

PREVENTIVE MEASURES TO REDUCE HARMFUL EFFECTS PRODUCED BY ELECTROMAGNETIC RADIATION ON HEALTH

Y. Stein^{1,2}

¹Faculty of Medicine, Hebrew University of Jerusalem, Campus Ein Kerem, Jerusalem, 9112102, Israel

²Department of Anesthesiology, Critical Care and Pain Medicine, Hadassah Medical Center, Jerusalem, 91120, Israel

Man-made electromagnetic waves are the most widely and rapidly expanding exposure in today's world, including exposure in several frequency groups: extremely low frequencies (ELF) from electricity lines, hybrid car batteries and high power lines (>3 Hz–3 kHz), radiofrequency (RF) and microwave frequencies including millimeter waves (3 kHz–300 GHz) from mobile phones, towers, base stations and wireless devices, and intermediate frequencies "Dirty Electricity" emitted from power lines.

While such organizations as ICNIRP (the International Commission on Non-Ionizing Radiation Protection) still continue to claim that electromagnetic radiation can cause "only thermal effects", clinging to theory that does not match facts and upholding obsolete thermal safety standards, extensive scientific evidence has clearly demonstrated that non-thermal health effects produced by electromagnetic radiation do exist, are important to health, and should be taken into consideration when safety standards are set. This review aims to highlight some evidence of biologic effects in various body systems, and to suggest preventive measures to reduce such effects on health.

Exposure to electromagnetic radiation at intensities lower than thermal safety standards has been associated with non-thermal biological effects including damage and changes to cells and DNA.

This review presents evidence of such effects demonstrated in: the hematologic system, the nervous system, the immune system, the reproductive system, the skin and muscles, the cardiovascular system, glucose metabolism, and electrohypersensitivity ("Microwave sickness"). Protective measures are then suggested to reduce these effects.

Key words: *electromagnetic radiation, non-thermal exposure, health, electrohypersensitivity, protective measures, safety standards.*

Exposure to electromagnetic radiation at intensities lower than thermal safety standards has been associated with non-thermal biological effects [1–3] including damage to cells and DNA and changes in them. This review focuses on providing evidence of such effects demonstrated in the hematologic, nervous, immune and reproductive systems, skin and muscles, cardiovascular system, glucose metabolism, and electrohypersensitivity ("microwave sickness"). Protective measures are then suggested to reduce these effects.

DNA effects. Lai and Singh [4] demonstrated an increase in DNA single and double-strand breaks in brain cells of rats after two hours of exposure to 60 Hz ELF, and effect

that could be blocked with melatonin and N-tert-butyl-a-phenylnitronone (PBN). Udroui et al. [5] found significant increases in micronuclei in liver and peripheral blood samples from newborn mice that had been exposed in-utero to ELF, 50 Hz, 650 mT magnetic field. Zothansiana et al. [6] found significantly ($p < 0.0001$) higher frequency of micronuclei in the peripheral blood lymphocytes of people living within 80 meters from mobile base stations, compared to those living 300 meters away from the RF radiation source.

Hematologic system. Workers occupationally exposed to microwave radiation had hematological changes in peripheral blood in correlation with time of exposure [7]. Signifi-

cant changes were seen in concentration and/or activity of glutathione (GSH), catalase (CAT) and superoxide dismutase (SOD) and rise in lipid peroxidation (LOO) in peripheral blood lymphocytes of people living near cell-phone base stations [6]. Lai [8] reviewed and summarized multiple studies that showed changes in levels of free radical activities such as oxygen (ROS) / nitrogen (RNS) species and endogenous antioxidant enzymes following exposure to EMF.

Nervous system. Kim et al. [9] discussed many effects seen in the nervous system, including neuronal cell apoptosis, changes in nerve myelin and in ion channels. Sheppard et al. [10] discussed the calcium-efflux effect in chick brain tissue, in specific frequency and amplitude windows of exposure to EMF. Eberhardt et al. [11] demonstrated effect produced by RF 900 MHz on rat blood brain barrier permeability and neuronal damage. Caruba et al. [12] demonstrated experimentally that low-frequency pulse by mobile phones triggered EEG evoked potentials in human volunteers. Effects produced by ELF on neurodegenerative diseases were shown by Benassi et al. [13] regarding Parkinson's disease, with significantly impaired redox homeostasis and thiol content in SH-SY5Y cells, and an increase in protein carbonylation; and by Bobkova et al. [14] with changes in spatial memory and brain amyloid- β in two animal models of Alzheimer's disease. A review by Terzi et al. [15] summarizes additional neurodegenerative effects. In children, ADHD symptoms were associated with higher use of cell phone [16]. Many health risks associated with exposure to Wi-Fi [17] as well as neuropsychiatric effects produced by EMF exposure are summarized by Pall [18].

Immune system. Szmigielski [19] conducted a literature review and concluded that "short-term exposure to weak RF radiation may temporarily stimulate certain humoral or cellular immune functions, while prolonged irradiation inhibits the same functions". El-Gohary & Said [20] reported effects produced by mobile phone RF EMF on immu-

noglobulin levels (IgA, IgE, IgM, and IgG); and on total leukocyte, lymphocyte, eosinophil, basophil, neutrophil and monocyte counts. Electrosmog effects on Vitamin-D receptor (VDR) and 1,25-dihydroxyvitamin-D (1,25-D), which are associated with many chronic inflammatory and autoimmune diseases are discussed by Marshall and Heil [21]. Lushnikov et al. [22] showed that under multiple repeated exposures, low-intensity extremely-high-frequency electromagnetic radiation (frequency of 42.0 GHz and energy flux density of 0.15 mW/cm² for 20 minutes daily) affected immunogenesis in mice. Belpomme & Irigaray [23] many of the patients had low-grade inflammation and an autoimmune response involving autoantibodies against O-myelin, and in 80 % of the patients with Electrohypersensitivity, several oxidative stress biomarkers were detected in peripheral blood.

Reproduction. Saygin et al. [24] reported pathophysiological changes in the testes of rats exposed to wireless frequencies (2.45 GHz) for 3 hours per day. Schauer & Mohamad Al-Ali [25] demonstrated that men who regularly carried mobile phones in trouser pockets showed higher percentage of pathologic morphology of sperm and lower levels of luteinizing hormone.

Skin. Johansson [26, 27] was one of the first to publish research papers about "screen dermatitis", an effect produced by EMF exposure on the skin reporting an increase in mast cells in facial skin samples of electrohypersensitive persons under long-term exposure. Cardona-Hernández et al. [28] reviewed some of the effects. Short-term skin exposure induces only a transient alteration of epidermal homeostasis, but it may still alter the protective capacity of the skin [29]. Esen & Esen [30] found lengthened latency of facial & head skin resistance response by approximately 200 ms following cell phone exposure. Belpomme & Irigaray [23] demonstrated cutaneous lesions, mostly on the hands patients, and particularly on the hand which held a mobile phone. Feldman et al. [31] demonstrated that coiled sweat glands acted

similarly to arrays of helical antennas, with a resonating frequency in the THz range that influenced RF-energy absorption of millimeter and submillimeter waves into human skin.

Muscle. Blank [32] discussed changes in biosynthetic patterns in muscle cells exposed to EMF stimuli that were similar to changes caused by other known stresses, such as heat shock. McCarty et al. [33] demonstrated muscle twitches in response to changes (on/off) in EMF exposure.

Cardiovascular system. Vangelova et al. [34] assessed long-term effects of occupational EMF exposure on the cardiovascular system and found that the radiofrequency EMR exposure was associated with greater risk of hypertension and dyslipidemia. Another occupational study by Wilen et al. [35] compared RF operators with unexposed workers and showed that time integrated exposure parameters were of some importance regarding symptoms such as fatigue, headaches, and warmth sensations in the hands, and that RF operators had lower heart rate and more episodes of Bradycardia.

Rats exposed to high-power microwave RF had lower heart rate than non-exposed (30 mW/cm^2 for 15 min – this is a very high exposure but the point is to demonstrate pathological changes in the myocardium). Exposed rats demonstrated histological and ultrastructural changes in the myocardium, with swollen and irregularly arranged myocytes, and some chromatin condensation with dark staining in nuclei [36].

My colleagues and I demonstrated severe and unique vascular calcification in the aortas of rats exposed to intermediate frequencies of 150–155 kHz in an animal model of chronic kidney disease. We thought that an irradiating device could remove calcium from cardiac valves, but the result was the opposite [37]. We repeated this study with ELF exposure to 50 Hz using cell phone chargers and found the same results but the data were not published. Two long-term RF exposure studies performed at the Ramazzini Institute and by the US Department of Health and Human Services National Toxicology Program (NTP) found clear

evidence of an association between long-term low-intensity RF EMF exposure and tumors in the hearts (and brains) of male rats [38, 39].

Glucose & metabolism. Meo & Al Rubeaan [40] compared groups of rats exposed to mobile phone radiation. The rats that were exposed for longer than 15 min/day for a 3 months had higher fasting blood glucose ($p < 0.015$) and serum insulin ($p < 0.01$) compared to unexposed and their insulin resistance was significantly increased ($p < 0.003$) compared to control rats. Ben Salah et al. [41] exposed rats to Wi-Fi (2.4 GHz) and noted an alternation in blood glucose level between hypo- and hyperglycaemia during 21 days that the rats were exposed to Wi-Fi, compared to the unexposed group. The exposed rats had an increase in plasma total proteins, triglycerides, creatinine, ALAT, ASAT and iron levels and decrease in plasma uric acid.

Electrohypersensitivity (EHS), formerly known as “Microwave sickness”. Most of the symptoms described by electrohypersensitive patients are a consequence of neural damage and over-sensitized neural responses [42]. Belpomme & Irigaray [43] showed an overlap between Multiple Chemical Sensitivity and Electrohypersensitivity in about 30 % of their large database on over than 2,000 patients. The patients’ typical symptoms were: “headache, tinnitus, hyperacusis, dizziness, balance disorder, superficial and/or deep sensibility abnormalities, fibromyalgia, vegetative nerve dysfunction, and reduced cognitive capability, including immediate memory loss, attention–concentration deficiency, and eventually temporal confusion. These symptoms were associated with chronic insomnia, fatigue, and depressive tendency, in addition to emotional lability and sometimes irritability”.

In an extensive study performed on one electrohypersensitive patient, McCarty et al. [33] demonstrated that within 100 seconds after initiation of EMF exposure ($p < 0.05$) the patient developed somatic responses to the exposure, including neural symptoms: temporal pain, headache; muscular symptoms: muscle twitching; and cardiovascular symptoms: skipped

heartbeats. The symptoms appeared following field transitions (off–on, on–off) rather than induced by the mere presence of the field. The patient was not able to consciously identify when the electromagnetic field was turned on or off.

Mechanistic studies. Many mechanistic studies have described the non-thermal interactions between electromagnetic fields and biological tissues [43]. Blackman et al. [44] presented the concept of multiple power-density windows. Liboff [45] discussed resonance effects. Panagopoulos et al. [46] suggested that an external oscillating field vibrating freed ions on the surface of a cell plasma membrane and irregularly gated electro-sensitive channels on the plasma membrane disrupting the cell's electrochemical balance and function. Friedman et al. [47] proposed a mechanism of short-term ERK activation by RF frequencies. Giuliani et al. [48] researched the “Zhadin current”, coherent excitations in mesoscopic regions of ions and biomolecules, that gave rise to electric currents and consequent magnetic fields in a cell, and Zhadin [49] analyzed Quantum mechanisms to further explain these effects. Blank and Goodman [50] demonstrated that DNA expressed two structural characteristics of a fractal antenna in an electromagnetic field, electronic conduction and self-symmetry.

Results. Based on the presented evidence presented that health effects from exposure to chronic exposure, low levels of EMF exist, the following Preventive & Protective Measures are adapted from Recommendations published by international scientist groups; medical organizations; environmental protection and self-help activist groups. Many of these groups have called for lowering allowed EMF exposure levels and halting plans to expand exposure with 5G networks [51–63].

An increase in distance and use reduction are important factors to reduce exposure and consequent health risks. Proximity is the

most important factor in exposure. Radiation levels fall dramatically with distance from the source.

A. The public realm. Figure 1 presents a comparison between allowed exposure limits to RF radiation (including from cell towers) in various countries. Reduction of exposure from cell phone towers / antennas is technically possible and is carried out in some countries better than in others. Keeping long distance from kindergartens and schools is extremely important, since children are a more susceptible population to any environmental exposure; and distancing antennas from bedrooms, to avoid unnecessary and harmful exposure during sleep.

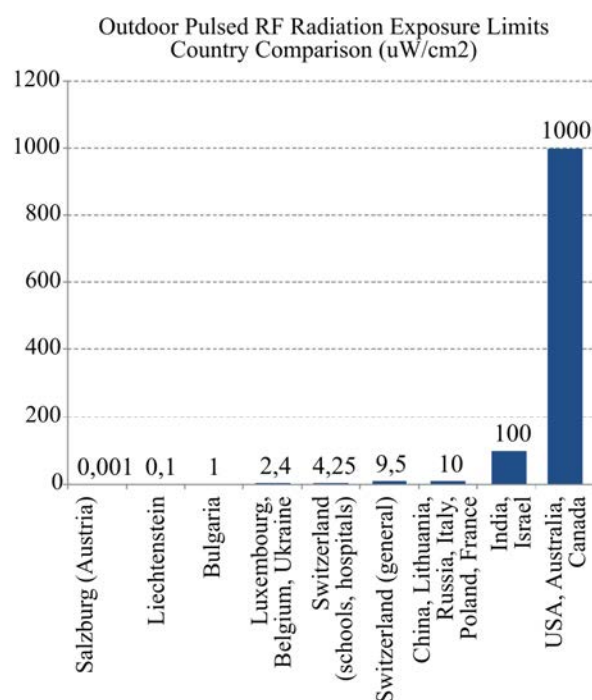


Figure 1. Country comparison. Outdoor Pulsed RF EMF exposure limits, uW/cm² ¹

Wireless utility meters and wireless devices in the public realm, while perhaps emitting low mean intensity levels of EMF, emit biologically important pulsed exposure that is more harmful, even at low measured intensities. Furthermore, EMF intensity measurements are often incorrect if performed using

¹ Copyright Environmental Health Trust; reproduced with permission.

BE SUPER-SMART REDUCE WIRELESS

Simple steps to practice safe tech.

TURN IT OFF WHEN NOT IN USE.
Avoid unnecessary radiation by powering off wireless devices, network equipment, and hotspots when not in use, like at bedtime.

PRE-DOWNLOAD INSTEAD OF STREAMING.
Remember that when you wirelessly stream videos or music the radiation goes into your body. It is better to pre-download audio and video files and then watch or listen with wireless connections turned off.

USE A PLUG-IN ETHERNET CORD.
It is super fast. Whenever possible connect your laptop, tablet, or computer with an ethernet cord (with Wi-Fi OFF, and Bluetooth OFF).

WIRED (NOT WI-FI & NOT BLUETOOTH)
Use a wired mouse, speakers, printer, game system, keyboard, tv, etc.

CORDED PHONE
Corded phones do not emit wireless radiation.

DISTANCE MATTERS.
Maximize the distance between people and wireless devices.

HEALTHY SLEEP
Remove electronics and wireless devices from around your bed. Do not sleep with your cell phone.

MINIMIZE FACETIME AND SOCIAL MEDIA ON CELL PHONES.
When you use facetime or post images, your phone emits more radiation. Instead, do social media or video sharing on a computer connected to the internet by ethernet cord (with Wi-Fi turned off).

Learn more at www.ehtrust.org

Figure 2. Ways to reduce Cellphone radiation from wireless devices¹

Ways to REDUCE Cell Phone Radiation

Here are some examples of recommendations made by the American Academy of Pediatrics, the Vienna Medical Association, and the Cyprus Medical Association.

AIRPLANE MODE
Learn how to set your phone to Airplane Mode with antennas OFF. Airplane Mode turns off most of the wireless antennas.

ANTENNAS OFF
Also be sure the Wi-Fi, Bluetooth, and Mobile Data antennas are OFF in the phone settings. Even with antennas off, you still can play music, take photos, and make videos.

AVOID MAKING CALLS IN CARS
The cell phone works harder to get a signal through metal, so the radiation is stronger.

TEXT INSTEAD OF TALK
Remember to hold the phone away from your body. Pics and video increase radiation.

SPEAKERPHONE
Keep the phone away from your brain by using speakerphone.

BEWARE THE LOW SIGNAL
The weaker your signal strength, the stronger the radiation from your phone.

DO NOT SLEEP WITH YOUR PHONE
Use a battery powered alarm clock, and power off the phone.

DISTANCE IS YOUR FRIEND
Phones should not be in your pocket, bra, or touching your body.

REDUCE TIME
Reduce the time you spend on cell phone and wireless overall. Choose safer tech.

Learn more at www.ehtrust.org

Figure 3. Ways to reduce exposure¹

HOW TO HARDWIRE YOUR LAPTOP OR TABLET

- 1. THIS IS AN ETHERNET CORD**

Ethernet cords come in different lengths. They allow the data to flow through the cord instead of wirelessly through the air- superfast.
- 2. DO YOU NEED AN ADAPTER?**

Is there an ethernet sized port on your device? If not, you will need an ethernet adapter. Adapters plug into USB or lightning ports. Research that you have the correct adapter for device's make & model.
- 3. PLUG ETHERNET INTO YOUR MODEM**

Plug one end of the ethernet into your modem or router.

You might want also an "ethernet switch" that "splits" the ethernet line so you can plug in multiple ethernet cords for computers.
- 4. PLUG ETHERNET INTO YOUR LAPTOP OR TABLET**

Plug the other end of your ethernet into your device.

This step is where you might need an adapter and maybe even a power adapter (for iPads).
- 5. TURN WI-FI & BLUETOOTH "OFF" IN DEVICE**

Go into the settings and turn the Wi-Fi /Bluetooth or any other wireless antennas OFF. For tablets turn "Airplane Mode" ON & check that Bluetooth is OFF.
- 6. MAKE YOUR ROUTER WI-FI FREE**

Turn Wi-Fi & other antennas OFF in settings. Be aware Wi-Fi can turn back on when reset so check with an EMF meter. Best is to buy your own Wi-Fi free modem. At minimum, turn Wi-Fi OFF at night.

C O N G R A T S

More expert info at EHTRUST.org

ENVIRONMENTAL HEALTH TRUST

Figure 4. How to hardwire your mobile device¹

Checklist for Low-EMF Computer

Set-up For Any Computer

- ✓ Device always on a table. Feet flat on floor. Screen is at—or slightly below—eye level.
- ✓ The "high-five test." If you can't properly high-five your computer screen, you're sitting too close. Position monitor at least 24 inches (61 cm) away from you.
- ✓ Reduce glare by adjusting screen tilt/position.
- ✓ Light your area with soft light beside your device (not fluorescent, not strong LED).
- ✓ Use laptops and tablets running on battery-only. Avoid or minimize use during charging.
- ✓ Use a three-prong grounded power cable for laptops, tablets, and desktops.
- ✓ Move electrical wires, chargers, and electric equipment away from your body.

Use Wired, Not Wi-Fi and Not Bluetooth

Use corded (not Wi-Fi, not Bluetooth) mouse, keyboard, printer, speakers, and other accessories.

Connect devices to your modem using ethernet cord. Check if you need an adapter to connect to the ethernet.

After connecting by ethernet cord, make sure Wi-Fi is OFF on device and modem, and make sure Bluetooth is off on devices.

Multiple users? Connect a corded ethernet switch to the modem or to the ethernet, then you can add more ethernet cords to numerous devices.

Remember Settings

- Device settings: Wi-Fi OFF & Bluetooth OFF. If you do this by Airplane Mode, confirm both are OFF.
- Turn OFF wireless antennas in your Wi-Fi router/modem. (Best is to replace with WiFi-free modem.)

Reduce Blue Light on ALL Screens

- Blue light blocker covers are usually available for all screens.
- Blue-blocking eyeglasses.
- Download software that reduces blue light and flicker.

More Expert Information at EHTRUST.org

ENVIRONMENTAL HEALTH TRUST

Figure 5. Reduce computer EMF exposure¹

a measurement device that does not have the adequate measurement speed [64].

Avoid use of Wi-Fi at school – always prefer safer wired technology that does not emit RF EMF.

B. Exposure from personal devices. The most extensive and problematic exposure comes from use of personal devices since they are closer to a body. Devices that emit pulsed waves are especially harmful even if the exposure intensity is not high. Figures 2–5 present exposure reduction strategies developed by the Environmental Health Trust and presented here with permission.

Recommendations on preventing health symptoms from EMF exposure. Distance wireless devices from your body:

- Avoid carrying cell phone on your body at all times. Reproductive organs, especially in pregnancy; the nervous system; and cardiovascular system are sensitive.

- When talking or texting, position the cell phone away from your body as far as possible, use speaker or an “air tube” wired headset (not Bluetooth).

- Avoid placing cordless home phones near you, especially when sleeping.

- Do not place a laptop or tablet device on your lap since these devices emit Radio Frequency radiation (RF EMF) like cell phones; it is especially important during pregnancy.

- Do not place a powered cell phone near you while you sleep.

- Do not charge a cell phone near your body.

Reduce use of emitting wireless devices in your home:

- Prefer use of corded home phones that do not emit RF radiation for most calls.

- Connect the internet router via Ethernet cables and turn off Wi-Fi.

- Use wired keyboard, mouse, etc.

- Turn Wi-Fi off when not in use (router and devices), especially at night.

- Turn off printers’ Wi-Fi feature since printers continuously emit very high levels of RFR.

Minimize exposure:

- Minimize time of phone use. Prefer texting to long phone conversations.

- Reduce use of streamed media on the cell phone; whenever possible download the content and then access it on “airplane mode”, with Wi-Fi and other modes (Bluetooth etc.) switched off, to reduce your exposure while handling the device.

- Children should only use cell phones for emergencies since cell phone radiation penetrates deeper into their brains.

- Avoid using cell phone inside spaces that are surrounded by metal, when the signal is weak, or when moving at high speed, for example in vehicles or elevators. The cell phone emits higher radiation because in such places it makes a greater effort to connect to the antenna, or to connect to changing distant antennas (when moving).

- Avoid charging laptops while in use. When charging, use a 3-pronged grounded cable [65].

Importance of this review. Health hazards caused by EMF exposure have not been adequately addressed by national and international organizations such as the World Health Organization [66–71]. It is necessary to reduce exposures to all frequencies of EMFs, according to the Precautionary Principle. Cellphone networks should be planned to emit reduced exposures – but global plans are only to expand exposure, on land and in space [70]. A recent study analyzed the expected exposure effects of planned G5 antenna density [72]. Calculating from known power consumption modeling, Ben Ishai [73] suggests that G5 networks would emit a 6-fold increased ambient radiation compared to current networks, and would require a thousand times as much electricity to power the networks.

Acknowledgements. The author thanks the *Environmental Health Trust* for graphics reproduction.

Funding. The research was not granted any financial support.

Conflict of interests. The author states no conflict of interests.

References

1. Markov M. Thermal Vs. Nonthermal Mechanisms of Interactions Between Electromagnetic Fields and Biological Systems. *Bioelectromagnetics Current Concepts. NATO Security Through Science Series*. In: S.N. Ayrapetyan, M.S. Markov eds. Dordrecht, Springer, 2006, pp. 1–15. DOI: 10.1007/1-4020-4278-7_1
2. ICNIRP Guidelines for Limiting Exposure to Electromagnetic Fields (100 Khz To 300 ghz). *Health Phys.*, 2020, vol. 118, no. 5, pp. 483–524. DOI: 10.1097/HP.0000000000001210
3. Belpomme D., Hardell L., Belyaev I., Burgio E., Carpenter D.O. Thermal and non-thermal health effects of low intensity non-ionizing radiation: An international perspective. *Environmental Pollution*, 2018, vol. 242, pt. A, pp. 643–658. DOI: 10.1016/j.envpol.2018.07.019
4. Lai H., Singh N.P. Melatonin and N-tert-butyl-alpha-phenylnitronone block 60-Hz magnetic field-induced DNA single and double strand breaks in rat brain cells. *J. Pineal Res*, 1997, vol. 22, no. 3, pp. 152–162. DOI: 10.1111/j.1600-079x.1997.tb00317.x
5. Udroui I., Cristaldi M., Ieradi L.A., Bedini A., Giuliani L., Tanzarella C. Clastogenicity and aneuploidy in newborn and adult mice exposed to 50 Hz magnetic fields. *Int. J. Rad. Biol.*, 2006, vol. 82, no. 8, pp. 561–567. DOI: 10.1080/09553000600876660
6. Zothansiyama, Zosangzuali M., Lalramdinpui M., Jagetia G.C. Impact of radiofrequency radiation on DNA damage and antioxidants in peripheral blood lymphocytes of humans residing in the vicinity of mobile phone base stations. *Electromagnetic Biology & Medicine*, 2017, vol. 36, no. 3, pp. 295–305. DOI: 10.1080/15368378.2017.1350584
7. Marino A.A. Time-dependent hematological changes in workers exposed to electromagnetic fields. *Am. Ind. Hyg. Assoc. J.*, 1995, vol. 56, no. 2, pp. 189–192. DOI: 10.1080/15428119591017231
8. Lai H. Exposure to Static and Extremely-Low Frequency Electromagnetic Fields and Cellular Free Radicals. *Electromagnetic Biology and Medicine*, 2019, vol. 38, no 4, pp. 231–248. DOI: 10.1080/15368378.2019.1656645
9. Kim J.H., Lee J.-K., Kim H.-G., Kim K.-B., Kim H.R. Possible Effects of Radiofrequency Electromagnetic Field Exposure on Central Nerve System, *Biomol. Ther.*, 2019, vol. 27, no. 3, pp. 265–275. DOI: 10.4062/biomolther.2018.152
10. Sheppard A.R., Bawin S.M., Adey W.R. Models of long-range order in cerebral macromolecules: Effects of sub-ELF and of modulated VHF and UHF fields. *Radio Science*, 1979, vol. 14, no. 6S, pp. 141–145. DOI: 10.1029/RS014i06Sp00141
11. Eberhardt J.L., Persson B.R., Brun A.E., Salford L.G., Malmgren L.O. Blood-brain barrier permeability and nerve cell damage in rat brain 14 and 28 days after exposure to microwaves from GSM mobile phones. *Electromagn. Biol. Med.*, 2008, vol. 27, no. 3, pp. 215–229. DOI: 10.1080/15368370802344037
12. Carrubba S., Frilot C. 2nd, Chesson A.L. Jr., Marino A.A. Mobile-phone pulse triggers evoked potentials. *Neurosci. Lett.*, 2010, vol. 469, no. 1, pp. 164–168. DOI: 10.1016/j.neulet.2009.11.068
13. Benassi B., Filomeni G., Montagna C., Merla C., Lopresto V., Pinto R., Marino C., Consales C. Extremely Low Frequency Magnetic Field (ELF-MF) Exposure Sensitizes SH-SY5Y Cells to the Pro-Parkinson's Disease Toxin MPP (.). *Mol. Neurobiol.*, 2016, vol. 53, no. 6, pp. 4247–4260. DOI: 10.1007/s12035-015-9354-4
14. Bobkova N.V., Novikov V.V., Medvinskaya N.I., Aleksandrova I.Y., Nesterova I.V., Fesenko E.E. Effect of weak combined static and extremely low-frequency alternating magnetic fields on spatial memory and brain amyloid- β in two animal models of Alzheimer's disease. *Electromagn. Biol. Med.*, 2018, vol. 37, no. 3, pp. 127–137. DOI: 10.1080/15368378.2018.1471700
15. Terzi M., Ozberk B., Deniz O.G., Kaplan S. The role of electromagnetic fields in neurological disorders. *J. Chem. Neuroanat.*, 2016, vol. 7, pt. B, pp. 77–84. DOI: 10.1016/j.jchemneu.2016.04.003
16. Byun Y.-H., Ha M., Kwon H.-J., Hong Y.-C., Leem J.-H., Sakong J., Kim S.Y., Lee C.G. [et al.]. Mobile Phone Use, Blood Lead Levels, and Attention Deficit Hyperactivity Symptoms in Children: a longitudinal study. *PLoS One*, 2013, vol. 8, no. 3, pp. e59742. DOI: 10.1371/journal.pone.0059742
17. Pall M.L. Wi-Fi is an important threat to human health. *Environmental Research*, 2018, no. 164, pp. 405–416. DOI: 10.1016/j.envres.2018.01.035

18. Pall M.L. Microwave frequency electromagnetic fields (EMFs) produce widespread neuropsychiatric effects including depression. *J. Chem. Neuroanat.*, 2016, vol. 75, pt. B, pp. 43–51. DOI: 10.1016/j.jchemneu.2015.08.001
19. Szmigielski S. Reaction of the immune system to low-level RF/MW exposures. *Sci. Total Environ.*, 2013, vol. 454–455, pp. 393–400. DOI: 10.1016/j.scitotenv.2013.03.034
20. El-Gohary O.A., Said M.A. Effect of electromagnetic waves from mobile phone on immune status of male rats: possible protective role of vitamin D. *Can. J. Physiol. Pharmacol.*, 2017, vol. 95, no. 2, pp. 151–156. DOI: 10.1139/cjpp-2016-0218
21. Marshall T.G., Rumann Heil T.J. Electrosmog and autoimmune disease. *Immunol. Res.*, 2017, vol. 65, no. 1, pp. 129–135. DOI 10.1007/s12026-016-8825-7
22. Lushnikov K.V., Gapeev A.B., Sadovnikov V.B., Chemeris N.K. Effect of the weak extremely-high-frequency electromagnetic radiation on the indices of the Humoral Immunity in healthy mice. *Biophysics*, 2001, vol. 46, no. 4, pp. 711–719.
23. Belpomme D., Irigaray P. Electrohypersensitivity as a Newly Identified and Characterized Neurologic Pathological Disorder: How to Diagnose, Treat, and Prevent It. *Int. J. Mol. Sci.*, 2020, vol. 21, no. 6, pp. 1915. DOI: 10.3390/ijms21061915
24. Saygin M., Asci H., Ozmen O., Cankara F.N., Dincoglu D., Ilhan I. Impact of 2.45 GHz microwave radiation on the testicular inflammatory pathway biomarkers in young rats: The role of gallic acid. *Environ. Toxicol.*, 2016, vol. 31, no. 12, pp. 1771–1784. DOI: 10.1002/tox.22179
25. Schauer I., Mohamad Al-Ali B. Combined effects of varicocele and cell phones on semen and hormonal parameters. *Wien Klin Wochenschr*, 2018, vol. 130, pp. 335–340. DOI: 10.1007/s00508-017-1277-9
26. Johansson O., Hilliges M., Björnhagen V., Hall K. Skin changes in patients claiming to suffer from “screen dermatitis”: a two-case open-field provocation study. *Exp. Dermatol.*, 1994, vol. 3, no. 5, pp. 234–238. DOI: 10.1111/j.1600-0625.1994.tb00282.x
27. Johansson O., Liu P.-Y. “Electrosensitivity”, “electrosupersensitivity” and “screen dermatitis”: preliminary observations from on-going studies in the human skin. *Proceedings of the COST 244: Biomedical Effects of Electromagnetic Fields. Workshop on Electromagnetic Hypersensitivity*. In: D. Simunic ed. Brussels/Graz, EU/EC (DG XIII), 1995, pp. 52–57.
28. Cardona-Hernández M.A., Fierro-Arias L., Cabrera Pérez A.L., Vidal-Flores A.A. Efectos de la radiación electromagnética en la piel [Effects of electromagnetic radiation on skin]. *Dermatol. Rev. Mex.*, 2017, vol. 61, no. 4, pp. 292–302 (in Spanish).
29. Simon D., Daubos A., Pain C., Fitoussi R., Vié K., Taieb A., de Benetti L., Cario-André M. Exposure to acute electromagnetic radiation of mobile phone exposure range alters transiently skin homeostasis of a model of pigmented reconstructed epidermis. *Int. J. Cosmet. Sci.*, 2013, vol. 35, no. 1, pp. 27–34. DOI: 10.1111/j.1468-2494.2012.00746.x
30. Esen F., Esen H. Effect of electromagnetic fields emitted by cellular phones on the latency of evoked electrodermal activity. *Int. J. Neurosci.*, 2006, vol. 116, no. 3, pp. 321–329. DOI: 10.1080/00207450500403371
31. Feldman Y., Puzenko A., Ishai P.B., Caduff A., Davidovich I., Sakran F., Agranat A.J. The electromagnetic response of human skin in the millimetre and submillimetre wave range. *Phys. Med. Biol.*, 2009, vol. 54, no. 11, pp. 3341–3363. DOI: 10.1088/0031-9155/54/11/005
32. Blank M. Electric stimulation of protein synthesis in muscle. *Advances in Chemistry*, 1995, vol. 250, pp. 143–153. DOI: 10.1021/ba-1995-0250.ch009
33. McCarty D.E., Carrubba S., Chesson A.L., Frilot C., Gonzalez-Toledo E., Marino A.A. Electromagnetic hypersensitivity: evidence for a novel neurological syndrome. *Int. J. Neurosci.*, 2011, vol. 121, no. 12, pp. 670–676. DOI: 10.3109/00207454.2011.608139
34. Vangelova K., Deyanov C., Israel M. Cardiovascular risk in operators under radiofrequency electromagnetic radiation. *Int. J. Hyg. Environ. Health*, 2006, vol. 209, no. 2, pp. 133–138. DOI: 10.1016/j.ijheh.2005.09.008
35. Wilen J., Hornsten R., Sandstrom M., Bjerle P., Wiklund U., Stensson O., Lyskov E., Mild K.H. Electromagnetic field exposure and health among RF plastic sealer operators. *Bioelectromagnetics*, 2004, vol. 25, no. 1, pp. 5–15. DOI: 10.1002/bem.10154

36. Zhang X., Gao Y., Dong J., Wang S., Yao B., Zhang J., Hu S., Xu X. [et al.]. The Compound Chinese Medicine “Kang Fu Ling” Protects against High Power Microwave-Induced Myocardial Injury. *PLoS One*, 2014, vol. 9, no. 7, pp. e101532. DOI: 10.1371/journal.pone.0101532
37. Shuvy M., Abedat S., Beerli R., Valitzki M., Stein Y., Meir K., Lotan C. Electromagnetic fields promote severe and unique vascular calcification in an animal model of ectopic calcification. *Experimental and Toxicologic Pathology*, 2014, vol. 66, no. 7, pp. 345–350. DOI: 10.1016/j.etp.2014.05.001
38. Falcioni L., Bua L., Tibaldi E., Lauriola M., De Angelis L., Gnudi F., Mandrioli D., Manservigi M. [et al.]. Report of final results regarding brain and heart tumors in Sprague-Dawley rats exposed from prenatal life until natural death to mobile phone radiofrequency field representative of a 1.8 GHz GSM base station environmental emission. *Environ. Res.*, 2018, vol. 165, pp. 496–503. DOI: 10.1016/j.envres.2018.01.037
39. NTP Technical Report on the Toxicology and Carcinogenesis Studies in Sprague-Dawley Rats Exposed to Whole-body Radio Frequency Radiation at a Frequency (900 Mhz) and Modulations (GSM and CDMA) Used by Cell Phones: Technical Report 595. *National Toxicology Program. Public Health Service*. U.S. Department of Health and Human Services, 2018. Available at: https://ntp.niehs.nih.gov/ntp/htdocs/lt_rpts/tr595_508.pdf?utm_source=direct&utm_medium=prod&utm_campaign=ntpgolinks&utm_term=tr595 (05.06.2021).
40. Meo S.A., Rubeaan K.A.I. Effects of exposure to electromagnetic field radiation (EMFR) generated by activated mobile phones on fasting blood glucose. *Int. J. Occup. Med. Environ. Health*, 2013, vol. 26, no. 2, pp. 235–241. DOI: 10.2478/s13382-013-0107-1
41. Salah M.B., Abdelmelek H., Abderraba M. Effects of olive leave extract on metabolic disorders and oxidative stress induced by 2.45 GHz WI-FI signals. *Environ. Toxicol. Pharmacol.*, 2013, vol. 36, no. 3, pp. 826–834. DOI: 10.1016/j.etap.2013.07.013
42. Stein Y., Udasin I. Electromagnetic hypersensitivity (EHS, microwave syndrome) – Review of mechanisms. *Environmental Research*, 2020, vol. 186, pp. 09445. DOI: 10.1016/j.envres.2020.109445
43. Belyaev I. Biophysical Mechanisms for Nonthermal Microwave Effects. *Electromagnetic Fields in Biology and Medicine (1st ed.)*. In: M.S. Markov ed. Boca Raton, CRC Press, 2015, Chapter 5, pp. 49–68.
44. Blackman C.F., Kinney L.S., House D.E., Joines W.T. Multiple power-density windows and their possible origin. *Bioelectromagnetics*, 1989, vol. 10, no. 2, pp. 115–128. DOI: 10.1002/bem2250100202
45. Liboff A.R. Geomagnetic cyclotron resonance in living cells. *J. Biological. Phys.*, 1985, vol. 13, no. 4, pp. 99–102.
46. Panagopoulos D.J., Karabarounis A., Margaritis L.H. Mechanism for action of electromagnetic fields on cells. *Biochemical and Biophysical Research Communications*, 2002, vol. 298, no. 1, pp. 95–102. DOI: 10.1016/S0006-291X(02)02393-8
47. Friedman J., Kraus S., Hauptman Y., Schiff Y., Seger R. Mechanism of short-term ERK activation by electromagnetic fields at mobile phone frequencies. *The Biochemical journal*, 2007, vol. 405, no. 3, pp. 559–568. DOI: 10.1042/BJ20061653
48. Giuliani L., D’Emilia E., Grimaldi S., Lisi A., Bobkova N., Zhadin M.N. Investigating the Icr Effect in a Zhadin’s Cell. *Int. J. Biomed. Sci.*, 2009, vol. 5, no. 2, pp. 181–186.
49. Zhadin M. On mechanism of combined extremely weak magnetic field action on aqueous solution of amino acid. *Non-thermal effects and mechanisms of interaction between electromagnetic fields and living matter. ICEMS Monograph. Eur. J. Oncology*, 2010, vol. 5, pp. 1–5.
50. Blank M., Goodman R. DNA is a fractal antenna in electromagnetic fields. *Int. J. Radiat. Biol.*, 2011, vol. 87, no. 4, pp. 409–415. DOI: 10.3109/09553002.2011.538130
51. Guideline of the Austrian Medical Association for diagnosis and treatment of EMF-related health problems and illnesses (EMF Syndrome). Austrian Medical Association, 2012. Available at: <https://vagbrytaren.org/Guideline%20%20AG-EMF.pdf> (11.08.2021).
52. Belyaev I., Dean A., Eger H., Hubmann G., Jandrisovits R., Kern M., Kundi M., Moshammer H. [et al.]. EUROPAEM EMF Guideline 2016 for the prevention, diagnosis and treatment

of EMF-related health problems and illnesses. *Rev. Environ. Health*, 2016, vol. 31, no. 3, pp. 363–397. DOI: 10.1515/reveh-2016-0011

53. O rekomendatsiyakh roditelyam po bezopasnomu ispol'zovaniyu mobil'nogo telefona [Recommendations for parents on the safe use of a mobile phone]. Federal'naya sluzhba po nadzoru v sfere zashchity prav potrebitelei i blagopoluchiya cheloveka. Available at: https://www.rospotreb-nadzor.ru/about/info/news/news_details.php?ELEMENT_ID=13375 (15.07.2021) (in Russian).

54. What you need to know about wireless radiation and your baby. The Baby Safe Project. Available at: https://128441a4-6b5e-4ac8-8d74-a461f5bada16.filesusr.com/ugd/2cea04_9747b215cd62435aa100d3d331ab0673.pdf (04.06.2021).

55. Living with Technology, Children's Health Remains their Inexplicable Right and our Own Obligation: Press release 24 June 2019. Cyprus Committee on Environment and Children's Health. Available at: <https://ehtrust.org/wp-content/uploads/PRESS-RELEASE-Cyprus-2019-Campaign-3.pdf> (07.06.2021).

56. Mallery-Blythe E. 2020 Consensus Statement of UK and International Medical and Scientific Experts and Practitioners on Health Effects of Non-Ionising Radiation (NIR). Physicians' Health Initiative for Radiation and Environment (PHIRE) & British Society for Ecological Medicine (BSEM). Available at: <https://phiremedical.org/wp-content/uploads/2020/11/2020-Non-Ionising-Radiation-Consensus-Statement.pdf> (07.06.2021).

57. Switzerland Doctors For Environmental Protection. 2020 Consensus Statement of UK and International Medical and Scientific Experts and Practitioners on Health Effects of Non-Ionising Radiation (NIR). Available at: <https://ehtrust.org/science/medical-doctors-consensus-statements-recommendations-cell-phoneswireless/> (07.06.2021).

58. Cell Phone Radiation & Children's Health: What Parents Need to Know. American academy of Pediatrics. Available at: <https://www.healthychildren.org/English/safety-prevention/all-around/Pages/Cell-Phone-Radiation-Childrens-Health.aspx> (08.06.2021).

59. 10 Years after the Freiburg Appeal: Radio-frequency Radiation Poses a Health Risk. Physicians Demand Overdue Precaution. International Doctors' Appeal 2012. Available at: http://freiburger-appell-2012.info/media/International_Doctors_Appeal_2012_Nov.pdf (17.05.2021).

60. Di Ciaula A. 5G networks in European Countries: appeal for a standstill in the respect of the precautionary principle. International Society of Doctors for Environment. Available at: https://www.isde.org/5G_appeal.pdf (14.06.2021).

61. The Venice Resolution. International commission for electromagnetic safety, 2008. Available at: <http://www.icems.eu/resolution.htm> (13.06.2021).

62. The Benevento Resolution. International Commission for Electromagnetic Safety, 2006. Available at: http://www.icems.eu/docs/BeneventoResolution_REVISED_march2008.pdf (13.06.2021).

63. Scientists call for Protection from Non-ionizing Electromagnetic Field Exposure: International Appeal. Available at: <https://emfscientist.org/index.php/emf-scientist-appeal> (20.06.2021).

64. Simunic D. Measurement of RF Near and Far Fields. WHO International Seminar on Biological Effects, Health Consequences and Standards for Pulsed Radiofrequency fields. Erice, November 21–30, 1999.

65. Step by step to safe technology. Environmental Health Trust. Available at: <https://ehtrust.org/resources-to-share/printable-resources/> (17.08.2021).

66. Belpomme D., Hardell L., Belyaev I., Burgio E., Carpenter D.O. Thermal and non-thermal health effects of low intensity non-ionizing radiation: An international perspective. *Environ. Pollut.*, 2018, vol. 242, pt. A, pp. 643–658. DOI: 10.1016/j.envpol.2018.07.019

67. Kostoff N., Heroux P., Aschner M., Tsatsakis A. Adverse Effects of 5G mobile networking technology under real-life conditions. *Toxicology Letters*, 2020, vol. 323, pp. 35–40. DOI: 10.1016/j.toxlet.2020.01.020

68. Russian National Committee of Non-Ionizing Radiation Protection – 2008 report. Available at: <https://www.who.int/peh-emf/project/mapnatreps/RUSSIA%20report%202008.pdf> (11.08.2021).

69. Scientists and Doctors Demand Moratorium on 5G. Increased radiation from cell towers poses potential risks, say scientists from around the world. Environmental Health Trust, 2017.

Available at: <https://ehtrust.org/scientists-and-doctors-demand-moratorium-on-5g-warning-of-health-effects/> (09.06.2021).

70. The 5G appeal. Available at: <https://www.5gappeal.eu/> (09.06.2021).

71. Stop 5G on Earth and in Space: International Appeal, An Emergency Appeal to the World's Governments by Scientists, Doctors, Environmental Organizations and Others. Available at: <https://www.5spaceappeal.org/the-appeal> (20.06.2021).

72. El-Hajj A.M., Naous T. Radiation Analysis in a Gradual 5G Network Deployment Strategy. *2020 IEEE 3rd 5G World Forum (5GWF)*, 2020, pp. 448–453. DOI: 10.1109/5GWF49715.2020.9221314

73. Ishai P.B. The Green Dilemma of 5G Densification. *The Times of Israel*. Available at: <https://blogs.timesofisrael.com/the-green-dilemma-of-5g-densification/> (19.06.2021).

Stein Y. Preventive measures to reduce harmful effects produced by electromagnetic radiation on health. Health Risk Analysis, 2021, no. 3, pp. 42–52. DOI: 10.21668/health.risk/2021.3.04.eng

Received: 03.06.2021

Accepted: 15.09.2021

Published: 30.09.2021