).

- 35 Lin, H., Head, M., Blank, M., Han, L., Jin, M., Goodman, R., "Myc-mediated transactivation of hsp70 expression following exposure to magnetic fields", *Journal of Cellular Biochemistry*, 69: 181-188 (1998).
- 36 Albertini, A., Zucchini, P., Noera, G., Cadossi, R., Napoleone, C.P., Pierangeli, A., "Protective effect of low frequency low energy pulsing electromagnetic fields on acute experimental myocardial infarcts in rats", *Bioelectromagnetics* 20: 372-377 (1999).
- 37 Pipkin, J.L., Hinson, W.G., Young, J.F., Rowland, K.L., Shaddock, J.G., Tolleson, W.H., Duffy, P.H., Casciano, D.A., Induction of stress proteins by electromagnetic fields in cultured HL-60 cells", *Bioelectromagnetics* 20: 347-357 (1999).
- 38 Daniells, C., Duce, I., Thomas, D., Sewell, P., Tattersall, J., de Pomerai, D., "Transgenic nematodes as biomonitors of microwave-induced stress", *Mutation Research* 399: 55-64 (1998).
- 39 Junkersdorf, B., Bauer, H., Gutzeit, H.O., "Electromagnetic fields enhance the stress response at elevated temperatures in the nematode *Caenorhabditis elegans*", *Bioelectromagnetics* 21: 100-106 (2000).
- 40 Han, L., Lin, H., Head, M., Jin, M., Blank, M., Goodman, R., "Application of magnetic field-induced heat shock protein 70 for presurgical cytoprotection", *Journal of Cellular Biochemistry* 71: 577-583 (1998).
- 41 Grant, G., and Steinberg, G., "Protection against focal cerebral ischemia following exposure to a pulsing electromagnetic field", *Electricity and Magnetism in Biology and Medicine*, 723 (1993).
- 42 Chow, K., and Tung, W.L., "Magnetic field exposure enhances DNA repair through the induction of DnaK/J synthesis", *FEBS Letters* 478 (2000) 133-136.
- 43 Chow, K., and Tung, W.L., "Magnetic field exposure stimulates transposition through the induction of DnaK/J synthesis", *Biochemical and Biophysical Research Communications* 270: 745-748 (2000).
- 44 Chow, K., and Tung, W.L., "Magnetic field exposure induces DNA degradation", *Biochemical and Biophysical Research Communications* 270: 1385-1388 (2001).