16. Biological Effects of EMF at 2.4 GHz of Radiofrequency

As in the prior evidence sections filed by Intervenor, this list of positive effect studies was compiled from the AGNIR (2003 & 2012) , SCENIHR (2007 & 2009) reviews and reviews listed below. Only seventeen (17), marked with an* , of the seventy nine (79) positive studies listed below have been included by AGNIR or SCENIHR in their reviews of the evidence for biological effects of EMF radiation on these topics, even though many of the studies were published during the same time period covered by their reviews. This is by no means a complete list of all studies of biological effects of exposures to 2.4 GHz of RF, but only the studies that were mentioned in the reviews listed in filings by this Intervenor. It would take more research and much more time to compile all of the existing studies of 2.4 GHz.

1. Albert, E.N., and Sherif, M., 1988, ***Morphological changes in cerebellum of neonatal rats exposed to 2.45 GHz microwaves, in: "Electromagnetic Fields and Neurobehavioral Functions,"*** M.E. O'Connor and R.H. Lovely,eds., *Prog Clin Biol Res* 257: 135-151. http://www.ncbi.nlm.nih.gov/pubmed/3344268 **Abstract:** One-day and six-day old Sprague-Dawley rats were exposed in the far field to 2.45 GHz (cw) microwaves at 10 mW/cm2 for five consecutive days, 7 hours per day (SAR 2W/kg). Pups were euthenized one day after exposure and the cerebella processed for light and electron microscopy. Matching cerebellar sections and folia from irradiated and sham irradiated animals were examined. Light microscopic examination revealed the presence of small deeply-stained cells with hyperchromatic pyknotic nuclei within the external granular layer (EGL). The number of these pyknotic cells in the experimental animals was nearly twice that in the controls. The Nissl bodies in Purkinje cells were finely dispersed. In some experimental animals mononuclear cellular infiltration was demonstrated. Under the electron microscope the deeply-stained pyknotic small cells presented electron dense nuclei with clumped chromatin, extrusion or disintegration of the nucleus, ruptured nuclear membrane, and the vacuolization of the cytoplasm. Eventually these cells became phagocytosed by surrounding EGL cells. Most of the Purkinje cells of experimental animals showed small, disorderly arrays of rough endoplasmic reticulum (RER) instead of the typical orderly stacks of parallel arrays. *These observations suggest that microwave radiation may interfere with early genesis of cerebellar microneurons and alter the metabolic status of Purkinje cells. However, this effect might be reversible.*

2. Aweda1 MA, Usikalu MR, Wan JH, Ding N, Zhu JY**. *Genotoxic effects of low 2.45 GHz microwave radiation exposures on Sprague Dawley rats.*** International Journal of Genetics and Molecular Biology Vol. 2(9), pp. 189-197, November 2010 Available online at:

http://www.academicjournals.org/ijgmb/PDF/pdf2010/Nov/Aweda%20et%20al.pdf and http://www.ncbi.nlm.nih.gov/pubmed/15045019 **Abstract:** These findings showed that exposure to 2.45 GHz MW radiation at **SAR even as low as 0.48 Wkg-1** is potentially genotoxic as it produced single DNA strand breaks. *These findings make us agree with Neil's (Cherry,1999) extensive arguments and criticisms of the ICNIRP (1998) guidelines on MW and other non-ionizing radiation exposure limits.*

3. *Busljeta I, Trosic I, Milkovic-Kraus S**. *Erythropoietic changes in rats after 2.45 GHz nonthermal irradiation***. International Journal of Hygiene and Environmental Health, 207(6):549-554, 2004. http://www.ncbi.nlm.nih.gov/pubmed/15729835 **Abstract:** The purpose of this study was to observe the erythropoietic changes in rats subchronically exposed to radiofrequency microwave (RF/MW) irradiation at nonthermal level…In the exposed animals erythrocyte count, haemoglobin and haematocrit were increased in peripheral blood on irradiation days 8 and 15. *Concurrently, anuclear cells and erythropoietic precursor cells were significantly decreased ($p < 0.05$) in the bone marrow on day 15, but micronucleated cells' frequency was increased. In the applied experimental condition, RF/MW radiation might cause disturbance in red cell maturation and proliferation, and induce micronucleus formation in erythropoietic cells.*

4. Ceyhan AM, Akkaya VB, Güleçol ŞC, Ceyhan BM, Özgüner F, Chen W. ***Protective effects of β-glucan against oxidative injury induced by 2.45-GHz electromagnetic radiation in the skin tissue of rats***. Arch Dermatol Res. 2012 Sep;304(7):521-7. http://www.ncbi.nlm.nih.gov/pubmed/22237725 **Abstract:** In recent times, there is widespread use of 2.45-GHz irradiation-emitting devices in industrial, medical, military and domestic application. *The aim of the present study was to investigate the effect of 2.45-GHz electromagnetic radiation (EMR) on the oxidant and antioxidant status of skin and to examine the possible protective effects of β-glucans against the oxidative injury.* Thirty-two male Wistar albino rats were randomly divided into four equal groups: control; sham exposed; EMR; and EMR + β-glucan. A 2.45-GHz EMR emitted device from the experimental exposure was applied to the EMR group and EMR + β-glucan group for 60 min daily, respectively, for 4 weeks. β-glucan was administered via gavage at a dose of 50 mg/kg/day before each exposure to radiation in the treatment group. The activities of antioxidant enzymes, superoxide dismutase (SOD), glutathione peroxidase (GSH-Px) and catalase (CAT), as well as the concentration of malondialdehyde (MDA) were measured in tissue homogenates of the skin. Exposure to 2.45-GHz EMR caused a significant increase in MDA levels and CAT activity, while the activities of SOD and GSH-Px decreased in skin tissues. Systemic β-glucan significantly reversed the elevation of MDA levels and the reduction of SOD activities. β-glucan treatment also slightly enhanced the activity of CAT and prevented the depletion of GSH-Px activity caused by EMR, but not statistically significantly. *The present study demonstrated the role of oxidative mechanisms in EMR-induced skin tissue damages and that β-glucan could ameliorate oxidative skin injury via its antioxidant properties.*

5. Cleary SF, Liu LM, Merchant RE. ***Glioma proliferation modulated in vitro by isothermal radiofrequency radiation exposure.*** Radiat Res. 1990 Jan;121(1):38-45. http://www.ncbi.nlm.nih.gov/pubmed/2300667 **Abstract:** Isothermal (37 +/- 0.2 degrees C) exposure of glioma cells (LN71) for 2 h to 27 or 2450 MHz continuous-wave radiofrequency (RF) radiation in vitro modulated the rates of DNA and RNA synthesis 1, 3, and 5 days after exposure. The alterations indicate effects on cell proliferation and were not caused by RF-induced cell heating. The dose response for either frequency of the radiation was biphasic. Exposure to specific absorption rates (SARs) of 50 W/kg ***or less*** stimulated incorporation rates of tritiated thymidine (3H-TdR) and tritiated uridine (3H-UdR), whereas higher SARs suppressed DNA and RNA synthesis. *Statistically significant time-dependent alterations were detected for up to 5 days postexposure, suggesting a kinetic cellular response to RF radiation and the possibility of cumulative effects on cell proliferation. General mechanisms of effects are discussed.*

6. Cleary SF, Liu LM, Merchant RE 1990. ***In vitro lymphocyte proliferation induced by radio-frequency electromagnetic radiation under isothermal conditions***. *Bioelectromagnetics 2*(l):47-56. http://www.ncbi.nlm.nih.gov/pubmed/2346507 **Abstract:** Whole human blood was exposed or sham-exposed in vitro for 2 h to 27 or 2,450 MHz radio-frequency electromagnetic (RF) radiation under isothermal conditions (i.e., 37 +/- 0.2 degrees C). Immediately after exposure, mononuclear cells were separated from blood by Ficoll density-gradient centrifugation and cultured for 3 days at 37 degrees C with or without mitogenic stimulation by phytohemagglutinin (PHA). Lymphocyte proliferation was assayed at the end of the culture period by 6 h of pulse labeling with 3H-thymidine (3H-TdR). Exposure to radiation at either frequency at specific absorption rates (SARs***) below*** 50 W/kg resulted in a dose-dependent, statistically significant increase of 3H-TdR uptake in PHA-activated or unstimulated lymphocytes. Exposure at 50 W/kg or higher suppressed 3H-TdR uptake relative to that of sham-exposed cells. There were no detectable effects of RF radiation on lymphocyte morphology or viability. *Notwithstanding the characteristic temperature dependence of lymphocyte activation in vitro, the isothermal exposure conditions of this study warrant the conclusion that the biphasic, dose-dependent effects of the radiation on lymphocyte proliferation were not dependent on heating.*

7. Cleary S, ed. ***Proceedings of the Symposium on the Biological Effects and Health Implications of Microwave Radiation*** U.S. Department of Health, Education, and Welfare Public Health Service Bureau of Radiological Health, 1970 Review [Copy Filed in Docket] **Excerpt: (pg 80): SUMMARY** 1. The lens is highly susceptible to damage by microwave radiation at several different frequencies, as it is also to damage by ionizing radiation. 2. Lens opacities have been induced by irradiation of the eye at frequencies from 2450 MHz to 10,000 MHz, continuous or pulsed wave.3. Microwave cataracts may result from a singleincident of exposure or they may develop as the cumulative effect of repeated exposures at power levels low enough so that no single exposure is itself harmful. 4. The radiation dose required for opacity induction, expressed as power density times duration of exposure, is not a constant. *5.* Irradiation causes a rise in intraocular temperature which is related to the power density. However, the induction of lens opacities is not dependent upon a critical temperature. 6. Following irradiation

and before opacities appear in the lens, there is a latent period which varies from one to six days. In the case of ionizing radiation the latent period is 25 days or more. The susceptibility of the lens to damage by microwave radiation is unrelated to the age of the animal, as is also the length of the latent period. With ionizing radiation, the younger the animal, the shorter is the latent period. 7. In their development, morphology and histopathology, microwave cataracts are similar to those induced by ionizing radiations. They represent a permanent alteration of lens transparency. 8. Inasmuch as opacities will develop in lenses removed immediately after irradiation and cultured in vitro, it appears that microwave cataracts develop as a direct effect of the radiation on the lens rather than as a result of a change in its intraocular environment. 9. During the latent period preceding onset of an opacity, two specific biological effects which can be identified in the lens are an early marked reduction in ascorbic acid level and an inhibition of DNA synthesis and cell division in the lens epithelium. 10. At the time when opacities first become apparent, there occurs an increase in lens electrolytesand water, suggesting that one result of microwave radiation is an increase in membrane permeability in the lens. 11. There is evidence to suggest that the double or triple "cortical banding" seen by slit-lamp examination as the first visible change in the lens following irradiation may be related to a change in ascorbic acid distribution in the lens cortex

8. Czerska EM, Elson EC, Davis CC 1992. Swicord ML, Czerski P. ***Effects of continuous and pulsed 2450-MHz radiation on spontaneous lymphoblastoid transformation of human lymphocytes in vitro.*** *Bioelectromagnetics* 13(4):247-259 http://www.ncbi.nlm.nih.gov/pubmed/1510735 **Abstract:** Normal human lymphocytes were isolated from the peripheral blood of healthy donors. One-ml samples containing (10(6)) cells in chromosome medium 1A were exposed for 5 days to conventional heating or to continuous wave (CW) or pulsed wave (PW) 2450-MHz radiation at non-heating (37 degrees C) and various heating levels (temperature increases of 0.5, 1.0, 1.5, and 2 degrees C). The pulsed exposures involved 1-microsecond pulses at pulse repetition frequencies from 100 to 1,000 pulses per second at the same average SAR levels as the CW exposures. Actual average SARs *ranged to* 12.3 W/kg. Following termination of the incubation period, spontaneous lymphoblastoid transformation was determined with an image analysis system. The results were compared among each of the experimental conditions and with sham-exposed cultures. At non-heating levels, CW exposure did not affect transformation. At heating levels both conventional and CW heating enhanced transformation to the same extent and correlate with the increases in incubation temperature. *PW exposure enhanced transformation at non-heating levels. This finding is significant (P less than .002).* At heating levels PW exposure enhanced transformation to a greater extent than did conventional or CW heating. This finding is significant at the .02 level. We conclude that PW 2450-MHz radiation acts differently on the process of lymphoblastoid transformation in vitro compared with CW 2450-MHz radiation at the same average SARs.

9. Conil E, Hadjem A, Lacroux F, Wong MF, Wiart J**.** ***Variability analysis of SAR from 20 MHz to 2.4GHz for different adult and child models using finite-difference time domain.*** Phys Med Biol 2008; http://www.ncbi.nlm.nih.gov/pubmed/18367785

Abstract: This paper deals with the variability of body models used in numerical dosimetry studies. Six adult anthropomorphic voxel models have been collected and used to build 5-, 8- and 12-year-old children using a morphing method respecting anatomical parameters. Finite-difference time-domain calculations of a specific absorption rate (SAR) have been performed for a range of frequencies from 20 MHz to 2.4 GHz for isolated models illuminated by plane waves. A whole-body-averaged SAR is presented as well as the average on specific tissues such as skin, muscles, fat or bones and the average on specific parts of the body such as head, legs, arms or torso. Results point out the variability of adult models. The standard deviation of whole-body-averaged SAR of adult models can reach 40%. All phantoms are exposed to the ICNIRP reference levels. *Results show that for adults, compliance with reference levels ensures compliance with basic restrictions, but concerning children models involved in this study, the whole-body-averaged SAR goes over the fundamental safety limits up to 40%.*

10. D'Andrea JA, DeWitt JR, Emmerson RY, Bailey C, Stensaas S, Gandhi OP. ***Intermittent exposure of rats to 2450 MHz microwaves at 2.5 mW cm2: behavioral and physiological effects.*** Bioelectromagnetics. 1986;7(3):315-28. http://www.ncbi.nlm.nih.gov/pubmed/3753534: **Abstract:** Long-Evans male adult rats were intermittently exposed for 14 weeks to continuous wave (CW) 2450-MHz microwaves at an average power density of 2.5 mW/cm2. The mean specific absorption rate was 0.70 W/kg (+/- 0.02 SEM)... Assessments of threshold for electric-footshock detection revealed a significant difference between microwave and sham-exposed animals. ..Behavioral measures made at the end of the 14-week exposure included an open-field test, shuttlebox avoidance performance, and schedule-controlled lever-pressing for food pellets. Statistically significant differences between microwave- and sham-exposed rats were observed for these measures.

11. D'Andrea JA, DeWitt JR, Gandhi OP, Stensaas S, Lords JL, Nielson HC. ***Behavioral and physiological effects of chronic 2,450-MHz microwave irradiation of the rat at 0.5 mW/cm2***. Bioelectromagnetics. 1986;7(1):45-56. http://www.ncbi.nlm.nih.gov/pubmed/3730001: **Abstract:** Adult male Long-Evans rats were intermittently exposed to 2450 MHz CW microwaves at an average power density of 0.5 mW/cm2 for 90 days. The resulting SAR was 0.14 W/kg (range 0.11 to 0.18 W/kg). The animals were exposed 7 h/day, 7 days/wk, for a total of 630 h in a monopole-above-ground radiation chamber while housed in Plexiglas holding cages. Daily measures of body mass and food and water intake indicated no statistically significant effects of microwave exposure. Monthly assessment of reactivity to electric footshock, levels of cholinesterase and sulfhydryl groups in blood, and 17-ketosteroids in urine revealed no reliable differences between 14 sham-exposed and 14 microwave-exposed rats. After the 90 days of exposure, seven rats, randomly chosen from each group, were assessed for open-field behavior, shuttlebox performance, and schedule-controlled (IRT schedule) lever pressing for food pellets. *Statistically significant differences between microwave-exposed and sham-exposed rats were observed in shuttlebox performances and lever pressing. Post mortem measures of mass of several organs and microscopic examination of adrenal tissue revealed no differences between the two groups of animals.*

12. Environmental Protection Agency. ***Evaluation of the Potential Carcinogenicity of Electromagetic Fields, Draft External Review.*** 1990 [Copy available] **Excerpt** (pg 7.12): In conclusion, several studies showing leukemia, lymphoma, and cancer of the nervous system in children exposed to magnetic fields from residential 60-Hz electrical power distributions systems, supported by similar findings in adults in several occupational studies also involving electrical power frequency exposures show a consistent pattern of response that suggests a causal link. Frequency components higher that 60Hz cannot be ruled out as contributing factors. Evidence from a large number of biological test systems shows that these fields induce biological effects that are consistent with several possible mechanisms of carcinogenesis.

13. George DF, Bilek MM, McKenzie DR**.** ***Non-thermal effects in the microwave induced unfolding of proteins observed by chaperone binding.*** Bioelectromagnetics. 2008 May;29(4):324-30. doi: 10.1002/bem.20382. http://www.ncbi.nlm.nih.gov/pubmed/18240290 **Abstract:** We study the effect of microwaves at 2,450 MHz on protein unfolding using surface plasmon resonance sensing. Our experimental method makes use of the fact that unfolding proteins tend to bind to chaperones on their unfolding pathway and this attachment is readily monitored by surface plasmon resonance. We use the protein citrate synthase (CS) for this study as it shows strong binding to the chaperone alpha crystallin when stressed by exposure to excess temperature. The results of microwave heating are compared with the effect of ambient heating and a combination of ambient and microwave heating to the same final temperature. We study the temperature distributions during the heating process. *We show that microwaves cause a significantly higher degree of unfolding than conventional thermal stress for protein solutions heated to the same maximum temperature.*

14. *Grigoriev YG, Grigoriev OA, Ivanov AA, Lyaginskaya AM, Merkulov AV, Shagina NB, Maltsev VN, Lévêque P, Ulanova AM, Osipov VA, Shafirkin AV**.*** ***Confirmation studies of Soviet research on immunological effects of microwaves: Russian immunology results.*** Bioelectromagnetics. 2010 Dec;31(8):589-602. Federal Medical Biophysical Centre FMBA, Moscow, Russia. *Review* http://www.ncbi.nlm.nih.gov/pubmed/20857454 **Abstract:** This paper presents the results of a replication study performed to investigate earlier Soviet studies conducted between 1974 and 1991 that showed immunological and reproductive effects of long-term low-level exposure of rats to radiofrequency (RF) electromagnetic fields. The early studies were used, in part, for developing exposure standards for the USSR population and thus it was necessary to confirm the Russian findings. In the present study, the conditions of RF exposure were made as similar as possible to those in the earlier experiments: Wistar rats were exposed in the far field to 2450 MHz continuous wave RF fields with an incident power density in the cages of 5 W/m² for 7 h/day, 5 days/week for a total of 30 days, resulting in a whole-body SAR of 0.16 W/kg. Effects of the exposure on immunological parameters in the brain and liver of rats were evaluated using the complement fixation test (CFT), as in the original studies, and an additional test, the more modern ELISA test. Our results, using CFT and ELISA, partly confirmed the findings of the early studies and indicated possible effects from non-thermal RF exposure on autoimmune processes. The RF exposure resulted in minor increases in formation of

antibodies in brain tissue extract and the exposure did not appear to be pathological. In addition, a study was conducted to replicate a previous Soviet study on effects from the injection of blood serum from RF-exposed rats on pregnancy and fetal and offspring development of rats, using a similar animal model and protocol. Our results showed the same general trends as the earlier study, suggesting possible adverse effects of the blood serum from exposed rats on pregnancy and fetal development of intact rats, however, application of these results in developing exposure standards is limited.

15. Grigor'ev IuG, Mikhaĭlov VF, Ivanov AA, Mal'tsev VN, Ulanova AM, Stavrakova NM, Nikolaeva IA, Grigor'ev OA. ***[Autoimmune processes after long-term low-level exposure to electromagnetic fields (the results of an experiment). Part 4. Manifestation of oxidative intracellular stress-reaction after long-term non-thermal EMF exposure of rats].*** Radiats Biol Radioecol. 2010 Jan-Feb;50(1):22-7. http://www.ncbi.nlm.nih.gov/pubmed/20297677 [2.4 GHz at power density .5 mW/cm2] **Abstract:** This paper presents the results of the study of the effects of long-term low-level exposure of rats to microwaves. Rats were exposed in far field to 2450 MHz continuous wave fields providing an incident power density at the cages of 500 microW/cm2 for 7 hours daily for a total of 30 days resulting in a whole-body SAR of 0.16 +/- 0.04 W/kg. Three groups ("EMF-exposure", "sham-exposure" and cage-control) were formed, each consisting of 16 rats. Circulating antibodies (IgA, IgG and IgM) directed against 16 chemical substances were evaluated in coded serum from each group of rats by enzyme multiplied analysis (ELISA test). An increased amount of compounds resulting from interaction of amino acids with nitric oxide (NO) or its derivatives (NO2-Tyrosine, NO-Arginine, NO-Cysteine + NO-Bovine Serum Albumin, NJ-Methionine + NO-Asparagine + No-Histidine, NO-BTrypnohan + NJ-Tyrosin), fatty acids with small chains, hydroxylated fatty acids, palmitic/myristic/oleic acid, AZE (product of oxidation of fatty acids) was found in blood serum from EMF-exposed rats. As a rule, antibodies to conjugated antigens were seen for IgM, rarely seen for IgG and were completely absent for IgA. The levels of antibodies were higher on day 7 after the exposure compared to those on day 14 after the exposure.

16. Gumral N, Naziroglu M, Koyu A, Ongel K, Celik O, Saygin M, Kahriman M, Caliskan S, Kayan M, Gencel O, Flores-Arce MF. ***Effects of selenium and L-carnitine on oxidative stress in blood of rat induced by 2.45-GHz radiation from wireless devices.*** Biol Trace Elem Res. 2009 Dec;132(1-3):153-63 http://www.ncbi.nlm.nih.gov/pubmed/19396408 **Abstract:** *The levels of blood lipid peroxidation, glutathione peroxidase, reduced glutathione, and vitamin C were used to follow the level of oxidative damage caused by 2.45 GHz electromagnetic radiation in rats.* The possible protective effects of selenium and L-carnitine were also tested and compared to untreated controls. Thirty male Wistar Albino rats were equally divided into five groups, namely Groups A1 and A2: controls and sham controls, respectively; Group B: EMR; Group C: EMR + selenium, Group D: EMR + L-carnitine. Groups B–D were exposed to 2.45 GHz electromagnetic radiation during 60 min/ day for 28 days. The lipid peroxidation levels in plasma and erythrocytes were significantly higher in group B than in groups A1 and A2 ($p<0.05$), although the reduced glutathione and glutathione peroxidase values were slightly lower in erythrocytes of group B compared to groups A1

and A2. The plasma lipid peroxidation level in group A2 was significantly lower than in group B ($p<0.05$). Erythrocyte reduced glutathione levels ($p<0.01$) in group B; erythrocyte glutathione peroxidase activity in group A2 ($p<0.05$), group B ($p<0.001$), and group C ($p<0.05$) were found to be lower than in group D. In conclusion, 2.45 GHz electromagnetic radiation caused oxidative stress in blood of rat. L-carnitine seems to have protective effects on the 2.45-GHz-induced blood toxicity by inhibiting free radical supporting antioxidant redox system although selenium has no effect on the investigated values.

17. Havas M, Marrongelle J, Pollner B, Kelley E, Rees CRG, Tully L. ***Non thermal effects and mechanisms of interaction between EMF and living matter; Provocation study using heart rate variability shows microwave radiation from 2.4 GHz cordless phone affects autonomic nervous system*** ICEMS Monograph, National Institute for the Study and Control of Cancer and Environmental Diseases, Ramazzini Institute, Eur. J. of Oncol.-Library, Vol. 5, 2010; [Copy Filed in Docket] http://www.icems.eu/papers/ramazzini_library5_part1.pdf & http://www.icems.eu/papers/ramazzini_library5_part2.pdf Abstract: *Aim:* The effect of pulsed (100 Hz) microwave (MW) radiation on heart rate variability (HRV) was tested in a double blind study. *Materials and Methods:* Twenty-five subjects in Colorado between the ages of 37 to 79 completed an electrohypersensitivity (EHS) questionnaire. After recording their orthostatic HRV, we did continuous real-time monitoring of HRV in a provocation study, where supine subjects were exposed for 3-minute intervals to radiation generated by a cordless phone at 2.4 GHz or to sham exposure. *Results:* Questionnaire: Based on self-assessments, participants classified themselves as extremely electrically sensitive (24%), moderately (16%), slightly (16%), not sensitive (8%) or with no opinion (36%) about their sensitivity. The top 10symptoms experienced by those claiming to be sensitive include memory problems, difficulty concentrating, eye problems, sleep disorder, feeling unwell, headache, dizziness, tinnitus, chronic fatigue, and heart palpitations. The five most common objects allegedly causing sensitivity were fluorescent lights, antennas, cell phones, Wi-Fi, and cordless phones. Provocation Experiment: Forty percent of the subjects experienced some changes in their HRV attributable to digitally pulsed (100 Hz) MW radiation. For some the response was extreme (tachycardia), for others moderate to mild (changes in sympathetic nervous system and/or parasympathetic nervous system). and for some there was no observable reaction either because of high adaptive capacity or because of systemic neurovegetative exhaustion. *Conclusions:* Orthostatic HRV combined with provocation testing may provide a diagnostic test for some EHS sufferers when they are exposed to electromagnetic emitting devices. This is the first study that documents immediate and dramatic changes in both Hearth Rate (HR) and HR variability (HRV) associated with MW exposure at levels

18. Ivanov AA, Grigor'ev IuG, Mal'tsev VN, Ulanova AM, Stavrakova NM, Skachkova VG, Grigor'ev OA. ***[Autoimmune processes after long-term low-level exposure to electromagnetic fields (the results of an experiment). Part 3. The effect of the long-term non-thermal RF EMF exposure on complement-fixation antibodies against homologenous tissue].*** Radiats Biol Radioecol. 2010 Jan-Feb;50(1):17-21. http://www.ncbi.nlm.nih.gov/pubmed/20297676 **Abstract:** This paper presents the

results of the study of immunological effects of long-term low-level exposure of rats to microwaves. Rats were exposed in the far field to 2450 MHz continuous wave fields providing an incident power density at the cages of 500 microW/cm2 for 7 hours daily for a total of 30 days, resulting in a whole-body SAR of 0.16 +/- 0.04 W/kg. Effects of the exposure on immunological parameters in the brain and liver of rats were studied using Complement Fixation Test at low temperature (4 degrees C). Three groups ("EMF-exposure", "sham-exposure" and cage-control) were formed, each consisting of 16 rats. On the 14th day after the 30-day exposure, titers of antibodies against brain tissue were 0.69 +/- 0.08 in the cage-control group, 0.89 +/- 0.05 in the sham-exposed group and 1.19 +/- 0.07 in the EMF-exposed group. The appearance of antibodies against liver antigens was less. The increase in titres of antibodies against brain homogenates in the sham-exposed and EMF-exposed groups could be explained by the stress-reaction of the animals and autoimmunization of organism.

19. Ivanov AA, Grigor'ev IuG, Mal'tsev VN, Ulanova AM, Stavrakova NM, Skachkova VG, Grigor'ev OA. ***[Autoimmune processes after long-term low-level exposure to electromagnetic fields (the results of an experiment). Part 3. The effect of the long-term non-thermal RF EMF exposure on complement-fixation antibodies against homologenous tissue].*** Radiats Biol Radioecol. 2010 Jan-Feb;50(1):17-21. http://www.ncbi.nlm.nih.gov/pubmed/20297676 **Abstract:** This paper presents the results of the study of immunological effects of long-term low-level exposure of rats to microwaves. Rats were exposed in the far field to 2450 MHz continuous wave fields providing an incident power density at the cages of ***500 microW/cm2*** [0.5 mW/cm2] for 7 hours daily for a total of 30 days, resulting in a whole-body SAR of 0.16 +/- 0.04 W/kg. Effects of the exposure on immunological parameters in the brain and liver of rats were studied using Complement Fixation Test at low temperature (4 degrees C). Three groups ("EMF-exposure", "sham-exposure" and cage-control) were formed, each consisting of 16 rats. On the 14th day after the 30-day exposure, titers of antibodies against brain tissue were 0.69 +/- 0.08 in the cage-control group, 0.89 +/- 0.05 in the sham-exposed group and 1.19 +/- 0.07 in the EMF-exposed group. The appearance of antibodies against liver antigens was less. The increase in titres of antibodies against brain homogenates in the sham-exposed and EMF-exposed groups could be explained by the stress-reaction of the animals and autoimmunization of organism.

20. Johnson RB, Spackman D, Crowley J, Thompson D, Chou CK, Kunz LL, Guy AW, 1983, ***Effects of long-term low-level radiofrequency radiation exposure on rats, vol. 4, Open field behavior and corticosterone***, USAF SAM-TR83-42, Report of USAF School of Aerospace Medicine, Brooks AFB, San Antonio, TX. Exposed rats to pulsed 2450-MHz RFR (10 ms pulses, 800 pps) from 8 weeks to 25 months of age (22 hr/day). **The average whole body SAR varied as the weight of the rats increased and was between 0.4-0.15 W.kg-1.** They reported a significantly lower open field activity only at the first test session, and a rise in the blood corticosterone level was also observed at that time.

21. Jorge-Mora T, Misa-Agustiño MJ, Rodríguez-González JA, Jorge-Barreiro FJ, Ares-Pena FJ, López-Martín E. ***The effects of single and repeated exposure to 2.45 GHz***

radiofrequency fields on c-Fos protein expression in the paraventricular nucleus of rat hypothalamus. Neurochem Res. 2011 Dec;36(12):2322-32. Epub 2011 Aug 5. http://www.ncbi.nlm.nih.gov/pubmed/21818659: **Abstract:** This study investigated the effects of microwave radiation on the PVN of the hypothalamus, extracted from rat brains. Expression of c-Fos was used to study the pattern of cellular activation in rats exposed once or repeatedly (ten times in 2 weeks) to 2.45 GHz radiation in a GTEM cell. The power intensities used were 3 and 12 W and the Finite Difference Time Domain calculation was used to determine the specific absorption rate (SAR). High SAR triggered an increase of the c-Fos marker 90 min or 24 h after radiation, and low SAR resulted in c-Fos counts higher than in control rats after 24 h. Repeated irradiation at 3 W increased cellular activation of PVN by more than 100% compared to animals subjected to acute irradiation and to repeated non-radiated repeated session control animals. The results suggest that PVN is sensitive to 2.45 GHz microwave radiation at non-thermal SAR levels

22. *Kesari KK, Behari J, Kumar S. ***Mutagenic response of 2.45 GHz radiation exposure on rat brain.*** Int J Radiat Biol. 2010 Apr;86(4):334-43: http://www.ncbi.nlm.nih.gov/pubmed/20353343 **Abstract:** PURPOSE: To investigate the effect of 2.45 GHz microwave radiation on rat brain of male wistar strain.MATERIAL AND METHODS: Male rats of wistar strain (35 days old with 130 +/- 10 g body weight) were selected for this study. Animals were divided into two groups: Sham exposed and experimental. Animals were exposed for 2 h a day for 35 days to 2.45 GHz frequency at 0.34 mW/cm(2) power density. The whole body specific absorption rate (SAR) was estimated to be 0.11 W/Kg. Exposure took place in a ventilated Plexiglas cage and kept in anechoic chamber in a far field configuration from the horn antenna. After the completion of exposure period, rats were sacrificed and the whole brain tissue was dissected and used for study of double strand DNA (Deoxyribonucleic acid) breaks by micro gel electrophoresis and the statistical analysis was carried out using comet assay (IV-2 version software). Thereafter, antioxidant enzymes and histone kinase estimation was also performed. RESULTS: A significant increase was observed in comet head ($P < 0.002$), tail length ($P < 0.0002$) and in tail movement ($P < 0.0001$) in exposed brain cells. An analysis of antioxidant enzymes glutathione peroxidase ($P < 0.005$), and superoxide dismutase ($P < 0.006$) showed a decrease while an increase in catalase ($P < 0.006$) was observed. A significant decrease ($P < 0.023$) in histone kinase was also recorded in the exposed group as compared to the control (sham-exposed) ones. One-way analysis of variance (ANOVA) method was adopted for statistical analysis. CONCLUSION: The study concludes that the chronic exposure to these radiations may cause significant damage to brain, which may be an indication of possible tumour promotion (Behari and Paulraj 2007).

23. Kesari KK, Kumar S, Behari J. ***Pathophysiology of microwave radiation: effect on rat brain.*** Appl Biochem Biotechnol. 2012 Jan;166(2):379-88. http://www.ncbi.nlm.nih.gov/pubmed/22134878 **Abstract:** The study aims to investigate the effect of 2.45 GHz microwave radiation on Wistar rats. Rats of 35 days old with 130 ± 10 g body weight were selected for this study. Animals were divided into two groups: sham exposed and experimental (six animals each). Animals were exposed for 2

h a day for 45 days at 2.45 GHz frequency (power density, 0.21 mW/cm(2)). The whole body specific absorption rate was estimated to be 0.14 W/kg. Exposure took place in a ventilated plexiglas cage and kept in an anechoic chamber under a horn antenna. After completion of the exposure period, rats were killed, and pineal gland and whole brain tissues were isolated for the estimation of melatonin, creatine kinase, caspase 3, and calcium ion concentration. Experiments were performed in a blind manner and repeated. A significant decrease ($P < 0.05$) was recorded in the level of pineal melatonin of exposed group as compared with sham exposed. A significant increase ($P < 0.05$) in creatine kinase, caspase 3, and calcium ion concentration was observed in whole brain of exposed group of animals as compared to sham exposed. One-way analysis of variance method was adopted for statistical analysis. *The study concludes that a reduction in melatonin or an increase in caspase-3, creatine kinase, and calcium ion may cause significant damage in brain due to chronic exposure of these radiations. These biomarkers clearly indicate possible health implications of such exposures.*

24. Kim MJ, Rhee SJ. ***Green tea catechins protect rats from microwave-induced oxidative damage to heart tissue***. J Med Food 2004; 7: 299-304. http://www.ncbi.nlm.nih.gov/pubmed/15383222 **Abstract:** We investigated the effects of green tea catechin on oxidative damage in microwave-exposed rats. The microwave-exposed rats received one of three diets: catechin-free (MW-0C), 0.25% catechin (MW-0.25C), or 0.5% catechin (MW-0.5C). Rats were sacrificed 6 days after microwave irradiation (2.45 GHz, 15 minutes). Cytochrome P(450) levels in the MW-0C group was increased by 85% compared with normal, but was 11% and 14% lower in the MW-0.25C and MW-0.5C groups than in the MW-0C group. NADPH-cytochrome P(450) reductase activity in the MW-0C group was increased by 29%, compared with the normal group, but was significantly less in the MW-0.25C and MW-0.5C groups. Superoxide dismutase activity in the MW-0C group was decreased by 34%, compared with the normal group, but in the MW-0.25C and MW-0.5C groups was 19% and 25% higher. The activity of glutathione peroxidase in the MW-0C group was decreased by 28% but remained near normal with catechin supplements. Superoxide radical concentrations in the MW-0C group were increased by 35%, compared with the normal group. However, superoxide radicals in the MW-0.25C and MW-0.5C groups were 11% and 12% lower, respectively, compared with the MW-0C group. *Microwave irradiation significantly increased levels of thiobarbituric acid-reactive substances, carbonyl values, and lipofuscin contents, but green tea catechin partially overcame the effects of the microwave irradiation.* In conclusion, the mixed function oxidase system was activated, the formation of superoxide radical, lipid peroxide, oxidized protein, and lipofuscin was increased, and the antioxidative defense system was weakened in heart tissue of microwave-exposed rats, but the oxidative damage was significantly reduced by catechin supplementation.

25. Kowalczuk CI, Saunders RD, Stapleton HR. ***Sperm count and sperm abnormality in male mice after exposure to 2.45 GHz microwave radiation.*** Mutat Res. 1983 Nov;122(2):155-61. http://www.ncbi.nlm.nih.gov/pubmed/6656806 **Abstract:** Adult male mice had the posterior halves of their bodies exposed at 44 W/kg in a waveguide system to 2.45 GHz microwave radiation for 30 min. They were killed sequentially over 10 weeks and assessed for decreased sperm count and abnormal sperm morphology. The response in each assay was maximal 2-4 weeks after the exposure. This corresponds to microwaves having their greatest effect on spermatids and spermatocytes. Male fertility, assessed as the proportion of normal sperm per epididymis, was compared with results of an earlier study on dominant lethality. It is concluded that reduced male fertility correlates well with reduced pregnancy rate but less well with pre-implantation survival. Whilst microwaves clearly induced abnormally shaped sperm, those which achieved fertilization cannot have possessed a dominant mutation which would result in the post-implantation death of the embryo.

26. *Lai H. ***Interactions of MW and temporally incoherent magnetic field on spatial learning in rat.*** Physiol Behav. 2004 Oct 15;82(5):785-9. http://www.ncbi.nlm.nih.gov/pubmed/15451642 **Abstract**: The effect of a temporally incoherent magnetic field ('noise') on microwave-induced spatial learning deficit in the rat was investigated. Rats were trained in six sessions to locate a submerged platform in a circular water maze. Four treatment groups of rats were studied: microwave-exposure (2450-MHz continuous-wave microwaves, power density 2 mW/cm(2), average whole-body specific absorption rate 1.2 W/kg), 'noise' exposure (60 mG), 'microwave+noise' exposure, and sham exposure. Animals were exposed to these conditions for 1 h immediately before each training session. One hour after the last training session, animals were tested in a 2-min probe trial in the maze during which the platform was removed. The time spent during the 2 min in the quadrant of the maze in which the platform had been located was scored. Results show that microwave-exposed rats had significant deficit in learning to locate the submerged platform when compared with the performance of the sham-exposed animals. Exposure to 'noise' alone did not significantly affect the performance of the animals (i.e., it was similar to that of the sham-exposed rats). However, simultaneous exposure to 'noise' significantly attenuated the microwave-induced spatial learning deficit (i.e. 'microwave+noise'-exposed rats learned significantly better than the microwave-exposed rats). During the probe trial, microwave-exposed animals spent significantly less time in the quadrant where the platform was located. However, response of the 'microwave+noise'-exposed animals was similar to that of the sham-exposed animals during the probe trial. Thus, simultaneous exposure to a temporally incoherent magnetic field blocks microwave-induced spatial learning and memory deficits in the rat.

27. Lai, H., Singh N.P. ***Acute Low-Intensity Microwave Exposure Increases DNA Single-strand Breaks in Rat Brain Cells***. Bioelectromagnetics, 16:207-210 (1995). http://www.ncbi.nlm.nih.gov/pubmed/7677797 **Abstract:** A dose rate-dependent [0.6 and 1.2 W/kg whole body specific absorption rate (SAR)] increase in DNA single-strand breaks was found in brain cells of rats at 4 h postexposure. Furthermore, in rats exposed for 2 h to continuous-wave 2450 MHz microwaves (SAR 1.2 W/kg), increases in brain

cell DNA single-strand breaks were observed immediately as well as at 4 h post exposure.

28. Lai, H., Singh N.P. ***Single- and Double-strand DNA Breaks in Rat Brain Cells After Acute Exposure to Radiofrequency Electromagnetic Radiation.*** Intl. J. Radiation Biology, 69: 513-521 (1996). http://www.ncbi.nlm.nih.gov/pubmed/8627134 **Abstract:** We investigated the effects of acute (2-h) exposure to pulsed (2-micros pulse width, 500 pulses s(-1)) and continuous wave 2450-MHz radiofrequency electromagnetic radiation on DNA strand breaks in brain cells of rat. The spatial averaged power density of the radiation was 2mW/cm2, which produced a whole-body average-specific absorption rate of 1.2W/kg. Single- and double-strand DNA breaks in individual brain cells were measured at 4h post-exposure using a microgel electrophoresis assay. An increase in both types of DNA strand breaks was observed after exposure to either the pulsed or continuous-wave radiation, No significant difference was observed between the effects of the two forms of radiation. We speculate that these effects could result from a direct effect of radiofrequency electromagnetic energy on DNA molecules and/or impairment of DNA-damage repair mechanisms in brain cells. Our data further support the results of earlier in vitro and in vivo studies showing effects of radiofrequency electromagnetic radiation on DNA.

29. Lee S, Johnson D, Dunbar K, Dong H, Ge X, Kim YC, Wing C, Jayathilaka N, Emmanuel N, Zhou CQ, Gerber HL, Tseng CC, Wang SM. ***2.45 GHz radiofrequency fields alter gene expression in cultured human cells.*** FEBS Lett. 2005 Aug 29;579(21):4829-36. http://www.ncbi.nlm.nih.gov/pubmed/16107253 **Abstract:** The biological effect of radiofrequency (RF) fields remains controversial. We address this issue by examining whether RF fields can cause changes in gene expression. We used the pulsed RF fields at a frequency of 2.45 GHz that is commonly used in telecommunication to expose cultured human HL-60 cells. We used the serial analysis of gene expression (SAGE) method to measure the RF effect on gene expression at the genome level. We observed that 221 genes altered their expression after a 2-h exposure. The number of affected genes increased to 759 after a 6-h exposure. Functional classification of the affected genes reveals that apoptosis-related genes were among the upregulated ones and the cell cycle genes among the downregulated ones. We observed no significant increase in the expression of heat shock genes. These results indicate that the RF fields at 2.45 GHz can alter gene expression in cultured human cells through non-thermal mechanism.

30. Maganioti A. E., Papageorgiou C. C., Hountala C. D., Kyprianou M. A., Rabavilas A. D., Papadimitriou G. N., Capsalis C. N. 2010. ***Wi-Fi electromagnetic fields exert gender related alterations on EEG***. 6th International Workshop on Biological Effects of Electromagnetic fields. http://www.istanbul.edu.tr/6internatwshopbioeffemf/cd/pdf/poster/WI-FI%20ELECTROMAGNETIC%20FIELDS%20EXERT%20GENDER.pdf **Abstract:** The present study investigated the influence of electromagnetic fields, similar to that

emitted by Wi-Fi system, on brain activity. Fifteen female and fifteen male subjects performed a short memory task (Wechsler test), both without and with exposure to a 2.4GHz Wi-Fi signal. For each subject, radiation condition and electrode, the amplitude in the frequency domain of the EEG signal was calculated from the recordings of 30 scalp electrodes, using the Fourier transform. The presence of radiation had no effect on the energies of alpha and beta band of male subjects, while it reduced these energies of female subjects, resulting in significantly lower energies, as compared to those of males. Delta and theta band energies did not experience any noteworthy effect from gender, radiation condition and their interaction. Conversely, there was a significant interaction effect (gender x radiation) on the energies of alpha and beta rhythms. Interestingly, this pattern was observed for a number of electrodes, which formed two distinct clusters. one located at right- anterior and the second at occipital brain areas.The present data support the idea that Wi-Fi signal may influence normal physiology through changes in gender related cortical excitability, as reflected by alpha and beta EEG frequencies.

31. Maes A, Verschaeve L, Arroyo A, De Wagter C, Vercruyssen L. ***In vitro cytogenetic effects of 2450 MHz waves on human peripheral blood lymphocytes.*** Bioelectromagnetics. 1993;14(6):495-501. http://www.ncbi.nlm.nih.gov/pubmed/8297394 **Abstract:** Cytogenetic analyses were performed on human peripheral blood lymphocytes exposed to 2450 MHz microwaves during 30 and 120 min at a constant temperature of 36.1 degrees C (body temperature). The temperature was kept constant by means of a temperature probe put in the blood sample which gives feedback to a microcomputer that controls the microwave supply. We found a marked increase in the frequency of chromosome aberrations (including dicentric chromosomes and acentric fragments) and micronuclei. On the other hand the microwave exposure did not influence the cell kinetics nor the sister chromatid exchange (SCE) frequency.

32. Matikka Virtanen H, Keshvari J, Lappalainen R. ***Temperature changes associated with radiofrequency exposure near authentic metallic implants in the head phantom--a near field simulation study with 900, 1800 and 2450 MHz dipole.*** Phys Med Biol. 2010 Oct 7;55(19):5867-81. doi: 10.1088/0031-9155/55/19/016. Epub 2010 Sep 16. http://www.ncbi.nlm.nih.gov/pubmed/20844329 **Abstract:** The effect of the head implant metal material on electromagnetic field induced temperature change was evaluated using clinically used metals with the highest and the lowest thermal conductivities. In some cases, remarkable increases in maximum temperatures of tissues (as much as 8 °C) were seen in the near field *with 1 W power level* whereas at lower power levels significant temperature increases were not observed.

33. McRee DI. ***Review of Soviet/Eastern European research on health aspects of microwave radiation.*** Bull N Y Acad Med. 1979 December; 55(11): 1133–1151. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1807746/pdf/bullnyacadmed00125-0169.pdf [Copy filed in Docket] **Excerpt (pg 1135):** In 1971 the United States and the Soviet Union agreed to cooperate in health-related research areas. In March 1972 an agreement was signed between the U.S. Department of Health, Education and Welfare and the U.S.S.R. Minstry of Health to cooperate in the area of cancer, heart and lung

disease, and environmental health. The directors of the National Cancer Institute, National Institute of Heart and Lung Diseases, and the National Institute of EnvironmeIntal Health Sciences were appointed to work with Soviet counterparts to develop cooperative plans for research in each of the specified areas. The formal agreement to cooperate in the area of the biological effects of microwave radiation was signed in October 1975. Since 1975 there have been yearly exchange visits by scientists from both countries. **Excerpt (pg 1139):** Most Soviet research is performed, therefore, at low levels of exposure for long exposure duration. They consider that power densities above 1mW/cm2 are high enough to produce harmful effects, and see no reason to perform research above this level. When we respond that in some of our experiments we see no significant changes at exposure levels above 1mW/cm., their answer is that we did not expose long enough. ***Most of their low level experiments are for six months to a year, while American experiments are usually in terms of a few weeks. Long-term experiments using low levels of microwaves must be performed in the United States before the Soviet results can be verified or refuted…*** American research consisted primarily of acute experiments with exposure levels generally of 5 mW/cm2 and above, while Soviet experiments were long-term, low-level experiments at 500,gW/cm2 and below. ***At the end of the first year of the cooperation, the Soviets reported changes in bioelectric brain activity at 10, 50, and 500,uW/cm.2 in rats and rabbits exposed for 7 hours/day for 30 days to 2,375 MHz. radiation.*** Levels of 10 and 50 ,uW/cm.2 stimulated brain activity, while 500 ,uW/cm.2 suppressed activity as seen from an increase of slow, high amplitude A-wave in rabbits. At 500 gW/cm.2 a decrease in capacity for work, in investigative activity, and sensitivity to electric shock threshold in rats were reported***. Research by American investigators on rats exposed to 5 mW/cm.2 for shorter durations of exposure to 2,450 MHz. radiation showed no statistical difference in electroencephalogram, no change in locomotive activity in a residential maze, and no change in performance on a fixed ratio schedule of reinforcement below 5 mW/cm.2 (0.5 and 1.0 mW/cm.2) but a trend toward decrease in performance at 5 mW/cm.2 and a large decrease in performance at 10 and 20 mW/Cm.2.*** It became obvious that, except for our being more familiar with their experimental design, we were no closer to understanding differences between American and Soviet results. ***It was then decided to perform a duplicate experiment to determine whether similar effects could be observed. Rats were exposed from above for seven hours/day, seven days/week for three months to 500 uW/cm.2. Dr. Richard Lovely of the University of Washington, project leader on the duplicate project, spent four weeks in the Soviet Union to observe the behavioral and biochemical tests performed on the animals. The American study found a drop insulfhydryl activity and blood cholinesterase as reported in the Soviet study. Blood chemical analyses at the termination of three months exposure indicated that exposed animals, relative to controls, suffered from aldosteronism. The latter interpretation of the high sodium-low potassiumlevels found in the blood was confirmed by necropsy and histopathologic study of the adrenal glands, revealing that the zona glomerulosa was vacuolated and hypertrophied***. *In addition, all behavioral parameters assessed at the end of three-month exposures revealed significant differences between groups in the same direction as those reported in the Soviet study, i.e., increased threshold to footshock detection, decreased activity in an open field, and poorer retention of an avoidance response when reassessedfollowing conditioning. This replication of the*

Soviet results at 500 puW/cm.2 emphasizes the need for additional long-term, low-level microwave bioeffects research.

34. Misa Agustiño MJ, Leiro JM, Jorge Mora MT, Rodríguez-González JA, Jorge Barreiro FJ, Ares-Pena FJ, López-Martín E. ***Electromagnetic fields at 2.45 GHz trigger changes in heat shock proteins 90 and 70 without altering apoptotic activity in rat thyroid gland***. Biol Open. 2012 Sep 15;1(9):831-8. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3507243/pdf/bio-01-09-831.pdf **Excerpt:** The rats were divided into 4 subgroups (n56); each rat was exposed to 30 min of microwave radiation at different levels: 0 (control), **1.5, 3.0 and 12 W.** The rats were kept alive for 24 h, then slaughtered and perfused with fixative. Summary: Non-ionizing radiation at 2.45 GHz may modify the expression of genes that codify heat shock proteins (HSP) in the thyroid gland. Using the enzyme-linked immunosorbent assay (ELISA) technique, we studied levels of HSP-90 and HSP-70. We also used hematoxilin eosin to look for evidence of lesions in the gland and applied the DAPI technique of fluorescence to search for evidence of chromatin condensation and nuclear fragmentation in the thyroid cells of adult female Sprague-Dawley rats. Fiftyfour rats were individually exposed for 30 min to **2.45 GHz** radiation in a Gigahertz transverse electromagnetic (GTEM) cell at different levels of non-thermal specific absorption rate (SAR), which was calculated using the finite difference time domain (FDTD) technique. Ninetyminutes after radiation,HSP- 90 and HSP-70 had decreased significantly (P,0.01) after applying a SAR of 0.04661.10 W/Kg or 0.10465.1023 W/Kg. Twenty-four hours after radiation, HSP-90 had partially recovered and HSP-70 had recovered completely. There were few indications of lesions in the glandular structure and signs of apoptosis were negative in all radiated animals. *The results suggest that acute sub-thermal radiation at 2.45 GHz may alter levels of cellular stress in rat thyroid gland without initially altering their anti-apoptotic capacity.*

35. Mitchell CL, McRee DI, Peterson NJ, Tilson HA. ***Some behavioral effects of short-term exposure of rats to 2.45 GHz microwave radiation.*** Bioelectromagnetics. 1988;9(3):259-68. http://www.ncbi.nlm.nih.gov/pubmed/3178900 **Abstract:** Rats were tested for neurobehavioral alterations immediately after exposure to 2.45-GHz (CW) microwave radiation at 10 mW/cm2 for 7 h. ..Microwave-exposed animals exhibited less activity than sham-exposed animals. This was most evident during the last 10-15 min of the 30-min test session…The microwave-exposed animals were less responsive to the stimuli than sham-exposed animals. Microwave exposure had no effect on the retention of a passive avoidance procedure when tested at 1 week after training. *Both the locomotor activity and acoustic startle data demonstrate that, under the conditions of this experiment, microwave exposure may alter responsiveness of rats to novel environmental conditions or stimuli.*

36. Mitchell CL, McRee DI, Peterson NJ, Tilson HA, Shandala MG, Rudnev MI, Varetskii VV, Navakatikyan MI. ***Results of a United States and Soviet Union joint project on nervous system effects of microwave radiation***. Environ Health Perspect. 1989 May;81:201-9. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1567540/ [2.4 GHz] **Abstract:** The U.S. group, but not the USSR group, found significantly less Na+,K+-

ATPase activity in the microwave-exposed animals compared to the sham exposed animals. Both groups found incidences of statistically significant effects in the power spectral analysis of EEG frequency, but not at the same frequency.

37. Navakatikian MA, and Tomashevskaya LA, ***Phasic behavioral and endocrine effects of microwaves of nonthermal intensity.*** 1994, In: "Biological Effects of Electric and Magnetic Fields, vol. 1", D.O. Carpenter, ed., Academic Press, San Diego, CA. Described a complex series of experiments in which they observed disruption of a behavior (active avoidance) by RFR. In the study, rats were first trained to perform the behavior and then exposed to either CW 2450-MHz RFR or pulsed 3000-MHz RFR (400-Hz modulation, pulse duration 2 ms, and simulation of radar rotation of 3, 6, and 29rotations/min) for 0.5-12 hrs or 15-80 days (7-12 hr/day). *Behavioral disruption was observed at a power density as low as* ***0.1 mW.cm-2 (0.027 W.kg-1).***

38. *Neubauer C, Phelan AM, H. Kues H, Lange DG. ***Microwave irradiation of rats at 2.45 GHz activates pinocytotic-like uptake of tracer by capillary endothelial cells of cerebral cortex.*** Bioelectromagnetics. 11:261-268 (1990). http://www.ncbi.nlm.nih.gov/pubmed/2285411 **Abstract:** Far-field exposures of male albino rats to 2.45-GHz microwaves (10-microseconds pulses, 100 pps) at a low average power density (10 mW/cm2; SAR approximately 2 W/kg) and short durations (30-120 min) resulted in increased uptakes of tracer through the blood-brain barrier (BBB). The uptake of systemically administered rhodamine-ferritin complex by capillary endothelial cells (CECs) of the cerebral cortex was dependent on power density and on duration of exposure. At 5 mW/cm2, for example, a 15-min exposure had no effect. Near-complete blockade of uptake resulted when rats were treated before exposure to microwaves with a single dose of colchicine, which inhibits microtubular function. A pinocytotic-like mechanism is presumed responsible for the microwave-induced increase in BBB permeability.

39. *Orendácová J, Raceková E, Orendác M, Martoncíková M, Saganová K, Lievajová K, Abdiová H, Labun J, Gálik J. ***Immunohistochemical study of postnatal neurogenesis after whole-body exposure to electromagnetic fields: evaluation of age- and dose-related changes in rats.*** Cell Mol Neurobiol. 2009 Sep;29(6-7):981-90. http://www.ncbi.nlm.nih.gov/pubmed/19305951 **Abstract:** It is well established that strong electromagnetic fields (EMFs) can give rise to acute health effects, such as burns, which can be effectively prevented by respecting exposure guidelines and regulations. Current concerns are instead directed toward the possibility that long-term exposure to weak EMF might have detrimental health effects due to some biological mechanism, to date unknown. (1) The possible risk due to pulsed EMF at frequency 2.45 GHz and mean power density 2.8 mW/cm(2) on rat postnatal neurogenesis was studied in relation to the animal's age, duration of the exposure dose, and post-irradiation survival. (2) Proliferating cells marker, BrdU, was used to map age- and dose-related immunohistochemical changes within the rostral migratory stream (RMS) after whole-body exposure of newborn (P7) and senescent (24 months) rats. (3) Two dose-related exposure patterns were performed to clarify the cumulative effect of EMF: short-term exposure dose, 2 days irradiation (4 h/day), versus long-term exposure dose, 3 days

irradiation (8 h/day), both followed by acute (24 h) and chronic (1-4 weeks) post-irradiation survival. (4) We found that the EMF induces significant age- and dose-dependent changes in proliferating cell numbers within the RMS. *Our results indicate that the concerns about the possible risk of EMF generated in connection with production, transmission, distribution, and the use of electrical equipment and communication sets are justified at least with regard to early postnatal neurogenesis.*

40. *Orendáčová J, Orendáč M, Mojžiš M, Labun J, Martončíková M, Saganová K, Lievajová K, Blaško J, Abdiová H, Gálik J, Račeková E. ***Effects of short-duration electromagnetic radiation on early postnatal neurogenesis in rats: Fos and NADPH-d histochemical studies.*** Acta Histochem. 2011 Nov;113(7):723-8 http://www.ncbi.nlm.nih.gov/pubmed/20950843 **Abstract:** The immediate effects of whole body electromagnetic radiation (EMR) were used to study postnatal neurogenesis in the subventricular zone (SVZ) and rostral migratory stream (RMS) of Wistar rats of both sexes. Newborn postnatal day 7 (P7) and young adult rats (P28) were exposed to pulsed electromagnetic fields (EMF) at a frequency of 2.45 GHz and mean power density of 2.8 mW/cm(2) for 2 h. Post-irradiation changes were studied using immunohistochemical localization of Fos and NADPH-d. We found that short-duration exposure induces increased Fos immunoreactivity selectively in cells of the SVZ of P7 and P28 rats. There were no Fos positive cells visible within the RMS of irradiated rats. These findings indicate that some differences exist in prerequisites of proliferating cells between the SVZ and RMS regardless of the age of the rats. Short-duration exposure also caused praecox maturation of NADPH-d positive cells within the RMS of P7 rats. The NADPH-d positive cells appeared several days earlier than in age-matched controls, and their number and morphology showed characteristics of adult rats. On the other hand, in the young adult P28 rats, EMR induced morphological signs typical of early postnatal age. *These findings indicate that EMR causes age-related changes in the production of nitric oxide (NO), which may lead to different courses of the proliferation cascade in newborn and young adult neurogenesis.*

41. Navakatikian MA, Gordienko VM, Slavnov VN, Nogachevskaia SI, Tomashevskaia LA. ***[The effect of microwave irradiation on the status of the thyroid gland].*** Radiobiologiia. 1990 Sep-Oct;30(5):679-84. http://www.ncbi.nlm.nih.gov/pubmed/2251358 **Abstract:** Multiple irradiation of rats with microwaves of continuous generation (2450 MHz, 1 mW/cm2) increased and of pulsed generation (3000 MHz, 0.1 to 2.5 mW/cm2) decreased the functional activity of the thyroid gland with no changes in the triiodothyronine and thyroxin in blood serum. The role of the thyroid gland in inducing behaviour effects of microwaves was demonstrated by the method of extirpation.

42. Navakatikian MA. ***Changes in the activity and conditioned-reflex behavior of white rats during and after chronic microwave irradiation].*** Radiobiologiia. 1988 Jan-Feb;28(1):120-5. http://www.ncbi.nlm.nih.gov/pubmed/3344322 **Abstract:** Albino rats were exposed to chronic (1-3 months) electromagnetic radiation (2375 MHz; 1, 5, 10, 50 and 500 microW/cm2; 7 hours a day). Inhibition of the activity during the open field tests and diminution of consolidation of the defence conditioned reflexes in a shuttle chamber

occurred during exposure (5 to 500 microW/cm2) while the activity increased and reflexes consolidation gradually normalized during the post-irradiation period.

43. *Neubauer et al. ***Microwave irradiation of rats at 2.45 GHz activates pinocytotic-like uptake of tracer by capillary endothelial cells of cerebral cortex***, Bioelectromagnetics (1990) 11: 261-268 http://www.ncbi.nlm.nih.gov/pubmed/2285411 **Abstract:** Far-field exposures of male albino rats to 2.45-GHz microwaves (10-microseconds pulses, 100 pps) at a low average power density (10 mW/cm2; SAR approximately 2 W/kg) and short durations (30-120 min) resulted in increased uptakes of tracer through the blood-brain barrier (BBB). The uptake of systemically administered rhodamine-ferritin complex by capillary endothelial cells (CECs) of the cerebral cortex was dependent on power density and on duration of exposure. At 5 mW/cm2, for example, a 15-min exposure had no effect. Near-complete blockade of uptake resulted when rats were treated before exposure to microwaves with a single dose of colchicine, which inhibits microtubular function. A pinocytotic-like mechanism is presumed responsible for the microwave-induced increase in BBB permeability.

44. *Orendácová J, Raceková E, Orendác M, Martoncíková M, Saganová K, Lievajová K, Abdiová H, Labun J, Gálik J. ***Immunohistochemical study of postnatal neurogenesis after whole-body exposure to electromagnetic fields: evaluation of age- and dose-related changes in rats.*** Cell Mol Neurobiol. 2009 Sep;29(6-7):981-90. http://www.ncbi.nlm.nih.gov/pubmed/19305951 **Abstract:** It is well established that strong electromagnetic fields (EMFs) can give rise to acute health effects, such as burns, which can be effectively prevented by respecting exposure guidelines and regulations. Current concerns are instead directed toward the possibility that long-term exposure to weak EMF might have detrimental health effects due to some biological mechanism, to date unknown. (1) The possible risk due to pulsed EMF at frequency 2.45 GHz and mean power density 2.8 mW/cm(2) on rat postnatal neurogenesis was studied in relation to the animal's age, duration of the exposure dose, and post-irradiation survival. (2) Proliferating cells marker, BrdU, was used to map age- and dose-related immunohistochemical changes within the rostral migratory stream (RMS) after whole-body exposure of newborn (P7) and senescent (24 months) rats. (3) Two dose-related exposure patterns were performed to clarify the cumulative effect of EMF: short-term exposure dose, 2 days irradiation (4 h/day), versus long-term exposure dose, 3 days irradiation (8 h/day), both followed by acute (24 h) and chronic (1-4 weeks) post-irradiation survival. (4) We found that the EMF induces significant age- and dose-dependent changes in proliferating cell numbers within the RMS. *Our results indicate that the concerns about the possible risk of EMF generated in connection with production, transmission, distribution, and the use of electrical equipment and communication sets are justified at least with regard to early postnatal neurogenesis.*

45. ***Orendáčová J, Orendáč M, Mojžiš M, Labun J, Martončíková M, Saganová K, Lievajová K, Blaško J, Abdiová H, Gálik J, Račeková E. ***Effects of short-duration electromagnetic radiation on early postnatal neurogenesis in rats: Fos and NADPH-d histochemical studies.*** Acta Histochem. 2011 Nov;113(7):723-8

http://www.ncbi.nlm.nih.gov/pubmed/20950843 **Abstract:** The immediate effects of whole body electromagnetic radiation (EMR) were used to study postnatal neurogenesis in the subventricular zone (SVZ) and rostral migratory stream (RMS) of Wistar rats of both sexes. Newborn postnatal day 7 (P7) and young adult rats (P28) were exposed to pulsed electromagnetic fields (EMF) at a frequency of 2.45 GHz and mean power density of 2.8 mW/cm(2) for 2 h. Post-irradiation changes were studied using immunohistochemical localization of Fos and NADPH-d. We found that short-duration exposure induces increased Fos immunoreactivity selectively in cells of the SVZ of P7 and P28 rats. There were no Fos positive cells visible within the RMS of irradiated rats. These findings indicate that some differences exist in prerequisites of proliferating cells between the SVZ and RMS regardless of the age of the rats. Short-duration exposure also caused praecox maturation of NADPH-d positive cells within the RMS of P7 rats. The NADPH-d positive cells appeared several days earlier than in age-matched controls, and their number and morphology showed characteristics of adult rats. On the other hand, in the young adult P28 rats, EMR induced morphological signs typical of early postnatal age. *These findings indicate that EMR causes age-related changes in the production of nitric oxide (NO), which may lead to different courses of the proliferation cascade in newborn and young adult neurogenesis.*

46. Paulraj R, Behari J. ***Single strand DNA breaks in rat brain cells exposed to microwave radiation.*** Mutat Res. 2006 Apr 11;596(1-2):76-80. Epub 2006 Feb 2: http://www.ncbi.nlm.nih.gov/pubmed/16458332 **Abstract:** This investigation concerns with the effect of low intensity microwave (2.45 and 16.5 GHz, **SAR 1.0 and 2.01 W/kg**, respectively) radiation on developing rat brain. Wistar rats (35 days old, male, six rats in each group) were selected for this study. These animals were exposed for 35 days at the above mentioned frequencies separately in two different exposure systems. After the exposure period, the rats were sacrificed and the whole brain tissue was dissected and used for study of single strand DNA breaks by micro gel electrophoresis (comet assay). Single strand DNA breaks were measured as tail length of comet. Fifty cells from each slide and two slides per animal were observed. One-way ANOVA method was adopted for statistical analysis. This study shows that the chronic exposure to these radiations cause statistically significant ($p<0.001$) increase in DNA single strand breaks in brain cells of rat.

47. *Paulraj R, Behari J. ***Protein kinase C activity in developing rat brain cells exposed to 2.45 GHz radiation.*** Electromagn Biol Med. 2006;25(1):61-70. http://www.ncbi.nlm.nih.gov/pubmed/16595335 **Abstract**: There is growing concern by the public regarding the potential human health hazard due to exposure to microwave frequencies. 2.45 GHz radiation widespread use in industry, research, and medicine, and leakage into the environment is possible. In order to quantitate this, experiments were performed on developing rat brain. Male Wistar 35-day-old rats (n = 6) were used for this study. Animals were exposed to **2.45 GHz radiation for 2 h/day for a period of 35 days at a power density of 0.344 mW/cm(2)** (SAR 0.11 W/kg). The control group was sham irradiated. After 35 days these rats were sacrificed and whole brain tissue was isolated for protein kinase C (PKC) assay. For morphological study the forebrain was isolated from the whole brain and PKC activity was measured using P(32) labeled ATP. Our study

reveals a statistically significant ($p < 0.05$) decrease in PKC activity in hippocampus as compared to the remaining portion of the whole brain and the control group. A similar experiment conducted on hippocampus and the whole brain gave a similar result. Electron microscopic study shows an increase in the glial cell population in the exposed group as compared to the control group. This present study is indicative of a significant change after exposure to the above-mentioned field intensity. This suggests that chronic exposures may affect brain growth and development.

48. Rudnev MI, Gonchar IM. ***[Nature of the changes in the morphofunctional and cytochemical indices of blood leukocytes as affected by low-intensity microwaves].*** Radiobiologiia. 1985 Sep-Oct;25(5):645-9. http://www.ncbi.nlm.nih.gov/pubmed/4070571 **Abstract:** A study was made of morphological composition of blood leukocytes, phagocytic activity, glycogen and alkaline phosphatase content of neutrophils of animals exposed to microwaves of low **intensity (1-500 mu W/cm2)* generated continuously (2375 MHz) and by impulses (9400 MHz).** The direction of the change in these indices and rate of the post irradiation recovery was shown to depend upon intensity and duration (30-120 days) of exposure. The response of albino rats and guinea pigs to the effect of microwaves was different. The effect of microwaves of the intensities under study on the mammalian organism was assessed. ***Note: 1-500 mW/cm2 = .001 mW/cm2 to .5 mW/cm2**

49. Rudnev M, Bokina A, Eksler N, and Navakatikyan M, 1978, ***The use of evoked potential and behavioral measures in the assessment of environmental insult. In: Multidisciplinary Perspectives in Event-Related Brain Potential Research,"*** D.A. Otto, ed., EPA-600/9-77-043, U.S. Environmental Protection Agency, Research Triangle Park, NC. Studied the behavior of rats exposed to CW 2375-MHz RFR at 0.5 mW**.**cm**-2** (SAR 0.1 W**.**kg**-1**), 7 h/day for 1 month. They reported a decrease in balancing time in a treadmill and inclined rod and motor activity in an open-field after 20 days of exposure. The open-field motor activity was found to be increased at 3 months post-exposure.

50. Saalman E, Nordén B, Arvidsson L, Hamnerius Y, Höjevik P, Connell KE, Kurucsev T. ***Effect of 2.45 GHz microwave radiation on permeability of unilamellar liposomes to 5(6)-carboxyfluorescein. Evidence of non-thermal leakage.*** Biochim Biophys Acta. 1991 Apr 26;1064(1):124-30. http://www.ncbi.nlm.nih.gov/pubmed/2025632 **Abstract:** The influence of 2.45 GHz microwave radiation on the membrane permeability of unilamellar liposomes was studied using the marker 5(6)-carboxyfluorescein trapped in phosphatidylcholine liposomes. The release of the fluorescent marker was followed by spectrofluorimetry after an exposure of 10 minutes to either microwave radiation or to heat alone of the liposome solutions. A significant increase of the permeability of carboxyfluorescein through the membrane was observed for the microwave-exposed samples compared to those exposed to normal heating only. Exposure to 2.45 GHz microwave radiation of liposomes has been previously found to produce increased membrane permeability as compared with heating. However, in contrast to previous studies, the observations reported here were made above the phase transition temperature of the lipid membrane. The experimental setup included monitoring of the temperature

during microwave exposure simultaneously at several points in the solution volume using a fiberoptic thermometer. Possible mechanisms to explain the observations are discussed.

51. *Sarimov R, Malmgren LOG, Markova E, Persson BRR, Belyaev IY. ***Nonthermal GSM microwaves affect chromatin conformation in human lymphocytes similar to heat shock.*** *IEEE Trans. Plasma Sci.* 2004;32:1600–1608

52. Sarkar S, Ali S, Behari J**, *Effect of low power microwave on the mouse genome: a direct DNA analysis.*** Mutation Research, 320(1-2):141-147, 1994. http://www.ncbi.nlm.nih.gov/pubmed/7506381 Mice testis **Abstract:** The potential mutagenic effect of low power microwave at the DNA sequence level in the mouse genome was evaluated by direct DNA analysis. Animals were exposed to microwave at a power density of **1 mW/cm2 for 2 h/day at a frequency of 2.45 GHz** over a period of 120, 150 and 200 days. HinfI digested DNA samples from testis and brain of control and exposed animals were hybridized with a synthetic oligo probe (OAT 36) comprising nine repeats of 5'-GACA-3'. As compared to control animals, band patterns in exposed animals were found to be distinctly altered in the range of 7-8 kb which was also substantiated by densitometric analysis. Though the mechanism of this rearrangement is not yet clear, the results obtained at the present dose are of significance. This dose, which has been set as the safe limit for general public exposure by the Non-Ionizing Radiation Committee of the International Radiation Protection Association, may imply a need for (re)evaluation of the mutagenic potential of microwaves at the prescribed safe limit for the personnel and people who are being exposed.

53. Saygin M, Caliskan S, Karahan N, Koyu A, Gumral N, Uguz A. ***Testicular apoptosis and histopathological changes induced by a 2.45 GHz electromagnetic field.*** Toxicol Ind Health. 2011 Jun;27(5):455-63. Epub 2011 Feb 10. http://www.ncbi.nlm.nih.gov/pubmed/21310776?dopt=Abstract **Abstract:** There is a growing public concern about the potential human health hazard caused by exposure to electromagnetic radiation (EMR). The objective of this study is to investigate the effects of 2450 mhz electromagnetic field on apoptosis and histopathological changes on rat testis tissue. Twelve-week-old male Wistar Albino rats were used in this study. Eighteen rats equally divided into three different groups which were named group I, II and III. Cage control (group I), sham control (group II) and 2.45 GHz EMR (group III) groups were formed. Group III were exposed to 2.45 GHz EMR, at 3.21 W/kg specific absorption rate for 60 minutes/ day for 28 days. There was no difference among the groups for the diameter of the seminiferous tubules, pyknotic, karyolectic and karyotic cells. *However, the number of Leydig cells of testis tissue of the rats in group III was significantly reduced comparing with the group I ($p < 0.05$). Estimation of spermatogenesis using the Johnsen testicular biopsy score revealed that the difference between groups is statistically significant.* The level of TNF-α, Caspase-3 and Bcl-2 were compared, and no significant difference was found between the groups. *When Bax apoptosis genes and Caspase-8 apoptosis enzyme were compared, there were significant differences between the groups ($p < 0.05$). Electromagnetic field affects spermatogenesis and causes to apoptosis due to the heat and other stress-related events in testis tissue.*

54. Shahin S, Singh VP, Shukla RK, Dhawan A, Gangwar RK, Singh SP, Chaturvedi CM. ***2.45 GHz Microwave Irradiation-Induced Oxidative Stress Affects Implantation or Pregnancy in Mice.*** Mus musculus. Appl Biochem Biotechnol 2013 http://www.ncbi.nlm.nih.gov/pubmed/23334843 [Copy filed in Docket] **Abstract:** The present experiment was designed to study the 2.45 GHz low-level microwave (MW) irradiation-induced stress response and its effect on implantation or pregnancy in female mice. Twelve-week-old mice were exposed to MW radiation (continuous wave for 2 h/day for 45 days, **frequency 2.45 GHz, power density = 0.033549 mW/cm(2)**, and specific absorption rate = 0.023023 W/kg). At the end of a total of 45 days of exposure, mice were sacrificed, implantation sites were monitored, blood was processed to study stress parameters (hemoglobin, RBC and WBC count, and neutrophil/lymphocyte (N/L) ratio), the brain was processed for comet assay, and plasma was used for nitric oxide (NO), progesterone and estradiol estimation. Reactive oxygen species (ROS) and the activities of ROS-scavenging enzymes- superoxide dismutase, catalase, and glutathione peroxidase-were determined in the liver, kidney and ovary. We observed that implantation sites were affected significantly in MW-irradiated mice as compared to control. Further, in addition to a significant increase in ROS, hemoglobin ($p < 0.001$), RBC and WBC counts ($p < 0.001$), N/L ratio ($p < 0.01$), DNA damage ($p < 0.001$) in brain cells, and plasma estradiol concentration ($p < 0.05$), a significant decrease was observed in NO level ($p < 0.05$) and antioxidant enzyme activities of MW-exposed mice. Our findings led us to conclude that a low level of MW irradiation-induced oxidative stress not only suppresses implantation, but it may also lead to deformity of the embryo in case pregnancy continues. We also suggest that MW radiation-induced oxidative stress by increasing ROS production in the body may lead to DNA strand breakage in the brain cells and implantation failure/resorption or abnormal pregnancy in mice.

55. Shutenko OI, Koziarin IP, Shvaĭko II. ***[Effect of a superhigh-frequency electromagnetic field on animals of different ages].*** Gig Sanit. 1981 Oct;(10):35-8. http://www.ncbi.nlm.nih.gov/pubmed/7308758 A Study of the effect of radio waves on metals in the body, using 90 young and mature white rats and a generator of 2375 MHz (12.6 cm) waves. Intensities of 100 µW / cm2 and 10 µW / cm2 were both effective in redistributing metals. The animals were exposed for 2 hours a day over a period of 10 weeks. There was an increase in copper content of the lungs and brain

56. Sinha RK***. Chronic non-thermal exposure of modulated 2450 MHz microwave radiation alters thyroid hormones and behavior of male rats.*** Int J Radiat Biol. 2008 Jun;84(6):505-13. http://www.ncbi.nlm.nih.gov/pubmed/18470749 ***Abstract:*** The purpose of this investigation was to analyze the effects of leakage microwave (2450 MHz) irradiation on thyroid hormones and behavior of male rats. MATERIALS AND METHODS: Experiments were carried out on two groups of male rats (exposure and control, respectively). Radio-immuno assay (RIA) methods were used for estimation of 3,5,3'-triiodothyronine (T3), thyroxine (T4) and thyrotrophin or thyroid stimulating hormone (TSH). The assessments of behavioral changes were performed in Open-Field (OF) and Elevated Plus-Maze (EPM) apparatuses. RESULTS: Following chronic microwave exposure, rats were found hyperactive and aggressive on the 16th and 21st days. Behavioral changes in OF were analyzed and found to be significantly changed

from controls ($p < 0.05$) for immobilization, rearing and ambulation behavior. In EPM, rats showed increased activity with decreased time spent in the open arm and more time spent in the center on the 11th ($p < 0.05$), 16th ($p < 0.05$) and 21st day ($p < 0.01$) after irradiation. Changes in behavioral parameters are also correlated with the trend of changes, compared to control animals, in hormonal blood levels of T3 (decreased on the 16th day, $p < 0.05$ and 21st day, $p < 0.01$) and T4 (increased on the 21st day, $p < 0.05$).CONCLUSION: Low energy microwave irradiation may be harmful as it is sufficient to alter the levels of thyroid hormones as well as the emotional reactivity of the irradiated compared to control animals

57. Semin IuA, Shvartsburg LK, Dubovik BV. ***Changes in the secondary structure of DNA under the influence of external low-intensity electromagnetic field].*** Radiats Biol Radioecol. 1995 Jan-Feb;35(1):36-41 http://www.ncbi.nlm.nih.gov/pubmed/12004616 **Abstract:** The effect of ultralow power pulse-modulated electromagnetic radiation (average power density 60 microW/cm2, carrying frequency 1.05; 2.12; or 2.39 GHz; modulating pulses with frequency 4 Hz) on the secondary structure of DNA was investigated. It was established that the exposure of beta-alanine and formaldehyde containing aqueous DNA solution to electromagnetic radiation had activated the process of DNA despiralization under the action of beta-alanine--formaldehyde reaction product. The effect of electromagnetic radiation on the secondary structure of DNA can be removed by lowering of molecular weight of DNA to 0.46 x 10(6) (at carrying frequency 1.05 GHz), or to 0.25 x 10(3) (at carrying frequency 2.39 GHz).

58. Shandala MG, Vinogradov GI, Rudnev MI, Rudakova SF. ***[Effect of microwave radiation on cellular immunity indices in conditions of chronic exposure].*** Radiobiologiia. 1983 Jul-Aug;23(4):544-6. http://www.ncbi.nlm.nih.gov/pubmed/6611886 **Abstract:** CBA male mice and albino mongrel rats were exposed to microwave radiation (2375 MHz) of various intensity during 1 to 3 months. The T-system immunity status was studied in vivo and in vitro. Substantial changes have been revealed in the cell immunity system, resulting from the long-term action of microwaves of a non-thermal intensity, and latent lesions manifested with functional loads.

59. Somosy Z, Thuroczy G, Kubasova T, Kovacs J, Szabo LD, ***Effects of modulated and continuous microwave irradiation on the morphology and cell surface negative charge of 3T3 fibroblasts.*** Scanning Microsc 5(4):1145-1155, 1991 http://www.ncbi.nlm.nih.gov/pubmed/1822036 Mouse embryo 3T3 cells were irradiated with ***2450 MHz*** continuous and low frequency (16 Hz) square modulated waves of absorbed energy ranging ***from 0.0024 to 2.4 mW/g.*** The low frequency modulated microwave irradiation yielded more morphological cell changes than did the continuous microwave fields of the same intensity. The amount of free negative charges (cationized ferritin binding) on cell surfaces decreased following irradiation by modulated waves but remained unchanged under the effect of a continuous field of the same dose. Modulated waves of 0.024 mW/g dose increased the ruffling activity of the cells, and caused

ultrastructural alteration in the cytoplasm. Similar effects were experienced by continuous waves at higher (0.24 and 2.4 mW/g) doses.

60. *Testylier G, Tonduli L, Malabiau R, Debouzy JC. ***Effects of exposure to low level radiofrequency fields on acetylcholine release in hippocampus of freely moving rats. Bioelectromagnetics.*** 2002 May;23(4):249-55. http://www.ncbi.nlm.nih.gov/pubmed/11948603 **Abstract: ...**We studied acetylcholine (ACh) release in the brain of freely moving rats exposed for 1 h during the day to a 2.45 GHz continuous wave radiofrequency field (RF) (2 or 4 mW/cm(2)) or exposed for 1 or 14 h during the night to a 800 MHz field modulated at 32 Hz (AM 200 mW/cm(2))…This work indicates that neurochemical modification of the hippocampal cholinergic system can be observed during and after an exposure to low intensity RF.

61. Tian F, Nakahara T, Wake K. ***Exposure to 2.45 GHz electromagnetic fields induces hsp70 at a high SAR of more than 20 W/kg but not at 5W/kg in human glioma MO54 cells.*** Int J Radiat Biol. 2002 May;78(5):433-40. http://www.ncbi.nlm.nih.gov/pubmed/12020433 **Abstract:** Purpose: to determine potential hazards from exposure to a high-frequency electromagnetic field (HFEMF) at 2.45 GHz by studies of the expression of heat-shock protein 70 (hsp70) in MO54 cells. Methods: MO54 cells were exposed to a HFEMF at average specific absorption rates (SAR) of 5, 20, 50 and 100 W/kg, using **input powers of 0.8, 3.2, 7.8 and 13 W, a**t a temperature of up to 39 degrees C. An annular culture dish provided three levels of exposure for a given input power, designated inner, middle and outer rings. Two control groups were used: the first was subjected to sham exposure and the second was a temperature control, used to determine the effect of high temperature using incubation in a conventional incubator at 39 degrees C. Cell survival was determined in intervals up to 24 h. Protein was extracted from MO54 cells in both groups after 2, 4, 8 and 16 h exposure times. Changes in the hsp70 protein levels were analysed by Western blots. Results: Cell survival decreased to about 30% after exposure to HFEMF for 24 h at an average SAR of 100 W/kg. With increasing exposure time, heat-shock protein hsp70 expression increased in M054 cells, except for an SAR of 5 W/kg.

62. Trosic I. ***Multinucleated giant cell appearance after whole body microwave irradiation of rats.*** International Journal of Hygiene and Environmental Health, 204(2-3):133-138, 2001**.** http://www.ncbi.nlm.nih.gov/pubmed/11759156 **Abstract:** Multinucleated giant cells are common for some chronic inflammatory processes in the lung. These cells are formed by fusion of macrophages, but how the process relates to the kinetics of alveolar macrophage generation is not clear. This study investigated the influence of 2450 MHz microwave irradiation on alveolar macrophage kinetics and formation of multinucleated giant cells after whole body irradiation of rats. The range of electromagnetic radiation was selected as 2450 MHz microwaves at a power density of 5-15 mW/cm2. A group of experimental animals was divided in four subgroups that received 2, 8, 13 and 22 irradiation treatments of two hours each. The animals were killed on experimental days 1, 8, 16, and 30. Free lung cell population was obtained by bronchoalveolar lavage. Cell response to the selected irradiation level was followed quantitatively, qualitatively and morphologically using standard laboratory methods. Total cell number retrieved by

lavage slightly decreased in treated animals showing time- and dose-dependence. Cell viability did not significantly change in the irradiated animal group (G2) as compared with the control group (G1). Multinucleated cells significantly increased ($p < 0.01$) in treated animals. The elevation of the number of nuclei per cell was time- and dose-dependent. Macrophages with two nucleoli were more common in animals treated twice or eight times. Polynucleation, that is three and more nucleoli in a single cell, was frequently observed after 13 or 22 treatments. Binucleation and multinucleation of alveolar macrophages were sensitive time- and dose-dependent morphological indicators of pulmonary stress.

63. Trosic I, Busljeta I, Kasuba V, Rozgaj R. ***Micronucleus induction after whole-body microwave irradiation of rats.*** Mutat Res. 2002 Nov 26;521(1-2):73-9. http://www.ncbi.nlm.nih.gov/pubmed/12438005 **Abstract:** Adult male Wistar rats were exposed for 2 h a day, 7 days a week for up to 30 days to continuous 2,450 MHz radiofrequency microwave (rf/MW) radiation at a power density of 5-10 mW/cm(2). Sham-exposed rats were used as controls. After ether anesthesia, experimental animals were euthanized on the final irradiation day for each treated group. Peripheral blood smears were examined for the extent of genotoxicity, as indicated by the presence of micronuclei in polychromatic erythrocytes (PCEs). The results for the time-course of PCEs indicated significant differences ($P<0.05$) for the 2nd, the 8th and the 15th day between control and treated subgroups of animals. Increased influx of immature erythrocytes into the peripheral circulation at the beginning of the experiment revealed that the proliferation and maturation of nucleated erythropoietic cells were affected by exposure to the 2,450 MHz radiofrequency radiation. Such findings are indicators of radiation effects on bone-marrow erythropoiesis and their subsequent effects in circulating red cells. The incidence of micronuclei/1,000 PCEs in peripheral blood was significantly increased ($P<0.05$) in the subgroup exposed to rf/MW radiation after eight irradiation treatments of 2 h each in comparison with the sham-exposed control group. It is likely that an adaptive mechanism, both in erythrocytopoiesis and genotoxicity appeared in the rat experimental model during the subchronic irradiation treatment

64. Trosic I, Busljeta I, Modlic B. ***Investigation of the genotoxic effect of microwave irradiation in rat bone marrow cells: in vivo exposure.*** *Mutagenesis,* 19(5):361-364,2004. http://mutage.oxfordjournals.org/content/19/5/361.long **Abstract:** An *in vivo* mammalian cytogenetic test (the erythrocyte micronucleus assay) was used to investigate the extent of genetic damage in bone marrow red cells of rats exposed to radiofrequency/microwave (RF/MW) radiation. Wistar rats ($n = 40$) were exposed to a 2.45 GHz continuous RF/MW field for 2 h daily, 7 days a week, at a power density of 5–10 mW/cm^2. The whole body average specific absorption rate (SARs) was calculated to be 1.25 ± 0.36 (SE) W/kg. Four subgroups were irradiated for 4, 16, 30 and 60 h. Sham-exposed controls ($n = 24$) were included in the study. The animals of each treated subgroup were killed on the final day of irradiation. Bone marrow smears were examined to determine the extent of genotoxicity after particular treatment times. The results were statistically evaluated using non-parametric Mann–Whitney and Kruskal–Wallis tests. In comparison with the sham-exposed subgroups, the findings of polychromatic erythrocytes (PCE) revealed significant differences ($P < 0.05$) for experimental days 8

and 15. The frequency of micronucleated PCEs was also significantly increased on experimental day 15 ($P < 0.05$). Pair-wise comparison of data obtained after 2, 8 and 30 irradiation treatments did not reveal statistically significant differences between sham-exposed and treated subgroups. Under the applied experimental conditions the findings revealed a transient effect on proliferation and maturation of erythropoietc cells in the rat bone marrow and the sporadic appearance of micronucleated immature bone marrow red cells

65. Trosic I, Busljeta I, Pavicic I. *Blood-forming system in rats after whole-body microwave exposure; reference to the lymphocytes.* Toxicol Lett. 2004 Dec 1;154(1-2):125-32. http://www.ncbi.nlm.nih.gov/pubmed/15475186 Abstract:The influence of 2.45 GHz microwave (RF/MW) irradiation on blood-forming cells after whole-body irradiation of rats was investigated. The exposures were conducted with a field power density of 5-10 mW/cm2, and whole-body average specific absorption rate (SAR) of 1-2 W/kg. Four experimental subgroups were created and irradiated 2, 8, 15 or 30 days, for 2 h a day, 7 days a week. Concurrent sham-exposed rats were also included in the study. The cell response was assessed by number and type of the bone marrow nuclear cells and peripheral blood white cells using standard laboratory methods. Significant decrease in lymphoblast count was obtained at 15 and 30th experimental day ($P < 0.05$), whereas other examined parameters did not significantly differed in comparison to the sham-exposed controls. The findings point out at stress response in blood-forming system in rats after selected microwave exposure, which could be considered rather as sign of adaptation than malfunction.

66. *Trosic I, Busljeta I. ***Erythropoietic dynamic equilibrium in rats maintained aftermicrowave irradiation.*** Experimental and Toxicologic Pathology, 57(3):247-251,2006. http://www.ncbi.nlm.nih.gov/pubmed/16410191 **Abstract:** The influence of 2.45 GHz microwave (RF/MW) irradiation on blood-forming cells after whole-body irradiation of rats was investigated. The exposures were conducted with a field power density of 5-10 mW/cm2, and whole-body average specific absorption rate (SAR) of 1-2 W/kg. Four experimental subgroups were created and irradiated 2, 8, 15 or 30 days, for 2 h a day, 7 days a week. Concurrent sham-exposed rats were also included in the study. The cell response was assessed by number and type of the bone marrow nuclear cells and peripheral blood white cells using standard laboratory methods. Significant decrease in lymphoblast count was obtained at 15 and 30th experimental day ($P < 0.05$), whereas other examined parameters did not significantly differed in comparison to the sham-exposed controls. The findings point out at stress response in blood-forming system in rats after selected microwave exposure, which could be considered rather as sign of adaptation than malfunction.

67. Vijayalaxmi, Frei, MR, Dusch, SJ, Guel, V, Meltz, ML, Jauchem, JR. ***Frequency ofmicronuclei in the peripheral blood and bone marrow of cancer-prone micechronically exposed to 2450 MHz radiofrequency radiation.*** Radiation Research,147(4):495-500, 1997 [b]. http://www.ncbi.nlm.nih.gov/pubmed/9092931 A correction was published in a subsequent issue of the journal, stating that there was actually a significant increase in micronucleus formation in peripheral blood and bone

marrow cells after chronic exposure to the radiofrequency radiation: "Vijayalaxmi, Frei, MR, Dusch, SJ, Guel, V, Meltz, ML, Jauchem, JR, ***Correction of an error in calculation in the article "Frequency of micronuclei in the peripheral blood and bone marrow of cancer-prone mice chronically exposed to 2450 MHz radiofrequency radiation***" (Radiation Research, 147(4):495-500, 1997). Radiation Research, 149(3):308, 1998 http://www.ncbi.nlm.nih.gov/pubmed/9496895

68. Virtanen H, Keshvari J, Lappalainen R**. *The effect of authentic metallic implants on the SAR distribution of the head exposed to 900, 1800 and 2450 MHz dipole near field.***Phys Med Biol. 2007 Mar 7;52(5):1221-36. Epub 2007 Jan 31. http://www.ncbi.nlm.nih.gov/pubmed/17301450 **Abstract:** The implants studied were skull plates, fixtures, bone plates and ear rings. The results indicate that some of the implants, under very rare exposure conditions, may cause a notable enhancement in peak mass averaged SAR.

69. Vukova T, Atanassov A, Ivanov R, Radicheva N. ***Intensity-dependent effects of microwave electromagnetic fields on acetylcholinesterase activity and protein conformation in frog skeletal muscles.*** Med Sci Monit. 2005 Feb;11(2):BR50-6. http://www.ncbi.nlm.nih.gov/pubmed/15668626 **Abstract:** BACKGROUND: This study was conducted to investigate the effects of continuous microwaves (2.45 GHz) of different field intensity on acetylcholinesterase activity and protein conformation in muscle fractions from frog skeletal muscles. MATERIALS/ METHODS: Acetylcholinesterase activity in samples from muscle homogenate fractions exposed for 30 min to microwaves of low (10 mW/cm2) or high (20 mW/cm2) intensity at almost constant temperature (1.8 degrees - 2.0 degrees C) was measured by spectrophotometry for three consecutive days after irradiation and compared with the activity in a sham-exposed fraction. Infrared spectroscopy (between 1400 cm(-1)-1800 cm(-1) was performed on the lyophilised fractions using Bruker IFS 113 v. RESULTS: A significant decrease in enzyme activity on the day of exposure (by 8.4% and 13.6% at high and low field intensity, respectively) was observed. Forty-eight hours later the decrease in enzyme activity in samples exposed to both high- and low-intensity microwaves was less than that in sham-exposed samples. Infrared spectroscopy data showed the Amide I band to be negligibly affected and the absorption maximum in the Amide II band to be significantly shifted from 1540 cm-' (shamexposed) to 1559 cm(1) (exposed) after irradiation. CONCLUSIONS: Exposure to microwaves results in non-thermal, intensity-dependent, prolonged modification of acetylcholinesterase activity in frog skeletal muscles traced up to 48 hrs after exposure. Infrared spectroscopy data argue for induced conformational changes in the secondary structure of muscle proteins: increased content of beta-structures, random coils, and amorphous structures, which were more expressed at low field intensity

70. Wang KJ, Yao K, Tan J, Lu DQ, Jiang H***. [Effects of microwave radiation on lens hydration and expression of PKC-alpha and transcription factors in lens epithelial cells].*** Zhonghua Lao Dong Wei Sheng Zhi Ye Bing Za Zhi. 2007 Aug;25(8):456-9. Chinese. http://www.ncbi.nlm.nih.gov/pubmed/17945099 **Abstract:** OBJECTIVE: To observe the effects of low power microwave radiation on lens hydration and lens

epithelial cells in vitro, and detect the expression of PKC-alpha, c-fos and c-jun in lens epithelial cells. METHODS: Rabbit lens were exposed to microwave radiation with frequency of 2450 MHz and power density of 0.5, 2.0 and 5.0 mW/cm(2) in vitro. The hydration of lens was measured after 8 hours. Morphological changes of lens epithelial cells were observed using a phase-contrast microscope and Hoechst 33258 staining. Expression of PKC-alpha, c-fos and c-jun were analyzed using gel electrophoresis and western blot analysis. RESULTS: After 2.0 and 5.0 mW/cm(2) microwave radiation, the hydration of lens was increased compared to control groups (P<0.05), the shape of lens epithelial cells showed shrinking and disorder and cells nuclei appeared chromatin condensation. There was no change of lens and lens epithelial cells after 0.5 mW/cm(2) microwave radiation. The expression of PKC-alpha was significantly increased in cell membrane, however, decreased in cell cytoplasm after 2.0 mW/cm(2) microwave radiation for 2, 4, 6 and 8 hours. There was significantly increased expression of c-fos and c-jun protein compared with control groups (P<0.05, P<0.01).CONCLUSION: Low power microwave radiation higher than 2.0 mW/cm(2) can activate PKC-alpha by increasing its expression in cell membrane, then induce high expression of c-fos and c-jun, which may relate to cellular signaling pathway of microwave radiation injury to lens and lens epithelial cells.

71. Wang KJ, Yao K, Lu DQ. ***Effects of different dose microwave radiation on protein components of cultured rabbit lens].*** Zhonghua Lao Dong Wei Sheng Zhi Ye Bing Za Zhi. 2007 Apr;25(4):208-10. Chinese. http://www.ncbi.nlm.nih.gov/pubmed/17535651
Abstract: OBJECTIVE: To study the effects of different dose microwave radiation on protein components of cultured rabbit lens, and analyze the mechanisms of lens injury caused by microwave radiation. METHODS: Cultured rabbit lens were exposed to microwave radiation with frequency of 2450 MHz and power density of 0.25, 0.50, 1.00, 2.00, 5.00 mW/cm(2) for 8 hours in vitro. The transparency of lens was observed. Changes of protein concentration were detected after different lens protein components were extracted, including water-soluble protein (WSP), urea soluble protein (USP), alkali soluble protein (ASP) and sonicated protein (SP). The influence of microwave radiation on WSP was analyzed using SDS-PAGE electrophoresis and coomassie-blue staining. RESULTS: Transparency of lens decreased after radiation. There was obvious opacification of lens cortex after 5.00 mW/cm(2) microwave radiation for 8 hours. After 1.00, 2.00 and 5.00 mW/cm(2) radiation, the percentage of WSP decreased while USP increased obviously. There was no change of ASP. The percentage of SP decreased when the power of microwave was 5.00 mW/cm(2). The low molecular weight protein of WSP decreased while high molecular weight protein increased after microwave radiation. CONCLUSION: Microwave radiation higher than 1.00 mW/cm(2) can affect the proportion of WSP and USP in cultured rabbit lens, and cause changes of lens transparency and refractive power, which leads to lens opacity.

72. Wang KJ, Yao K, Lu DQ, Jiang H, Tan J, Xu W. [Effect of low-intensity microwave radiation on proliferation of cultured epithelial cells of rabbit lens]. Zhonghua Lao Dong Wei Sheng Zhi Ye Bing Za Zhi. 2003 Oct;21(5):346-9. http://www.ncbi.nlm.nih.gov/pubmed/14761396 Abstract: OBJECTIVE: To compare the effects of different doses of microwave on the proliferative activity and cell cycle of cultured epithelial cells of rabbit lens, and to investigate the limit tolerant of microwave exposure. METHODS: Cultured epithelial cells of rabbit lens were exposed to microwave radiation with frequency of 2,450 MHz and power density of 0.10, 0.25, 0.50, 1.00, 2.00 mW/cm(2) for 8 h in vitro. HE staining was used to observe the morphological changes of lens epithelial cells, the proliferative activity and cell cycle were measured by MTT assay and PI fluorescent staining. RESULTS: 8 h after radiation, 0.50, 1.00 and 2.00 mW/cm(2) microwave could decrease the proliferation of lens epithelial cells, make the cells disordered arrangement, shrinkage, detachment, and inhibit the synthesis of cell DNA. CONCLUSION: Microwave exceeding 0.50 mW/cm(2) may make injury to lens epithelial cells after 8 hour radiation, which may be related to the effect of microwave radiation on cell cycle

73. Wang B, Lai H. ***Acute exposure to pulsed 2450-MHz microwaves affects watermaze performance of rats.*** Bioelectromagnetics 2000, 21:52-56. http://www.ncbi.nlm.nih.gov/pubmed/10615092 **Abstract:** Rats were trained in six sessions to locate a submerged platform in a circular water maze. They were exposed to pulsed 2450-MHz microwaves (pulse width 2 micros, 500 128;pulses/s, average power density 2 mW/cm(2), average whole body specific absorption rate 1.2 W/kg) for 1 h in a circular waveguide system immediately before each training session. One hour after the last training session, they were tested in a probe trial during which the platform was removed and the time spent in the quadrant of the maze in which the platform had been located during the 1-min trial was scored. Three groups of animals, microwave-exposed, sham-exposed, and cage control, were studied. Microwave-exposed rats were slower than sham-exposed and cage control rats in learning to locate the platform. However, there was no significant difference in swim speed among the three groups of animals, indicating that the difference in learning was not due to a change in motor functions or motivation. During the probe trial, microwave-exposed animals spent significantly less time in the quadrant that had contained the platform, and their swim patterns were different from those of the sham-exposed and cage control animals. The latter observation indicates that microwave-exposed rats used a different strategy in learning the location of the platform. These results show that acute exposure to pulsed microwaves caused a deficit in spatial "reference" memory in the rat.

74. Yao K, Wang KJ, Sun ZH, Tan J, Xu W, Zhu LJ, Lu DQ. ***Low power microwave radiation inhibits the proliferation of rabbit lens epithelial cells by upregulating P27Kip1 expression.*** Mol Vis. 2004 Feb 25;10:138-43. http://www.molvis.org/molvis/v10/a18/ http://www.molvis.org/molvis/v10/a18/v10a18-yao.pdf **Abstract:** Purpose: The goal of this study was to examine the effects of low

power microwave radiation (<10 mW/cm2) on the proliferation of cultured rabbit lens epithelial cells (RLEC) **Methods:** Cultured RLEC were exposed to continuous microwave radiation at a **frequency of 2,450 MHz and power densities of 0.10, 0.25, 0.50, 1.00, and 2.00 mW/cm2 for 8 h**. Cell morphologic changes were observed under a phasecontrast microscope. Cell viability was measured using the MTT assay and cell cycle analysis was measured using flow cytometry. After exposure to 2.00 mW/cm2 microwave radiation for 4, 6, and 8 h, the expression of cell cycle-regulatory proteins, P21WAF1 and P27Kip1, was examined using western blot analysis. Finally, the levels of P21WAF1 and P27Kip1 mRNA were analyzed by reverse transcription-polymerase chain reaction (RT-PCR). **Results: After 8 h of radiation treatment, cells treated with 0.50, 1.00, and 2.00 mW/cm2 microwave radiation exhibited decreased cell viability, increased cell condensation and an inhibition of DNA synthesis.** RLEC showed significant G0/G1 arrest. No obvious changes could be detected in the 0.10 and 0.25 mW/cm2 microwave treatment groups. Protein expression of P27Kip1 was markedly increased after microwave radiation. However, the mRNA levels were unchanged. On the other hand, there were no detectable differences in P21WAF1 protein xpression and mRNA levels between microwave treatment and control groups.

75. Yao KT. ***Cytogenetic consequences of microwave irradiation on mammalian cells incubated in vitro.*** J Hered. 1982 Mar-Apr;73(2):133-8. http://www.ncbi.nlm.nih.gov/pubmed/7096980 **Abstract:** A 2450 MHz microwave oven was converted into a microwave incubator. Rat kangaroo RH5 and RH16 cells were incubated in the incubator and were subcultured every 5 to 7 days. The temperature of the cell cultures in the incubator was maintained at 37 degrees C. The cells were incubated with direct microwave irradiation continuously for 50 passages and then returned to a conventional incubator and allowed to grow for another 30 passages. Cell growth rate was significantly reduced after 7 or 15 subculture passages under irradiation. Chromosome aberrations emerged after the cells had been microwave-incubated for about 20 passages. The long-term irradiation caused 0.84 chromosome breaks per cell in RH5 cell cultures and 0.10 breaks per cell in RH16 cell cultures. After the cell cultures had been returned to the conventional incubator and maintained for 30 passages, the number of chromosomes breaks was greatly reduced in both cell cultures. *The number of polyploid cells was increased to 35 percent and 31 percent during the irradiation, and was significantly reduced in the conventional incubator. Many RH5 cells lost one chromosome and became 10-chromosome cells. The number of 10-chromosome cells increased during irradiation and continued to increase after being returned to the conventional incubator.*

76. Ye J, Yao K, Lu D, Wu R, Jiang H. ***Low power density microwave radiation induced early changes in rabbit lens epithelial cells.*** Chin Med J (Engl). 2001 Dec;114(12):1290-4. http://www.cmj.org/Periodical/paperlist.asp?id=LW8344&linkintype=pubmed [conducted at 2.4 GHz frequency] **Abstract: Objective** To determine whether low power density microwave radiation can induce irreversible changes in rabbit lens epithelial cells (LECs) and the mechanisms of the changes. **Methods** One eye of each rabbit was exposed to 5 mW/cm^2 or 10 mW/cm^2 power density microwaves for 3 hours, while the contralateral eye served as a control. Annex in V-propidium iodide (PI) two-color flow

cytometry (FCM) was used to detect the early changes in rabbit lens epithelial cells after radiation. **Results** Lots of rabbit LECs were in the initial phase of apoptosis in the 5 mW/cm^2 microwave radiation group. A large number of cells became secondary necrotic cells, and severe damage could be found in the group exposed to 10 mW/cm^2 microwave radiation. **Conclusion** Low power densities of microwave radiation (5 mW/cm^2 and 10 mW/cm^2) can induce irreversible damage to rabbit LECs. This may be the non-thermal effect of microwave radiation.

77. Zhang MB, He JL, Jin LF, Lu DQ. ***Study of low-intensity 2450-MHz microwave exposure enhancing the genotoxic effects of mitomycin C using micronucleus test and comet assay in vitro.*** Biomedical and Environmental Sciences 15(4):283-290, 2002. http://www.ncbi.nlm.nih.gov/pubmed/12642984 **Abstract:** OBJECTIVE: To determine the interaction between 2450-MHz microwaves (MW) *radiation and mitomycin C (MMC). METHODS:* The synergistic genotoxic effects of low-intensity 2450-MHz microwave and MMC on human lymphocytes were studied using single cell gel electrophoresis (SCGE) assay (comet assay) and cytokinesis-blocked micronucleus (CBMN) test in vitro. The whole blood cells from a male donor and a female donor were either only exposed to 2450-MHz microwaves (5.0 mW/cm2) for 2 h or only exposed to MMC (0.0125 microgram/mL, 0.025 microgram/mL and 0.1 microgram/mL) for 24 h; and the samples were exposed to MMC for 24 h after exposure to MW for 2 h. CONCLUSION: The low-intensity 2450-MHz microwave radiation cannot induce DNA and chromosome damage, but can increase DNA damage effect induced by MMC in comet assay.

78. Zhang MB, Jin LF, He JL, Hu J, Zheng W. ***Effects of 2,450 MHz microwave on DNA damage induced by three chemical mutagens in vitro].*** Zhonghua Lao Dong Wei Sheng Zhi Ye Bing Za Zhi. 2003 Aug;21(4):266-9. Chinese http://www.ncbi.nlm.nih.gov/pubmed/14761437 **Abstract:** OBJECTIVE: To study the combined damage-effects of low-intensity 2,450 MHz microwave (MW) with three chemical mutagens on human lymphocyte DNA. CONCLUSION: 2 450 MHz MW (5 mW/cm(2)) did not induce DNA damage directly, but could enhance the DNA damage effects induced by MMC.

79. Zotti-Martelli L, Peccatori M, Scarpato R, Migliore L. ***Induction of micronuclei in human lymphocytes exposed in vitro to microwave radiation.*** Mutation Research, 472(1-2):51-58, 2000. http://www.ncbi.nlm.nih.gov/pubmed/14761437 **Abstract:** OBJECTIVE: To study the combined damage-effects of low-intensity 2,450 MHz microwave (MW) with three chemical mutagens on human lymphocyte DNA.METHODS: DNA damage of lymphocytes exposed to microwave and(or) with chemical mutagens were observed at different incubation time (0 h or 21 h) with comet assay in vitro. Three combination-exposure ways of MW with chemicals were used: MW irradiation before chemical exposures, simultaneously exposed to MW and chemicals and MW irradiation after chemical exposures. The three chemical mutagens were mitomycin C (MMC, DNA crosslinker), bleomycin (BLM, radiometric agent), methyl methanesulfonate (MMS, alkylating agent). The exposure time of MW and chemical mutagens were 2 h and 3 h respectively. CONCLUSION: 2450 MHz MW (5 mW/cm(2)) did not induce DNA

damage directly, *but could enhance the DNA damage effects induced by MMC*. The synergistic effects of 2450 MHz MW with BLM and MMS were not obvious.