

Review Article

Electrohypersensitivity (EHS) is an Environmentally-Induced Disability that Requires Immediate Attention

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A growing number of countries are beginning to acknowledge that electrohypersensitivity (EHS) exists and a few countries have classified it as a disability or a functional impairment attributable to the environment. Epidemiological studies and *in vivo* experiments show that exposure to non-ionizing radiation (NIR) from extremely low to microwave frequency electromagnetic fields (EMF) at exposure intensities far below the maximum limits in international guidelines increases anxiety, depression, and physiological stress and impairs cognitive functions that include concentration, memory and learning. Furthermore, exposure to NIR contributes to neurodegenerative diseases including dementia, Alzheimer's disease, amyotrophic lateral sclerosis, multiple sclerosis, Parkinson's disease, attention deficit hyperactivity disorder and autism spectrum disorder. Exposure of the fetus to NIR (mobile phone) affects the neonatal heart and can lead to emotional and behavioral problems in human offspring. Similar exposures in laboratory studies report impaired cognitive performance, neuronal losses and pathological changes in the brain of rat offspring. The scientific and medical communities have repeatedly sent out urgent warnings, in the form of appeals, declarations and testimonies, that exposure to NIR needs to be reduced from a public health perspective. These warnings have been largely ignored. With continued development of wireless technology and the imminent roll out of new and densified technologies (e.g., 5G technology, satellite constellations, repeaters, wearables, Internet of Things), society will pay an enormous price for disregarding these warnings. It is long overdue for those responsible for public health, the health of children and health policy to take these warnings seriously and to provide a refuge for those afflicted by EHS. EHS is real, it is exacerbated by exposure to NIR, it is increasing among the population and when severe it becomes a disability. Action is long overdue to minimize exposure to NIR and to provide a safe environment that all can enjoy.

Keywords: electrohypersensitivity, EHS, non-ionizing radiation, electromagnetic fields (EMF), electromagnetic radiation (EMR), microwaves, radio frequency, disability, Alzheimer's disease, Parkinson's disease, multiple sclerosis, ADHD, autism, fetus, neurodegenerative disorders, amyotrophic lateral sclerosis, anxiety, depression

How to cite: Havas M, Electrohypersensitivity (EHS) is an Environmentally-Induced Disability that Requires Immediate Attention. J Sci Discov (2019); 3(1):jsd18020; DOI:10.24262/jsd.2.2.18020; Received October 30th, 2018, Revised December 03rd, 2018, Accepted December 12nd, 2018, Published February 2nd, 2019.

Introduction

With each new product, technology or development comes the potential for a novel health challenge that may not have been foreseen. This was the case with asbestos, leaded gasoline, tobacco and x-rays and is now the case with non-ionizing radiation (NIR). The scenario is virtually identical for all of these products. A new technology is discovered (e.g., x-rays) or novel uses for an existing product are promoted (e.g., lead in gasoline). It becomes popular and is widely used, resulting in a greater

population coming in contact with the "element". A few people (or animals) become sick following exposure. Initially, the early warning scientists and medical doctors, who recognize the culprit, are ignored. As the body bags accumulate and the statistics improve, the naysayers and the doubt promoters become less convincing. After one or two generations have passed and the old guard is replaced with new blood, policy to protect public and environmental health is eventually implemented. The environment and those still living begin to heal.

The purpose of this report is to provide scientific evidence documenting the effects of non-ionizing radiation (NIR) in the form of electromagnetic fields (EMF)^(a) and electromagnetic radiation (EMR)^(b) primarily as they pertain to cognitive and physical impairment of persons, leading to symptoms consistent with electrohypersensitivity (EHS) and symptoms that are considered a disability in some countries and some jurisdictions. Scientific studies are provided that document an association (human epidemiological studies) and a cause-effect relationship (*in vivo* animal studies) with different types of electrosmog^(c) exposure ranging from extremely low frequency electromagnetic fields (ELF EMF)—associated with the generation, transmission, distribution and use of electricity—to microwave radiation (MWR) generated by our use of wireless devices including cell and cordless phones, cell and cordless phone base stations, Wi-Fi, bluetooth, smart utility meters, smart appliances, electronic equipment, etc.

Increasing Exposure to Non-ionizing Radiation (NIR)

Our exposure to NIR has increased dramatically since Nikola Tesla harnessed the power of Niagara Falls and electricity flowed along wires, bringing light into homes and electric power to cities. Alternating current (AC) at 50/60 Hz was soon followed by radio, radar, television, cellular telephones, Wi-Fi, smart meters, smart appliances, smart homes and smart cities—with “smart” referring to devices that are able to receive and transmit digitized information and thus communicate with one another and can be controlled remotely by phone or Internet or other network connections. At the urging of the telecom industry, governments are making available higher frequencies (millimetre waves, 30 to 300 GHz, <https://spectrum.ieee.org/video/telecom/wireless/everything-you-need-to-know-about-5g>) of the electromagnetic spectrum for the 5th Generation (5G) technology and the Internet of Things (IOT). Although, at the writing of this paper, frequencies not in the millimetre part of the electromagnetic spectrum are being advanced as 5G technology. While 5G can include frequencies from 600 MHz to 6 GHz, these lower frequencies are only slightly faster than 4G and are not millimetre waves (mm waves) (Table 1).

Those promoting 5G technology are plowing ahead without properly testing for possible long-term health effects that many in the telecom industry deny exist. This is exactly what the tobacco industry did in the 1950s and 60s. However, instead of the National Institute of Health (NIH) or the Environmental Protection Agency (EPA) establishing guidelines to protect human and environmental health, this task has been taken over by the Federal Communication Commission (FCC), which has no expertise in this area. Furthermore, there is a revolving door between the telecom industry and the FCC with senior positions in FCC populated by industry insiders. Conflict of interest is being ignored.

By auction, governments sell licenses to the highest bidder to generate and use specific NIR frequencies in the electromagnetic spectrum. They receive considerable revenue and are unwilling to change existing guidelines as that might reduce their income stream. According to The Wall Street Journal, in 2015 the FCC raised almost \$45 billion in U.S. wireless spectrum sales [1].

Another important point to consider is that guidelines that were established decades ago are based on a thermal effect and non-thermal effects are largely ignored [2]. These thermal guidelines are outdated and hinge on a false premise that if it doesn't heat your body it can't hurt you. Guidelines around the world vary by orders of magnitude as some are based on thermal effects, others are based on non-thermal biological effects, and still others are based on a precautionary approach. This range in limits indicates there is a large discrepancy in what is considered “safe” (Table 2).

Consumers are enamored with their smart phone that is a miniature computer with many useful applications that convert the phone into a camera, video/audio recorder, photo album, mirror, clock, stop watch, calendar, map, global positioning system with real time navigation, etc. Smart phones seem to place the world at your fingertips. Most believe that if this technology were harmful, it would not have been approved by government agencies responsible for public health. However, when microwave frequencies were originally deployed the technological uses were limited to the military (RADAR) and a few occupational settings (microwave heating). Today, microwave exposure is nearly ubiquitous and exposure is no longer limited to adults who are occupationally exposed.

Pregnant women, infants, students, the elderly, and those who are sick are exposed to radio frequency radiation (RFR). Most governing bodies are not questioning the assumption of safety in any meaningful way.

History of Electrohypersensitivity (EHS)

The concept of EHS has been around since at least the beginning of the 20th century when we first started using electricity, although it has been recognized by different names. Initially it was called *asthenic syndrome* (a weakening of the nervous system associated with pain, weakness, fatigue, anxiety and loss of consciousness) and was common among telephone operators [3]. In the early days of radar it was called *radio wave sickness* or *microwave illness* [4]. *Screen dermatitis* was the term used when individuals exposed to video display terminals' and TV monitors' EMF emissions experienced inflammation of the nerves resulting in an increase in histamine-positive mast cells with symptoms of itching, pain, swelling and rashes [5]. Later *electromagnetic field (EMF) intolerance* and *electromagnetic sensitivity* and *hypersensitivity* were used. The World Health Organization refers to it as an *idiopathic environmental intolerance attributed to electromagnetic fields*. Since this radiation stresses the body and causes premature aging I prefer to call it *rapid aging syndrome*.

Most of the health research related to EMR exposure was initiated following the military use of radar during the Second World War. Much of the early work on the health effects of EMR was done in the former Soviet Union and in Eastern Europe. In the U.S. this research was classified for decades due to the cold war.

A NASA Technical Translation (F-708) of work in the former Soviet Union, entitled *Influence of Microwave Radiation on the Organism of Man and Animals* [6], describes the four stages of this "illness" attributable to chronic microwave exposure.

Stage I: Symptoms include mild complaints consistent with the asthenic syndrome. They are characterized by a general feeling of ill-being toward the end of the working day, fatigue, mild frontal headaches, irritability, lowered performance, sometimes drowsiness and pains in the heart region. All of these symptoms are mildly expressed and, as a rule, disappear-after rest and sleep.

Stage II: Asthenic manifestations are aggravated and accompanied by distinct shifts in the emotional sphere. During this time, the disturbances are manifest clinically in a wide variety of syndromes: neurasthenia-like, asthenic with pronounced emotional reactions, obsessive (with fixed ideas and fears), disturbances of mood ... Headaches in the frontal and occipital regions become particularly frequent. These headaches are at first transitory, but ... become more severe and persistent. The headaches are accompanied by sensations of heavy-headedness and pressure on the eyeballs. The patients are periodically disturbed by dizziness, nausea, and vomiting. The headaches are sometimes described as "helmets" in which the head is being crushed. Palpitation and pains in the region of the heart occur quite frequently. Together with these complaints, there are progressive weakness and fatiguability, especially during the second half of the working day. By the end of the day, the patients feel incapable of working and completely debilitated and broken down, so that they find it necessary to rest for 2-3 hours. Working efficiency declines sharply. Irritability and loss of self-control are noted. The subjects are irritated by bright light, flickering in front of the eyes, and sudden loud noises ... The symptoms [at this stage] are reversible.

Stage III: During this period, the complaints enumerated above become much more severe and are compounded by a number of new symptoms indicating the presence of psycho-organic disturbance ... As a rule, mood is unstable; the depressive states are frequent, last longer (up to several days), and are accompanied by anxiety and restlessness. The irritability and conflicts grow stronger. The affective reactions are accompanied by a sharp aggravation of the headaches and by violent vascular-vegetative shifts. As they grow stronger, the debilitating effects often result in total indifference to the surroundings, a state of apathy. Efficiency on the job deteriorates sharply. After working for a short time, these persons are incapable of performing the most elementary occupational duties. Attention is drawn to the fussiness and sluggish thinking of the subjects and their tendency to become immersed in details. Fixed dreads and ideas, some exaggerated and with hypochondriac content ... emotionally colored thoughts receive a disproportionate amount of attention and are hard to talk away. Some narrowing of the range of interests and desires is observed,

although there are no pronounced intellectual derangements. These clinical disturbances lowered the efficiency of the patients substantially, and hospital treatment was required during periods of poor health.

Stage IV: The medical histories of these patients record conditions resembling acute microwave sickness. During this period, the clinical abnormalities indicate organic injury to the brain and symptoms of neuropsychic disturbances appear. The frequent somatic complaints (injury to the cardiovascular system) are frequently accompanied by cardiovascular insufficiency and phenomena of paroxysmal tachycardia. By themselves, these disorders can affect the patient's ability to work. At the same time, the neuropsychic disturbances are strongly manifested, often dominate the picture, and take a severe course. The diencephalic crises are more profound, with impaired consciousness, and occur more frequently. The headaches and sensopathic disturbances to perception become more severe ... Impairment of memory is noted, and in some cases the symptoms resemble the clinical picture observed on injury to the frontal lobes ... Brain bioelectric activity appears in pathological variants. As a rule, therapeutic measures produce only a slight improvement. The pathological disturbances enumerated above may result in loss of ability to work and make disability arrangements necessary (disability group III or even II).

Since 1970, many new devices have been developed that generate radio frequency radiation (RFR) and microwave radiation (MWR). Eager adoption of cell phones, Wi-Fi and other wireless technology has increased ambient microwave levels considerably especially in urban environments. Consequently, exposures that were restricted to the military and occupational settings are now common in the population at large. Just as microwave exposure in the workplace can disable employees, it can also disable individuals within the population who are chronically or intensely exposed.

Common EHS symptoms include some combination of sleep disturbances, chronic fatigue, chronic pain, difficulty concentrating, "brain fog", poor short-term memory, depression, anxiety, irritability, dizziness, nausea, nose bleeds, frequent nightly urination, skin problems, heart palpitations, tinnitus, visual disturbances and in severe cases loss of consciousness. Refer to Bevington [7]

for a full list of symptoms.

Recognition of EHS as an Illness and as a Disability (Functional Impairment attributed to the Environment)

According to the World Health Organization: "A disability is an impairment that may be cognitive, developmental, intellectual, mental, physical, sensory or some combination of these. It substantially affects a person's life activities and may be present from birth or occur during a person's lifetime." <https://en.wikipedia.org/wiki/Disability>.

The EHS symptoms mentioned above include sensory disturbances, physical disturbances, cognitive impairment, and also intellectual, mental and developmental problems that are covered under the definition of disabilities.

Sweden recognized persons with EHS as functionally impaired in 2000 [7].

In Sweden, accommodations are made for those with EHS. Those accommodations include: sanitizing their homes in regard to EMF (e.g., replacing ordinary electric cables with special cables; replacing electric stove with gas stove; using special wallpaper and paint on walls, roofs/ceilings and floors to shield living areas from RFR; applying special film on windows to minimize penetration of RFR from external sources). Should these measures be insufficient, persons can rent special cottages in the countryside far from electrosmog exposure. Some hospitals have special rooms where EMF is minimized to very low levels of exposure so that persons disabled by EMF can access medical care. Employees also have legal rights to be supported by their employer so they can work despite their impairment. For example, they can get low-emission computers, replace fluorescent lights with incandescent bulbs; replace wireless phones with wired phones, etc. Specially designed cars are available for persons with EHS so they can transport themselves between home and work. Politicians proposed having passenger sections in trains and subways where mobile phones are prohibited to allow persons with EHS access to public transit[5]. Johansson clearly classifies the environment as being impaired and not the individual. When you fix the environment the impairment goes away. The same is true for buildings that lack wheelchair access; the person is disabled from entering the building yet once a ramp is provided there is

no longer a disability.

Table 1. Different parts of the electromagnetic spectrum showing frequency, wavelength, applications and biological effects.

Biological Effects	Frequency Hertz (Hz)	Wavelength Meter (m)	Name of Spectrum	Applications	Type of Radiation
oxidative stress	1 YHz	10^{-16}	Gamma Radiation (<1 pm)	• nuclear physics	Ionizing Radiation (IR)
	1 ZHz	10^{-14}	X-rays (10 - 0.01 nm)	• medical X-rays	
heating	1 EHz	10^{-12}	Ultraviolet Radiation (380 - 10 nm)	• sunlamp	Non-Ionizing Radiation (NIR)
	1 PHz	10^{-10}	Infrared Radiation (300 GHz - 400 THz)	• heating	
oxidative stress	1 THz	10^{-4}	Visible Light (380 nm - 780 nm)		Non-Ionizing Radiation (NIR)
	1 GHz	10^{-2}	Microwave Radiation (300 MHz - 300 GHz)	• 5G technology • military (ADS) • TV (UHF) • mobile phones • WiFi • smart meters • RADAR	
	1 MHz	10^2	Radio Frequency Radiation (300 Hz - 300 GHz)	• Electronic Devices • Radio • TV (VHF)	
	1 kHz	10^4	Extremely Low Frequency (≤ 300 Hz)	• Electric Power • Electric Appliances • Electric Railway	

Abbreviations: k-kilo; M-mega; G-giga; T-tera; P-peta; E-exa; Z-zeta; Y-yotta; c-centi; m-milli; μ -micro; n-nano; p-pico; f-femto; ADS-active denial system; 5G-fifth generation; UHF-ultra high frequency; VHF-very high frequency

Table 2. International radio frequency exposure guidelines for 1800 MHz range and common levels of exposure in natural and urban environments [based on: www.slt.co]

Guidelines	Power Density (microW/cm ²)	Exposure Times	Limit Based on	Reference
Most of Western Europe	1,000	30 min	thermal/heating	IEEE C95.1-1999 & ICNIRP
USA	1,000	30 min	thermal/heating	(FCC) IEEE C95.1-1999 & ICNIRP
Canada	439	6 min	thermal/heating	Safety Code 6, Table 5 (2015)
Russia, China, Italy, Most of Eastern Europe	10	3 hours plus	biological effects	Sanitary Norms
Switzerland	10	long term	precautionary	Ordinance on Protection from Non-ionizing radiation
Toronto, Canada	10	long term	precautionary	Toronto Board of Health, Proposed 1999
BiInitiative Report	0.1	long term	biological & precautionary	BiInitiative Report Recommendations 2007
Salzburg Resolution	0.1	long term	precautionary	Preventive Public Health Protection, Salzburg, 2000
European Parliament	0.010 6	long term	precautionary	Resolution 1815, Strasburg, 2011
Germany (sleeping areas)	0.000 01	long term	precautionary	Building Biology Guidelines; level of no biological concern
Exposures	Power Density (microW/cm ²)	Exposure Times	Exposure	Reference
Average indoor urban exposure Toronto, Canada	0.02 – 0.5	–	urban	Safe Living Technologies, Inc. 2011
Cell Phone Operation Requirements	0.000 000 1	–	cell phone requirements	
Natural Cosmic Radiation	0.000 000 000 1	long term	natural	MAES 2000

In 2002, the Architectural and Transportation Barriers Compliance Board of the United States recognized persons with both multiple chemical sensitivity (MCS) and electrohypersensitivity (EHS) as being disabled.

“The Board recognizes that multiple chemical sensitivities and electromagnetic sensitivities may be considered disabilities under the ADA if they so severely impair the neurological, respiratory or other functions of an individual that it substantially limits one or more of the individual’s major life activities. The Board plans to

closely examine the needs of this population, and undertake activities that address accessibility issues for these individuals.”
<https://www.access-board.gov/research/completed-research/indoor-environmental-quality/introduction>.

However, despite this recognition, few accommodations have been made for persons with EHS. Often the best information they receive is from others experiencing similar situations. Few health care professionals are familiar with this illness and even fewer

know how to help those affected. Although new products intended to protect against electrosmog exposure are available in the market place, many of these have not been independently or adequately tested to determine if their claims are valid.

In Canada, the Human Rights Commission adopted a policy forbidding discrimination against persons with environmental sensitivities (ES) and published two reports, on the medical [8] and the legal [9] perspectives of ES—which include chemical and electromagnetic sensitivities—although without mentioning it as a disability.

The European Union (2009) Parliamentary Resolution (2008/2211(INI)) Point 28, "Calls on Member States to follow the example of Sweden and to recognise persons that suffer from electrohypersensitivity as being disabled so as to grant them adequate protections as well as equal opportunities."

Germany recognized EHS in 2012 under WHO's ICD (International Classification of Diseases), under classification Z58.4 Elektrosensibilität but not necessarily as an impairment.

In France, the French Agency for Food, Environmental and Occupational Health and Safety (ANSES) duly acknowledges both the suffering endured by those with EHS and a clear need for more research on treatment of this condition (<https://www.anses.fr/en/glossaire/1521>). Yet, the link with exposure to EMF is considered by ANSES as not yet convincingly demonstrated.

In 2013, the Israeli Supreme Court ordered the government to investigate the number of children with EHS and stated they would provide a solution on an individual basis for any child with sensitivity to RFR (<https://www.emfacts.com/2013/07/the-israeli-supreme-court-ordered-the-israeli-government-to-investigate-the-number-of-children-currently-suffering-from-ehs/>).

In Australia, the Federal Appeals Court recognized EHS triggered by a case of occupational overexposure to EMF.

https://stopsmartmetersau.files.wordpress.com/2013/03/administrative_appeals_tribunal_of_australia_dr_alexander_mcdonald_and_comcare_28_02_2013.pdf

Clearly a number of countries recognize EHS as an illness and a few classify it as a disability that requires special compensation and/or elimination of barriers to

accessibility.

In this report, scientific evidence is provided that documents the effects of non-ionizing radiation (NIR), as it pertains to cognitive and physical impairment of persons that falls within the classification of EHS and would be considered a disability in some countries.

Categories of Neurological Disorders

The research is categorized into the following headings although there is some overlap between these categories and the list of studies is far from exhaustive, as thousands of research articles exist on these topics as they relate to electromagnetic exposure:

- A. Alzheimer's Disease (AD), Dementia, and Neurodegenerative Diseases
- B. Amyotrophic Lateral Sclerosis (ALS) and Parkinson's Disease (PD)
- C. Multiple Sclerosis (MS)
- D. Attention Deficit Hyperactivity Disorder (ADHD) and Autism Spectrum Disorder (ASD)
- E. Cognitive Disorders affecting Concentration, Memory, Learning and Stress Response
- F. Mood Disorders: Anxiety and Depression
- G. Fetal Exposure and Effects on Offspring

A. Alzheimer's Disease (AD), Dementia and Neurodegenerative Diseases

Alzheimer's disease (AD) and other forms of dementia are on the rise and are not restricted to the elderly. A strong connection has been documented between AD and extremely low frequency electromagnetic field exposure in occupational settings [10]. Among Swiss railway employees, for every 10 microT years of cumulative exposure, senile dementia mortality increased by 5.7% (95% CI 1.3-10.4) and AD by 9.4% (95% CI 2.7-16.4) [11]. Early onset AD has been associated with occupational exposure to ELF EMF [12]; especially in men [13,14]; with high odds ratios of ≥ 3 , indicating a 3-fold increased risk of developing AD [15]; and supported in meta-analyses [16,17].

B. Amyotrophic Lateral Sclerosis (ALS) and Parkinson's Disease (PD)

Other types of neurological disorders have been associated with exposure to ELF EMF in occupational settings including Parkinson's disease (PD) mortality [18] and Amyotrophic Lateral Sclerosis (ALS) incidence [19–22].

Several studies report a decrease in Purkinje cells in the cerebellum of rats with exposure to 900 MHz cellular phone frequencies for short periods daily [23,24]. Purkinje cells are nerve cells in the cerebellum that release the neurotransmitter GABA (gamma-aminobutyric acid), which exerts an inhibitory action on certain neurons and thus reduces the transmission of nerve impulses. In PD, the amount of GABA decreases in the brain and may be responsible for tremors, dystonia, dyskinesia and restless leg syndrome. There is also some evidence that GABA may function as a dopamine antagonist, blocking the effect of this neurotransmitter, which is already depleted in PD.

C. Multiple Sclerosis (MS)

Multiple Sclerosis (MS) is a neurological disorder that involves demyelination (sclerosis) of the nerves in the brain and spinal cord leading to cognitive and physical impairment depending on the location of the sclerosis. This has been documented in humans exposed to poor-quality electrical power [25], to high energy EMR [26] and to microwave (835 MHz) frequencies in laboratory experiments [27]. The latter study documented demyelination of cortical neurons in mice. According to a review [28], the most vulnerable are likely to be those *in utero* through to at least mid-teen years, and also the elderly.

D. Attention Deficit Hyperactivity Disorder (ADHD) and Autism Spectrum Disorder (ASD)

Another serious concern are the rapid increases in Attention Deficit Hyperactivity Disorder (ADHD) and Autism Spectrum Disorder (ASD), especially among boys. This increase in ASD is likely due to various environmental insults, one of which may be exposure to electromagnetic pollution as the increase seems coincident in time with the deployment of wireless technology [29] and the vulnerable mechanisms (such as voltage gated calcium channels) may be disrupted by environmental agents, various genes associated with autism or agent-gene interactions [30].

Laboratory studies with mice support the hypothesis of a causal link between perinatal exposure to ELF EMF and ASD [31]. In this study, male BALB/C mice were exposed to ELF EMF during the last week of gestation and for 7 days after delivery. The exposed mice demonstrated: a decrease in exploratory activity; a lack of normal sociability and preference for social novelty while maintaining normal anxiety-like behavior, locomotion, motor coordination and olfaction.

In a school study [32], ADHD symptoms in elementary classrooms were reduced when the electrical power quality in the classroom was improved. This suggests that poor-quality electrical power or dirty electricity exacerbates the symptoms of ADHD.

A case study on treatment of an ADHD-diagnosed 9-year-old boy suggests that screen time reduction is effective in decreasing ADHD-related behavior [33].

E. Cognitive Disorders affecting Concentration, Memory, Learning and Stress Response

Human Studies: Epidemiological studies with humans indicate that microwave radiation at exposures well below the maximum in federal guidelines affect specific cognitive aspects of behavior such as attention, learning, memory, discrimination and time perception [34]. This has been documented with cell phone use by adolescents—resulting in headache, concentration difficulties, fatigue and sleep disturbances, and this was dose-dependent [35]—and with cell phone use in occupational settings [36]. Lack of attention and concentration may occur in subjects who talk on mobile phones while holding them to their heads for more than 90 min/d compared to subjects who use phones less than 30 min/d [37]. In another study with adolescents, a detriment in memory performance over one year was negatively associated with cumulative duration of wireless phone use and more strongly with radio frequency EMF (RF-EMF) dose [38]. In a meta-analysis, Barth et al. [39] concluded that EMF exposure emitted by GSM mobile phones have a small impact on human attention and working memory. Furthermore, GSM mobile phone emissions increase inter-hemispheric functional coupling and could relate to changes in cognitive/motor function among epileptics [40].

Firefighters exposed to cellular antennas on firehalls showed abnormal brain activity with functional MRI scans

and complained of headaches, intermittent cognitive and memory problems, intermittent disorientation and sensitivity to EMR exposure [41].

For people living near (within 300 m) a cellular phone network base station, symptoms such as nausea, headache, dizziness, irritability, discomfort, nervousness, depression, sleep disturbance, difficulty concentrating, memory loss and lowering of libido were statistically more prevalent than for those living further away (> 300 m) [42,43].

A decrease in human hormone profiles that include testosterone, progesterone, ACTH, cortisol and thyroid hormones (T3 and T4) was documented for those who lived near a cellular phone network base station for more than 3 years compared to those who lived more than 500 m away [44], and this change in hormones may account for the symptoms experienced. Sangun et al. [45] expressed similar concerns on the detrimental effects of EMF on thyroid functions, adrenal hormones, glucose homeostasis and melatonin levels.

In a provocation experiment with human subjects exposed to GSM 900 MHz antenna emissions at 5.2, 153.6 and 2126.8 $\mu\text{W}/\text{m}^2$, there was an increase in psychobiological stress markers with an increase in cortisol or alpha-amylase depending on the exposure scenario [46].

Animal Studies: Similarly, *in vivo* studies with laboratory animals (mostly rats) exposed to non-ionizing electromagnetic radiation (EMR) have documented altered hormones and neurotransmitters that have an effect on learning, memory and stress. These studies indicate a cause-effect relationship and provide evidence regarding the mechanisms involved.

Rats exposed at 6 months of age to GSM cell phone radiation showed a memory performance deficit [47]. Exposure of chick embryos to mobile phone radiation developed impaired social behaviour and cerebellar retardation [48]. Some of the biochemical/biophysical responses to radio frequency exposure include neurotransmitters disturbances, reduced neurone growth and increases in oxidative stress, programmed cell death (apoptosis), increase in stress proteins and DNA damage.

Monoamine Neurotransmitters: The exposure of adult rats to EMR may cause disturbances in monoamine neurotransmitters, and this may underlie many of the adverse effects reported with EMR exposure including memory, learning and stress [49]. A different study

concluded that low-intensity MWR may cause learning and memory disturbances by altering levels of brain monoamine neurotransmitters at mRNA and protein levels [50]. In the long term, chronic microwave exposure could induce cognitive deficit involving 5-HT (serotonin) in rats [51]. The content of amino acids neurotransmitters, the expression of NMDAR subunits and the variation of hippocampal structure might contribute to the long-term cognitive impairment after microwave exposure [52].

Oxidative Stress: Rats exposed to MWR at 2.45 GHz had detrimental changes in the brain resulting in lowered learning and memory and increased anxiety along with a fall in brain antioxidant enzyme systems [53] [Note: 2.45 GHz is the frequency used in Wi-Fi and microwave ovens]. Increased oxidative stress due to MWR exposure may contribute to cognitive impairment and inflammation in brain in Fischer rats [54]. Rats exposed at 6 months of age to GSM cell phone frequencies showed a memory performance deficit [47]. Saikhedkar et al. [55] concluded that mobile phone radiation at 900 MHz increased production of reactive oxygen species and resulted in extensive neuronal damage resulting in alterations in behavior related to memory and learning. Similarly, exposure to 2.45 GHz impaired learning and spatial memory in adult male mice via oxidative stress and apoptosis, and this may be the underlying mechanism for spatial memory loss [56].

Neurite Growth: Exposure to 1800 MHz radiofrequency radiation at 4 W/kg for 3 days impairs neurite outgrowth of embryonic neural stem cells. The authors concluded that more attention should be given to the potential adverse effects of RF-EMF exposure on brain development [57].

Stress Proteins: Microwave exposure at 900–2450 MHz led to a decline in cognitive function, increase in HSP70 level (stress protein) and DNA damage in male rat brains [58].

Inflammation: Kumari et al. [59] concluded that 7.5 kHz magnetic field (MF) exposure may lead to mild learning and memory impairment, possibly through an inflammatory reaction in the hippocampus, of mice exposed to 12 or 120 μT for 5 weeks.

F. Mood Disorders: Anxiety and Depression

Mood disorders that include anxiety or depression are increasing among all age groups and, in some cases,

leading to suicide. Some of this has been related to cell phone use among adolescents [60,61], to Wi-Fi exposure [62] and to microwave exposure in general [63] resulting in diverse neuro-psychiatric effects. Increases in depression and anxiety also occur with chronic exposure to ELF EMF [64] and have been replicated in laboratory studies with rats [65].

People living within 300 m of cell phone base stations have a greater incidence of depression [42,43] and a greater risk of developing neuropsychiatric problems [66].

Pall [63] reviewed the literature and reported that RFR exposure from shortwave, radio station, occupational and digital TV antennas may produce neuropsychiatric effects. Among the more commonly reported changes are depression/depressive symptoms, restlessness/anxiety, sleep disturbance/insomnia, headache, fatigue/tiredness, dysesthesia, concentration/attention dysfunction, memory changes, dizziness, irritability, loss of appetite/body weight, nausea, skin burning/tingling/dermographism and EEG changes.

Adolescent mice exposed to 1.8 GHz had higher levels of anxiety [67]; and rats exposed to 2.45 GHz experienced detrimental changes in the brain with evidence of increased anxiety and impaired learning and memory [53].

G. Fetal Exposure and Effects on Offspring

Of particular concern are prenatal and postnatal exposures to MWR with pregnant women using mobile phones, cordless phones, laptop computers or tablets held close to the fetus. This can affect neonatal heart rate and cardiac output [68] and lead to behaviour difficulties, such as emotional and hyperactivity problems in the offspring by age 7 [69,70]. In one study, data from 5 countries (Denmark, Korea, the Netherlands, Norway and Spain) showed that maternal cell phone use during pregnancy was associated with a slight but statistically significant increased risk of behaviour problems, particularly hyperactivity and inattention, in the offspring. The association was moderately consistent across and between cohorts [71].

Animal studies with rats indicate adverse effects on offspring with maternal exposure to mobile phone radiation. Exposure to mobile phones (900 MHz pulsed for 6 h/day) adversely affects the cognitive performance of both female and male Wistar rat offspring [72].

Maternal exposure to a continuous 900 MHz electromagnetic field provokes neuronal loss and pathological changes in cerebellum of 32-day-old female rat offspring and affects the development of Purkinje cells in the female rat cerebellum long after the postnatal period [73].

Not all *in vivo* studies with humans document immediate reactions to electrosmog exposure. For some there is a delayed response and for others no response is detected [74]. The human body is a highly complex system of homeostatic controls and its response to environmental insults is a function of not only the vastly differing genetics but also the highly variable environmental stresses to which people are exposed. However, despite this complexity and variability, far too many studies are documenting adverse effects of NIR that cannot continue to be ignored, especially with the imminent rollout of 5G technology that emits a broader and higher range of non-ionizing EMR frequencies some of which are known to be biologically-active. The 5G rollout plans to install millions more antennas as NIR emitters to enable billions more machine-user devices.

Medical Recognition of EHS

In 2016, the EMF Working Group of the European Academy for Environmental Medicine (EUROPAEM) released a report that provides guidelines for the prevention, diagnosis and treatment of EMF-related health problems and illnesses. The following are comments from this publication regarding the recognition, diagnosis and treatment of EHS [75]:

1. New wireless technologies and applications have been introduced without any certainty about their health effects, raising new challenges for medicine and society. Since individual susceptibility and environmental factors are frequently neglected, it is now necessary to take NIR exposure into account when providing a medical diagnosis.
2. EHS symptoms are becoming more frequent and more severe.
3. The emerging electromagnetic hypersensitivity (EHS) is more frequently recognized by health authorities, disability administrators and case workers, politicians, as well as courts of law.
4. The primary method of treatment should mainly

focus on the prevention or reduction of EMF exposure (i.e. reducing or eliminating all sources of high EMF exposure at home and at the workplace). The reduction of EMF exposure should also be extended to public spaces such as schools, hospitals, public transport, and libraries to enable persons with EHS an unhindered use (accessibility measure).

5. If a detrimental EMF exposure is reduced sufficiently, the body has a chance to recover and EHS symptoms will be reduced or even disappear.

6. There is increasing evidence that EMF exposure has a major impact on the oxidative and nitrosative regulation capacity in affected individuals. This concept also may explain why the level of susceptibility to EMF can change and why the range of symptoms reported in the context of EMF exposures is so large.

7. Based on our current understanding, a treatment approach that minimizes the adverse effects of peroxynitrite—as has been increasingly used in the treatment of multisystem illnesses—works best.

On July 8, 2015, a court in Toulouse, France, ruled in favor of a woman with the diagnosis “syndrome of hypersensitivity to electromagnetic radiation” and determined her disability to be 85% with substantial and lasting restrictions on access to employment.

Cancer and Reproduction

While the focus of this paper is on the effects of NIR on EHS, these frequencies have been associated with cancers in people who use cell phones for more than 10 years [76,77], in people who live near cell phone network base stations, broadcast antennas (radio, TV, radar) and power lines [78–83] and in people occupationally exposed to NIR[84–86]. Furthermore, we have at least three well-controlled, animal studies documenting that microwave radiation causes cancer [87–89]. It is only a matter of time until the IARC (International Agency for Research on Cancer) classification will change from a 2B (possibly carcinogenic) to a 2A (probably carcinogenic) or a 1 (carcinogenic to humans) for RFR since we know that this radiation increases free radicals by interfering with the neutralization of reactive oxygen species [90].

Furthermore, evidence exists that NIR damages sperm and contributes to miscarriages [91–94] at levels far below

the maximums in thermal guidelines.

International Appeals and Declarations

Since 1997, scientists and physicians have penned more than 37 appeals, declarations and resolutions to bring about more protective guidelines and to educate the public and members of the health care professions (list available at <http://magdahavas.com/international-experts-perspective-on-the-health-effects-of-electromagnetic-fields-emf-and-electromagnetic-radiation-emr/>).

One of those appeals, International EMF Scientist Appeal, was submitted to the World Health Organization and United Nations on May 11, 2015 and was signed by more than 200 scientists, medical doctors and engineers who do research in this area; those signatories are from 41 countries [95] (see also www.EMFScientist.org).

The Appeal requested the following:

1. children and pregnant women be protected;
2. guidelines and regulatory standards be strengthened;
3. manufacturers be encouraged to develop safer technology;
4. utilities responsible for the generation, transmission, distribution, and monitoring of electricity maintain adequate power quality and ensure proper electrical wiring to minimize harmful ground current;
5. the public be fully informed about the potential health risks from electromagnetic energy and taught harm reduction strategies;
6. medical professionals be educated about the biological effects of electromagnetic energy and be provided training on treatment of patients with electromagnetic sensitivity;
7. governments fund training and research on electromagnetic fields and health that is independent of industry and mandate industry cooperation with researchers;
8. media disclose experts' financial relationships with industry when citing their opinions regarding health and safety aspects of EMF-emitting technologies; and
9. white-zones (radiation-free areas) be established.

The concept of white-zones is extremely important for persons who have EHS, as their symptoms become worse

when they are exposed to electrosmog. This makes it difficult, or impossible, for them to use public transit and, in some case, to be in a vehicle on roadways that are frequented by cellular network antennas or in high-traffic areas where ever more vehicles are equipped with ever more always-on RF emitting antennas. Cycling, walking or using assistive mobility equipment in such areas can be intolerable due to electrosmog exposure. All of this provides a significant barrier to employment and providing oneself with the necessities of life. Simple tasks like shopping in stores located near cellular network antennas or hydro fields or equipment with public or private Wi-Fi, cordless phones or pagers, bluetooth, wireless HVAC or anti-theft systems becomes increasingly challenging. Electrosmog provides a barrier to travel by train or airplane (or even enter an airport or train station), especially those equipped with Wi-Fi; to stay in hotels; to go to schools, libraries and community centres, as many of these (and other) venues have converted Ethernet cables to Wi-Fi routers for Internet connectivity; to visit parks and open spaces that have “city-wide” Wi-Fi; to access buildings that house public services or government offices; and to attend facilities for routine medical or other health care. For many with EHS, even living in their own homes, whether in multi-unit dwellings (apartment buildings and condominiums) or single-family dwellings on small lots, due to the proximity of neighbors who have any of the various cordless or wireless technologies (in their houses, yards or parked vehicles), large solar panel installations, automobile charging stations or so-called “smart” utility meters (for electricity, water or natural gas) becomes unbearable. All of this is likely to get much worse with 5G (5th Generation) technology currently being tested in select communities with rollout scheduled to begin in 2020.

Persons with severe EHS who are no longer able to live in their own homes, unwillingly but out of necessity, sleep in forests in cars or move to rare, remote communities for “EMF Refugees”. A few of these communities exist in the U.S. There is a high-profile one in Green Bank, West Virginia where giant radio telescopes are surrounded by a 10-mile RFR exclusion zone to avoid electromagnetic interference (EMI) for the telescopes.

The Committee on the Rights of Persons with Disabilities (International Justice Resource Centre) [7] has this to say about accessibility:

"As long as goods, products and services are open or provided to the public, they must be accessible to all, regardless of whether they are owned and/or provided by a public authority or a private enterprise. The strict application of universal design to all new goods, products, facilities, technologies and services should ensure full, equal and unrestricted access for all potential consumers, including persons with disabilities, in a way that takes full account of their inherent dignity and diversity."

According to Seletun Statement 2010 (<http://emfsafetynetwork.org/wp-content/uploads/2011/07/Seletun-Statement-2010.pdf>) [96]

“Public access to public places and public transportation should be available without undue risk of EMF exposure, particularly in enclosed spaces (trains, airplanes, buses, cars, etc) where the exposure is likely to be involuntary.”

Furthermore, “Persons with Electrohypersensitivity need the classification, “functionally impaired.”

The U.S. Department of Labor, Job Accommodation Network (JAN) provides accommodation ideas for electromagnetic sensitivity and their statement is reproduced below (<https://askjan.org/disabilities/Electrical-Sensitivity.cfm?>):

1. There are people who report sensitivity to electromagnetic fields. Although it has been difficult for the environmental health and medical communities to define, individuals with electromagnetic sensitivity report various symptoms including but not limited to fatigue, weakness, neurological issues, immunological issues, gastrointestinal issues, increased irritability, lack of ability to think clearly and quickly, sleep disturbance, overall malaise, and anxiety.

2. Despite the medical community's difficulty in defining electromagnetic sensitivity, individuals with the condition may benefit from job accommodations. The following is a quick overview of some of the accommodations that might be useful. To discuss an accommodation situation with a consultant, contact JAN directly.

3. Accommodation ideas for individuals with electromagnetic sensitivity:

- a) Allow communication via typewriter or handwritten notes rather than via computer or cover the computer with Plexiglass or other

- shielding material
- b) Provide headset/handset extenders or alternate headsets to lengthen the distance between devices that trigger symptoms and the employee's body
 - c) Change the employee's shift to allow for less exposure to others' devices
 - d) Relocate workplace away from areas where symptoms are triggered. This may include limiting certain types of devices in the vicinity of the employee's workstation
 - e) Allow telework (Note: regarding work at home, unless the employee wants to work at home, other options should be explored first to keep the employee in the workplace)
 - f) Allow the employee to meet with others in areas where triggers are minimized or allow remote access to meetings or activities that must take place in areas that trigger symptoms.
 - g) Provide wired telephones and network connections
 - h) Provide building-wide and/or workspace shielding of equipment and devices, for example add filters to fluorescent lights and tape electrical cords .
 - i) Individuals with electrical sensitivity may also experience limitations from fragrance sensitivity and/or photosensitivity

The focus of the U.S. Administration for Community Living (ACL) strategic plan for the period 2013–2018 states: “Maximize the independence, well-being, and health of older adults, people with disabilities, and their families and caregivers.”

It is becoming imperative that persons who have EHS be included among those with disabilities or functional impairment due to electrosmog exposure and be entitled to barrier-free inclusivity in all aspects of society. Just as someone in a wheel chair is unable to enter a building that does not have a ramp, a person with EHS is unable to enter a building that has Wi-Fi, smart meters and other sources of microwave radiation.

Reducing EMF/EMR exposure and provision of a “safe” workplace, school, travel, shopping, health care and home environments is essential for persons who have EHS. This can be done initially the same way medical clinics have introduced “scent-free” environments aiming to automatically provide identifiable, barrier-free access to any and all people in a community who have multiple

chemical sensitivity (MCS). Similarly, the introduction of “smoke-free” environments, for the sake of health rather than disability, has been successful in many countries. Establishing “white-zones” (electrosmog-free zones) combined with an educational program about them would be an important step for any venue and community to take in supporting people who suffer disability due to EHS. Further, similar to laws, policies and practices that enable non-smoking areas, scent-free or easier wheelchair or eyesight-impaired access at buildings and landscapes, generally a beneficial side-effect is that the physical environment becomes enhanced in ways advantageous to all users and passerby in the space and not only to those who suffer from EHS. Providing electrosmog-free environments not only enhances accessibility for those with EHS but it may also delay development of EHS in people who are currently symptom free.

Conclusion

Environments contaminated by electrosmog can be devastating to those individuals who are already impaired by electromagnetic exposures. Unfortunately, these environments may also induce impairment in previously unimpaired individuals. Fetal exposure is particularly disturbing as it can affect the life of the offspring, as shown in both human and animal studies. The research reported here is regarding undesirable disruption of neurological and hormonal functions such that either cognitive or physical ability becomes impaired.

According to this research, exposure to EMF or EMR at levels far below the maximum limits in federal guidelines can contribute to deficits in memory and learning; increase the stress response and lead to mood disorders, including both anxiety and depression; contribute to symptoms of autism and attention deficit hyperactivity disorder; contribute to neurodegenerative disorders and exacerbate symptoms of multiple sclerosis, amyotrophic lateral sclerosis, Parkinson’s disease and various types of dementia, including Alzheimer’s disease. Removal of the EMF/EMR exposure can ameliorate the impairing symptoms for many with EHS and/or reduce requirements for prescriptive medications and care. Mechanisms of action involve neurotransmitter disturbances, oxidative stress, programmed cell death (apoptosis), increase in

stress proteins, reduced growth of nerve cells, DNA damage and altered hormonal levels.

With the impending deployment of 5G (5th Generation Wireless technology and the Internet of Things), exposure to mm waves will dramatically increase, further densifying our current electrosmog exposure.

Scientists and physicians familiar with EHS have submitted multiple appeals and declarations to governing agencies in an attempt to reduce exposure to electromagnetic frequencies. They recommend establishing more protective emission and exposure guidelines; designing technologies that emit EMR less often, at lower intensity and with a reduced radiation footprint; educating health care providers; informing the public; and establishing radiation-free environments for persons with EHS.

Agencies responsible for assuring disabled persons are included, and welcomed, in their communities and have equal access to necessities and enjoyment of life have provided little support for those suffering with EHS, presumably due to lack of information and/or unintentional, yet nevertheless in appropriate, attitudinal barriers. It is my hope that this document will encourage federal and state agencies, as well as other jurisdictions and decision-makers, to take EHS seriously and to help individuals affected by this physiological condition and to support their families. According to the World Health Organization (2015) the level of severity of EHS is classified as being severe for approximately 10% of individuals who report EHS symptoms. This percentage is likely to increase as more EMF-emitting technologies, such as 5G, mm waves and Internet of Things, are deployed.

Conflict of interest

None.

Acknowledgement

I would like to thank the four anonymous reviewers for their comments and Barb Payne for proofreading the final version of this manuscript.

Notes:

- a. EMF generally refers to frequencies below 300 Hertz (Hz) with a Hz representing one cycle per second.
- b. EMR generally refers to frequencies from 300 Hz to 300 GHz, although frequencies above 10 GHz are currently rare in the environment. This will change with introduction of 5G (5th Generation wireless technology). EMR is the same as radio frequency radiation (RFR), whereas microwave radiation (MWR) refers to the upper part of the RF spectrum from 300 MHz to 300 GHz. The spectrum above 30 GHz is also known as millimetre waves (mm waves).
- c. Electrosmog is used as a general term to include all forms of non-ionizing electromagnetic frequencies that cause adverse effects.

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