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Abstract: Chronic diseases and illnesses associated with non-specific symptoms are on the rise. In addition to chronic stress in social and work environments, physical and chemical exposures at home, at work, and during leisure activities are causal or contributing environmental stressors that deserve attention by the general practitioner as well as by all other members of the health care community. It seems necessary now to take "new exposures" like electromagnetic fields (EMF) into account. Physicians are increasingly confronted with health problems from unidentified causes. Studies, empirical observations, and patient reports clearly indicate interactions between EMF exposure and health problems. Individual susceptibility and environmental factors are frequently neglected. New wireless technologies and applications have been introduced without any certainty about their health effects, raising new challenges for medicine and society. For instance, the issue of so-called non-thermal effects and potential long-term effects of low-dose exposure were scarcely investigated prior to the introduction of these technologies. Common electromagnetic field or EMF sources: Radio-frequency radiation (RF) (3 MHz to 300 GHz) is emitted from radio and TV broadcast antennas, Wi-Fi access points, routers, and clients (e.g. smartphones, tablets), cordless and mobile phones including their base stations, and Bluetooth devices. Extremely low frequency electric (ELF EF) and magnetic fields (ELF MF) (3 Hz to 3 kHz) are emitted from electrical wiring, lamps, and appliances. Very low frequency electric (VLF EF) and magnetic fields (VLF MF) (3 kHz to 3 MHz) are emitted, due to harmonic voltage and current distortions, from electrical wiring, lamps (e.g. compact fluorescent lamps), and electronic devices. On the one hand, there is strong evidence that long-term exposure to certain EMFs is a risk factor for diseases such as certain cancers, Alzheimer's disease, and male infertility. On the other hand, the emerging electromagnetic hypersensitivity (EHS) is more and more recognized by health authorities, disability administrators and case workers, politicians, as well

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as courts of law. We recommend treating EHS clinically as part of the group of chronic multisystem illnesses (CMI), but still recognizing that the underlying cause remains the environment. In the beginning, EHS symptoms occur only occasionally, but over time they may increase in frequency and severity. Common EHS symptoms include headaches, concentration difficulties, sleep problems, depression, a lack of energy, fatigue, and flu-like symptoms. A comprehensive medical history, which should include all symptoms and their occurrences in spatial and temporal terms and in the context of EMF exposures, is the key to making the diagnosis. The EMF exposure is usually assessed by EMF measurements at home and at work. Certain types of EMF exposure can be assessed by asking about common EMF sources. It is very important to take the individual susceptibility into account. The primary method of treatment should mainly focus on the prevention or reduction of EMF exposure, that is, 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). If a detrimental EMF exposure is reduced sufficiently, the body has a chance to recover and EHS symptoms will be reduced or even disappear. Many examples have shown that such measures can prove effective. To increase the effectiveness of the treatment, the broad range of other environmental factors that contribute to the total body burden should also be addressed. Anything that supports homeostasis will increase a person's resilience against disease and thus against the adverse effects of EMF exposure. 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. 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. This EMF Guideline gives an overview of the current knowledge regarding EMF-related health risks and provides recommendations for the diagnosis, treatment and accessibility measures of EHS to improve and restore individual health outcomes as well as for the development of strategies for prevention.

Keywords: accessibility measures; Alzheimer's disease; cancer; chronic multisystem illnesses (CMI); diagnosis; electric; electromagnetic field (EMF); electromagnetic hypersensitivity (EHS); infertility; leukemia; magnetic; medical guideline; nitrosative stress; non-ionizing; oxidative stress; peroxynitrite; prevention; radiation; static; therapy; treatment.

Current state of the scientific and political debate about EMF-related health problems from a medical perspective

Introduction

The Environmental Burden of Disease Project assessed the influence of nine environmental stressors (benzene, dioxins including furans and dioxin-like PCBs, second-hand smoke, formaldehyde, lead, noise, ozone, particulate matter and radon) on the health of the population of six countries (Belgium, Finland, France, Germany, Italy, and the Netherlands). Those nine environmental stressors caused 3%–7% of the annual burden of disease in the six European countries (1).

The Bundespsychotherapeutenkammer (BPtK) study in Germany showed that mental disorders had increased further and especially burnout as a reason of inability to work increased seven-fold from 2004 to 2011 (2). In Germany, 42% of early retirements in 2012 were caused by mental disorders, depression being the leading diagnosis (3). In Germany, psychotropic drugs are in third place for the prescriptions of all drugs (4).

The consumption of methylphenidate (Ritalin, Medikinet, Concerta), a psychotropic drug prescribed as a treatment for attention deficit hyperactivity disorder (ADHD) especially for young children and adolescents, has increased alarmingly since the early 1990s. According to statistics of the German Federal Institute for Drugs and Medical Devices (Bundesinstitut für Arzneimittel und Medizinprodukte), prescriptions have increased even more dramatically since 2000 and reached a climax in 2012. In 2013, only a slight decline in the number of prescriptions was observed (5). Interestingly, the rapid increase in the use of methylphenidate coincides with the enormous expansion of mobile telecommunication and other related technologies, posing an open research question.

In Germany, work disability cases and absence days due to mental health disorders more than doubled from 1994 to 2011 (6). In the Organization for Economic Co-operation and Development (OECD) countries, a huge

variability in the prescription of antidepressants has occurred and generally an increasing trend has been observed. Socioeconomic status and therapeutic standards cannot fully explain these observations (7). Functional disturbances like chronic inflammation and changes of neurotransmitter functions caused by environmental influences have hardly been investigated.

A steady increase in the prevalence of allergic/asthmatic diseases globally has occurred, with about 30%–40% of the world population now being affected by one or more allergic/asthmatic conditions (8).

It is suspected that environmental conditions such as the increasing exposure of the population to electromagnetic fields (EMFs) play a causal role for EMF-related health effects (9–12), including exposure to radio-frequency radiation (RF), which emanates from, e.g. cordless phones (DECT), mobile phone base stations, and mobile phones (GSM, GPRS, UMTS, LTE), especially smartphones, data cards for laptop and notebook computers, wireless LAN (Wi-Fi), wireless and powerline communication-based smart meters, but also exposure to extremely low frequency (ELF) electric fields (EF) and magnetic fields (MF) including "dirty electricity", which emanate from disturbances on electric wiring, power lines, electric devices, and other equipment. For the society and the medical community, all of this raises new challenges.

While biophysical and biochemical mechanisms of biological effects of EMF at low-intensity levels are not exactly known, significant progress has been achieved in the last decades, and there are numerous data indicating that these mechanisms may overlap for ELF and RF effects (13–18). In the following sections, we provide some background information on important aspects of EMF biological effects. However, this must not be misunderstood as a full review of the evidence. We do not always strictly differentiate between RF and ELF fields because of the above mentioned overlap in biological mechanisms. It should also be mentioned here that very specific exposure conditions may trigger biological responses in one individual, but not in others. Anecdotal reports, however, indicate that such individual responsiveness or susceptibility does expand over time and the intolerance then extends over a broad range of exposure conditions.

Chronic diseases and illnesses associated with unspecific symptoms are on the rise. In addition to chronic stress in social and work environments, physical and chemical exposures at home, at work, and during leisure activities are causal or contributing environmental stressors that deserve attention by the general practitioner as well as by all other members of the health care community. It seems certainly necessary now to take "new exposures" like EMF into account, or as stated by Hedendahl et al. (19): *"It is time to consider ELF EMF and RF EMF as environmental pollutants that need to be controlled"*.

Worldwide statements of organizations regarding EMF

The recommendations of the World Health Organization (WHO) regarding ELF electric and magnetic fields and RF radiation, compiled by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) (20, 21), are based on currents induced in the body (ELF) and thermal effects (RF).

Thermal effects are defined as effects that originate in elevated temperatures from the absorption of electromagnetic energy. The specific absorption rate (SAR) is defined as the rate of absorption of electromagnetic energy in a unit mass of biological tissue. It is proportional to the incremental temperature increase in that tissue. Indeed while a significant temperature increase must be avoided as it can be of immediate adverse health consequences (tissue necrosis, cardiac stress, etc.) exposures can be without (measureable) temperature increase either because of heat dissipation or because the exposure is too low to be associated with relevant heating. The latter type of exposure is termed non-thermal. Biological and health-relevant effects at non-thermal levels have been shown and discussed by many research groups all over the world (9, 10, 22–24).

The ICNIRP recommendations were adopted by the EU in its Council Recommendation of 1999, without considering long-term non-thermal effects. However, it should be stressed that at an international EMF conference in London (2008), Professor Paolo Vecchia, ICNIRP Chairman from 2004 to 2012, said about the exposure guidelines "What they are not": *"They are not mandatory prescriptions for safety"*, *"They are not the' 'last word' on the issue"*, and *"They are not defensive walls for industry or others"* (25).

For all RF-based non-thermal EMF effects, SAR estimates are not an appropriate exposure metric, but instead either the field intensity or power density (PD) in combination with exposure duration should be used in safety standards (26, 14, 27). In contrast to the ICNIRP guidelines, the Russian safety standards, are based on non-thermal RF effects, which were obtained by several research institutes in the former Soviet Union during decades of studies on chronic exposures to RF (28, 29).

In contrast to the WHO headquarter in Geneva, the International Agency for Research on Cancer (IARC), a WHO-affiliated specialized agency in Lyon, classified

extremely low frequency magnetic fields (ELF MF) as possibly carcinogenic to humans (Group 2B) in 2002 (30) and radio-frequency radiation in 2011 (24).

It should be noted that, during the last 20 years, more than 20 position papers and resolutions regarding EMF and health have been adopted by EMF researchers and physicians. These include the Vienna EMF Resolution, Austria, 1998; Stewart Report, UK, 2000; Salzburg Resolution, Austria, 2000; Freiburg Appeal, Germany, 2002; Catania Resolution, Italy, 2002; Irish Doctors' Environmental Association Statement, Ireland, 2005; Helsinki Appeal, Finland, 2005; Benevento Resolution, Italy, 2006; Venice Resolution, Italy, 2008; Porto Alegre Resolution, Brazil, 2009; Russian National Committee on Non-Ionizing Radiation Protection Resolution, Russia, 2001; International Doctors' Appeal, Europe, 2012; and the Report of the Standing Committee on Health, Canada, 2015 (31–34).

In August 2007 and December 2012, the BioInitiative Working Group, an international group of 29 experts with different competences, published two groundbreaking reports "BioInitiative 2007/resp. 2012 – A Rationale for a Biologically-based Public Exposure Standard for Electromagnetic Fields (ELF and RF)" edited by Cindy Sage and David O. Carpenter, calling for preventive measures against EMF exposure based on the available scientific evidence (9, 10). The BioInitiative reports are global milestones with respect to a comprehensive review of biological effects and health effects of low-intensity electromagnetic radiation as well as the conclusions and recommendations given for the public. The BioInitiative report 2012 includes sections on the evidence for effects on: gene and protein expression, DNA, immune function, neurology and behavior, blood-brain barrier, brain tumors and acoustic neuromas, childhood leukemia, melatonin, Alzheimer's disease, breast cancer, fertility and reproduction, fetal and neonatal disorders, autism, disruption by the modulating signal, EMF medical therapeutics, as well as sections on: statement of the problem, the existing public exposure standards, evidence for inadequacy of the standards, the precautionary principle, global public health examples, key scientific evidence and public health recommendations, and summary for the public and conclusions.

As it is mostly neglected as a health hazard, the European Environment Agency compared the risks of non-ionizing radiation (EMF) to other environmental hazards such as asbestos, benzene, and tobacco, urgently recommending to implement a precautionary approach regarding EMF (35). This position was confirmed and elaborated more comprehensibly in further publications in 2011 and 2013 (36, 37).

In September 2008, a statement of the European Parliament called for a review of the EMF limits set out in the EU Council Recommendation of 1999, which was based on the ICNIRP guidelines, with reference to the BioInitiative Report (38). This was further strengthened in the European Parliament resolution of April 2009 (39).

At the meeting in November 2009 in Seletun, Norway, a scientific panel adopted a Consensus Agreement that recommends preventative and precautionary actions that are warranted now, given the existing evidence for potential global health risks from EMF exposure (40). Besides general and specific recommendations, e.g. for mobile and cordless phone use, the panel recommended exposure limits for ELF magnetic fields and radio-frequency radiation. It was stated by the panel: "Numeric limits recommended here do not yet take into account sensitive populations (EHS, immune-compromised, the fetus, developing children, the elderly, people on medications, etc.). Another safety margin is, thus, likely justified further below the numeric limits for EMF exposure recommended here".

Since 2007 the Highest Health Council of the Ministry of Health in Austria has recommended to take preventive action by reducing exposure levels from RF devices which may lead to long-term human exposure of at least a factor of 100 below the guideline levels of the European Commission and by issuing rules on how to reduce one's individual exposure to RF radiation from mobile phones (41).

In May 2011, the Parliamentary Assembly of the Council of Europe adopted the report "The Potential Dangers of Electromagnetic Fields and their Effects on the Environment" (42). The Assembly recommended many preventive measures for the member states of the Council of Europe with the aim to protect humans and the environment, especially from high-frequency electromagnetic fields such as: *"Take all reasonable measures to reduce exposure to electromagnetic fields, especially to radiofrequencies from mobile phones, and particularly the exposure of children and young people who seem to be most at risk from head tumors"*, or *"Pay particular attention to 'electrosensitive' people who suffer from a syndrome of intolerance to electromagnetic fields and introduce special measures to protect them, including the creation of wave-free areas not covered by the wireless network"*.

Recognizing that patients are being adversely affected by EMF exposure, the American Academy of Environmental Medicine (AAEM) published recommendations regarding EMF exposure in July 2012. The AAEM called for physicians to consider electromagnetic exposure in diagnosis and treatment and to recognize that EMF exposure *"may be an underlying cause of the patient's disease process"* (43).

Since 2014, the Belgian government has prohibited the advertising of mobile phones for children under the age of

7 and has required the specific absorption rate (SAR) of mobile phones be listed. Furthermore, at the point of sale, well-marked warnings must be posted that instruct users to use headsets and to minimize their exposure (44).

In January 2015, the French parliament adopted a comprehensive law that protects the general public from excessive exposure to electromagnetic waves. Among other things, it was passed to ban Wi-Fi in nurseries for children under the age of 3 and to enable Wi-Fi at primary schools with children under the age of 11 only when used specifically for lessons. Public places offering Wi-Fi must clearly advertise this fact on a sign. At the point of sale of mobile phones, the SAR value must be clearly shown. In the future, any mobile phone advertisement must include recommendations on how users can reduce RF radiation exposure to the head such as the use of headsets. Data on local EMF exposure levels shall be made more easily accessible to the general public, among others, through country-wide transmitter maps. Also, the French government will have to submit a report on electromagnetic hypersensitivity to the parliament within a year (45).

As of February 2016, 220 scientists from 42 countries have signed an international Appeal, directed to the United Nations (UN) and WHO, calling for protection from non-ionizing electromagnetic field exposure. The appeal addresses the scientifically proven effects on health and the inadequate international guidelines (ICNIRP) to date and their use by the WHO. In addition, nine requests were made, including that: *"the public be fully informed about the potential health risks from electromagnetic energy and taught harm reduction strategies"* and that *"medical professionals be educated about the biological effects of electromagnetic energy and be provided training on treatment of patients with electromagnetic sensitivity"* (46).

In September 2015 an International Scientific Declaration on Electromagnetic Hypersensitivity and Multiple Chemical Sensitivity was published by the Scientific Committee following the 5th Paris Appeal Congress, which took place on 18 May 2015 at the Royal Academy of Medicine, Brussels, Belgium. It calls upon national and international agencies and organizations to recognize EHS and multiple chemical sensitivity as a disease and urges particularly the WHO to include EHS and MCS in the International Classification of Diseases. It also asks national and international agencies and organizations to adopt simple precautionary measures of prevention, to inform the public, and to appoint truly independent expert groups to evaluate these health risks based on scientific objectivity, which is not the case today (47).

EMF and cancer

Except for a few investigations in occupational settings, epidemiological research of EMF started in 1979 when Wertheimer and Leeper published their study about the relationship between the proximity to so-called power line poles (ELF MF) with "service drop" wires and the occurrence of childhood cancer (specifically leukemia and brain tumors) (48). At the same time Robinette et al. studied mortality in a cohort of Korean War veterans having been trained on military radars (RF) in the early 1950s (49). Both studies found indications of increased risks and initiated a new era of studying health-relevant effects from exposure to EMFs.

ELF MF

In the following years, a large number of investigations about the relationship between childhood leukemia and extremely low frequency magnetic fields (ELF MF) have been published. However, the results seemed inconsistent until in 2000 two pooled analyses (50, 51) were conducted, providing little indication of inconsistency and demonstrating an increase of leukemia risk with increasing average exposure levels that was significant for levels above 0.3 or 0.4 μT relative to averages below 0.1 μT but without indication of a threshold. Based on these findings, the International Agency for Research on Cancer (IARC) classified ELF MF in 2002 as a Group 2B (possible) carcinogen (30). To this category belong, e.g. lead, DDT, welding fumes, and carbon tetrachloride.

Since then additional epidemiological studies have been conducted that gave essentially the same results (52, 53). The only study to date on the gene-environment interaction in relation to power-frequency MF reported a significant effect enhancement in children with a polymorphism in a DNA-repair gene (54). In a review on childhood leukemia and ELF MF, Kundi concluded that there is sufficient evidence from epidemiological studies of an increased risk for childhood leukemia from exposure to power-frequency MF that cannot be attributed to chance, bias, or confounding. Therefore, according to the rules of IARC, such exposures ought to be classified as a Group 1 (definitive) carcinogen (55).

The BioInitiative Report 2012 (56) stated: "*Children who have leukemia and are in recovery have poorer survival rates if their ELF exposure at home* (*or where they are recovering*) *is between 1mG* [*0.1 μT*] *and 2 mG* [*0.2 μT*] *in one study; over 3 mG* [*0.3 μT*] *in another study*" (56).

RF

There were several mechanisms identified which might be responsible for carcinogenic effects of RF (23). Epidemiological studies of RF before the general rise in exposure to mobile telecommunication devices was very restricted and only a few studies had been conducted in the vicinity of radio transmitters, radar stations, for occupational exposures, and in radio amateurs. After the introduction of digital mobile telephony, the number of users of mobile phones increased dramatically and it was recommended in the 1990s to perform epidemiological studies with a focus on intracranial tumors. Since the first publication in 1999 by the Swedish group of Prof. Lennart Hardell (57), about 40 studies have been published. The majority of these studies investigated brain tumors, but salivary gland tumors, uveal melanoma, malignant melanoma of the skin, nerve sheath tumors, testicular cancer, and lymphoma were also studied. Many of these studies are inconclusive because exposure durations are too short; however, two series of investigations, the international Interphone Study conducted in 13 countries and the Swedish studies of the Hardell group, had a significant proportion of long-term mobile phone users and could in principle be used for risk assessment. In 2011, IARC classified radio-frequency electromagnetic fields (RF) as a Group 2B carcinogen based on evidence from epidemiological studies and animal experiments (24). Since then, additional studies have corroborated the assumption of a causal relationship between mobile phone use and cancer (58–60). Hardell and Carlberg (61) concluded that RF EMF ought to be classified as a definitive human carcinogen (IARC Group 1). The evidence for a causal relationship between long-term mobile and cordless phone use and the risk of glioma has increased further: in 2014, a study by Carlberg and Hardell (62) showed significantly decreased survival rates in patients with glioblastoma multiforme (astrocytoma grade IV) and the use of wireless phones and, in 2015, another pooled case-control study by Hardell and Carlberg (63) including latency periods of >25 years.

That also other tumors might be related to EMF exposure is exemplified by the observation in women who have worn their mobile phone in their bra for prolonged periods of time and later developed breast cancer at that site (64).

The Italian Supreme Court confirmed a previous decision by the Civil Court of Appeals of Brescia (no. 614 of 10 December 2009) that ruled that the National Institute for Workmen's Compensation (INAIL) must compensate a worker who had developed a tumor in the head due to long-term, heavy use of mobile phones while on the job. The case was an ipsilateral neuroma of the trigeminal nerve in a subject who had occupational exposure for >10 years, with >15,000 h on mobile and cordless phones. The court recognized that *"it is likely* (*qualified probability*) *that RF have a role which is at least contributory in the development of the origin of the tumor suffered by the subject"* (65).

Many modern devices emit EMF of different frequency ranges simultaneously. For example, mobile phones create EMF in RF, VLF, and ELF frequency ranges and also a static magnetic field; for a review see (23). Therefore, it is important to consider combined exposures for the assessment of health effects.

Genotoxic effects

Genotoxic effects of EMF dealing with DNA damage, mutations, chromatin structure, and DNA repair have recently been reviewed by Henry Lai in the Bioinititive Report (66) and by the IARC Working Group in the assessment of RF carcinogenicity (24). In general, about half of the available studies found genotoxicity (positive reports), although other studies did not (negative reports) (23). Of note, a similar ratio of positive and negative RF studies was reported for other biological endpoints (67–69). The evident reason for this eventual inconsistency is strong dependence of the EMF effects on a number of physical and biological parameters, which significantly varied between studies. These dependencies were established for both ELF (70–72) and RF effects (24, 27).

Among other parameters, in human lymphocytes, an individual variability in chromatin response to ELF has been reported, which might suggest a stronger response in cells from EHS individuals (72). The same research group performed comparative studies on genotoxicity with cells from EHS and carefully matched control subjects (73–75). The response of lymphocytes to RF from GSM mobile phones (915 MHz) and power-frequency magnetic fields (50 Hz) was investigated (73). The 53BP1 protein, which participates in the formation of DNA repair foci at the location of DNA double-strand breaks (DSB), was analyzed by immunostaining in situ. Exposure to either 915 MHz or 50 Hz significantly condensed chromatin and inhibited the formation of DNA repair foci. The EMF-induced responses in lymphocytes from healthy and hypersensitive donors were similar but not identical to the stress response induced by heat shock. The effects of GSM on chromatin and DNA repair foci in lymphocytes from EHS were further confirmed (74, 75). Although individual variability was observed, effects of RF from mobile phones strongly

depended on the carrier frequency/frequency channel (74–77). Regardless of the cell type (human lymphocytes, fibroblasts, or stem cells), the effects at the 905 MHz/GSM channel 74 on DNA repair foci and chromatin were consistently lower as compared to the effects at the 915 MHz/GSM channel 124. The data also indicated stronger effects of exposure to RF from UMTS mobile phone radiation at the frequency of 1947.4 MHz. These data provided evidence that different frequency channels of different types of mobile communications technologies should be tested separately in provocation studies with EHS. While some minor differences were detected, very similar ELF/RF effects were observed in cells from EHS and matched control subjects. It is likely that compensatory reactions at a more complex level of biological organization such as reactions of tissues, organs, and organ systems are less efficient in persons with EHS, thereby providing a stronger connection of the EMF cellular response with symptoms of hypersensitivity.

Neurological effects of EMF

Neurological and behavioral effects were among the earliest topics of research on potential adverse effects of ELF as well as RF EMFs (78, 79). Concerning epidemiological evidence, more than a decade before the seminal publication of Wertheimer and Leeper (48), Haynal and Regli reported in 1965 an approximately four-fold higher prevalence of a history of electrical engineering jobs in patients with amyotrophic lateral sclerosis (ALS) than in control subjects (80).

Functional, morphological, and biochemical changes at the cellular, tissue, and organism level, as well as behavioral changes have been studied under experimental conditions, and epidemiology has assessed the association between occupational and residential exposure to EMFs and neurodegenerative diseases as well as neurological symptoms.

Research has shown that EMFs (RF and ELF) have deleterious effects on brain neurons and brain functioning (81). Epidemiological research has also shown an increased risk for Alzheimer's and dementia from occupational and residential exposure to ELF.

Neurological effects of radio-frequency radiation

Early studies of RF are difficult to assess because the descriptions of exposure conditions are often insufficient to derive the relevant dosimetric quantities. As early as 1932, Schliephake (82) reported effects that he considered to be non-thermal: *„Es treten Erscheinungen auf, wie wir sie bei Neurasthenikern zu sehen gewohnt sind: starke Mattigkeit am Tag, dafür in der Nacht unruhiger Schlaf, zunächst ein eigenartig ziehendes Gefühl in der Stirn und Kopfhaut, dann Kopfschmerzen, die sich immer mehr steigern, bis zur Unerträglichkeit. Dazu Neigung zu depressiver Stimmung und Aufgeregtheit."* [*"Phenomena occur that we are accustomed to seeing in neurasthenics: pronounced fatigue during the day, however, restless sleep at night, in the beginning, a peculiar pulling sensation on the forehead and scalp, and then headaches that increase beyond the limit of tolerance. In addition, a tendency to depressive moods and agitation"*.] Such symptoms, not unlike those later summarized as microwave or radio wave sickness syndrome, have been found in a substantial percentage of exposed workers in the Soviet Union (83) and also in individuals presenting as electrohypersensitive (see below).

Experimental research in humans was scarce before the advent of digital mobile telephony. Since the earliest studies (84, 85) on brain electrical activity, a large evidence base has been compiled that indicates subtle changes in CNS function after and during short-term exposure to different types of RF. Experimental investigations were predominantly about effects on EEG power spectra (e.g. 86–96), event related potentials (e.g. 97–104), sleep (e.g. 105–119) and cognitive function (e.g. 120–131). A few investigations were about effects on glucose metabolism (132, 133) and regional cerebral blood flow (134, 135), applying PET scan imaging. Animal studies covered a wide variety of behavioral aspects, ranging from learning and memory (e.g. 136–141) to anxiety-related behavior (142).

The reaction of the CNS to RF is not restricted to the presence of the exposure but persists for some time after the exposure, making short-term cross-over studies uninformative. The location of exposure could be of relevance under certain circumstances, but often effects are bilateral after unilateral exposure, suggesting involvement of subcortical structures. Effects on sleep may depend on individual characteristics, which led to the conclusion that conflicting results are not strong evidence against an effect (113). Pulsed RF is more effective than continuous waves, but there is some evidence of the importance of exposure characteristics including the site of coupling of the RF field and its modulation.

In the 2012 update of the BioInitiative Report, Henry Lai summarized the experimental evidence as follows (143): *"Almost all the animal studies reported effects, whereas more human studies reported no effects than effects. This may be caused by several possible factors:* (a) *Humans are less susceptible to the effects of RFR than*

are rodents. (b) *It may be more difficult to do human than animal experiments, since it is, in general, easier to control the variables and confounding factors in an animal experiment*. (c) *In the animal studies, the cumulative exposure duration was generally longer and studies were carried out after exposure, whereas in the human studies, the exposure was generally one time and testing was done during exposure. This raises the question of whether the effects of RFR are cumulative"*.

Neurological effects of extremely low frequency electromagnetic fields (ELF EMF)

Neurophysiological investigations of ELF EMFs were already conducted in the 1970s. Studies of chick and cat brain tissue (e.g. 144–146) revealed effects of weak ELF EMFs and ELF modulated RF fields that depended on intensity and frequency (so-called window effects). Adey proposed in 1981 (147) that effects are due to a primary interaction of EMFs at the cell membrane surface inducing a cascade of intracellular processes. This early insight has been corroborated by recent studies on various transmitter receptors in the brain such as N-methyl-D-aspartate receptors, dopamine and serotonin receptors (e.g. 148–151). Some of these more recent studies also reported frequency window effects as well as intensity window effects on the neurodevelopment in the rat (152).

Behavioral effects of ELF EMF have been studied at rather high levels in the 1970s and 1980s (e.g. 153, 154), while recent studies include low-level exposures and support effects on behavior at different levels of complexity. These include: changes in locomotor activity (e.g. 148, 149, 155, 156), anxiety (e.g. 157–159) and depression-like behavior (160, 161). *"Since different behavioral effects have been observed in different exposure conditions, species of animals, and testing paradigms, they provide the strongest evidence that exposure to ELF EMF can affect the nervous system"*. (Lai, 2012, BioInitiative Report, section 9, Evidence for effects on neurology and behavior effects, 143). Also in humans, effects were reported at low levels (e.g. 162–164).

Neurodegenerative diseases

The most prevalent of neurodegenerative diseases is Alzheimer's disease with an estimated 45 million patients worldwide for 2015, followed by Parkinson's disease, Huntington's disease, amyothrophic lateral sclerosis (ALS), and other motoneuron diseases (MND). To date, the pathophysiology of these diseases is incompletely understood. In many of these diseases, atypical protein assemblies, mitochondrial dysfunction, and programmed cell death play a role and some genetic changes have been detected. As some such changes could be a consequence of oxidative stress (see below), disruption of calcium homoeostasis, and disturbance of intracellular signaling pathways, there is a theoretical possibility that EMFs could contribute to the risk of these diseases. Since the 1980s, more than 30 epidemiological studies assessing the potential relationship between exposure to ELF EMFs and neurodegenerative diseases have been conducted. In the last years, several meta-analyses have been published. Concerning Parkinson's disease, there is little evidence of an association (165). Concerning ALS, Zhou et al. (166) summarize their results as follows: *"Although there are potential limitations from study selection bias, exposure misclassification, and the confounding effect of individual studies in this meta-analysis, our data suggest a slight but significant ALS risk increase among those with job titles related to relatively high levels of ELF EMF exposure"*. A review by Vergara et al. came to another conclusion (167): *"Our results do not support MF [magnetic fields] as the explanation for observed associations between occupational titles and MND"*. This discrepancy can be resolved by discriminating between different methods of endpoint assessment (incidence, prevalence or mortality data) and the potential for misclassification due to various sources of exposure data used. If these factors are considered, there is a consistent relationship between ELF EMF from occupational exposure and ALS/MND, and also the few studies about residential exposure are in line with an increased risk from exposure to MF (168).

Blood-brain barrier

All exchanges between blood and brain are strictly regulated by the blood-brain barrier (BBB). The BBB prevents the passage of various molecules from the blood into the brain and vice versa. An increase in a normally low BBB permeability for hydrophilic and charged molecules could potentially be detrimental. While the data on ELF effects are very sparse, several research groups investigated whether RF affects the BBB. These data have recently been reviewed (169–171). Although some BBB studies reported negative data, other studies, including replicated studies with rats from the Swedish group of Leif Salford and Bertil Persson, suggested that RF from mobile phones may affect the BBB under specific exposure conditions (171). More recent studies showing EMF effects at specific conditions of

exposure (150, 172, 173) and not showing effects on the BBB under other conditions (174) are in line with this suggestion.

EMF and infertility and reproduction

Infertility and reproduction disorders are on the rise. Based on the BioInitiative Report (175), it should be concluded that men who use – and particularly those who wear a mobile phone, personal digital assistant (PDA) or pager on their belt or in a pocket – show adverse effects on sperm quality, motility, and pathology. The usage of mobile phones, the exposure to mobile phone radiation, or the storage of a mobile phone close to the testes of human males affects sperm count, motility, viability, and structure (176–184). Animal studies have demonstrated oxidative and DNA damage, pathological changes in the testes of animals, decreased sperm mobility and viability, and other measures of deleterious damage to the male germ line (182, 185–188).

There are also some studies of adverse birth outcomes in EMF-exposed women. A case-control study (189) and a population-based prospective cohort study (190) from California showed an association between miscarriage and the maximum value measured by a 24-h body-worn magnetic field dosimeter.

Electromagnetic hypersensitivity (EHS)

An increasing number of humans are continuously exposed in their daily life to increasing levels of a combination of static, ELF and VLF (very low frequencies, in general terms from 3 kHz to 3 MHz, in detailed terms from 3 kHz to 30 kHz) electric and magnetic fields and RF electromagnetic fields. These exposures are of different signal patterns, intensities, and technical applications for varying periods of time. All these fields are summarized as EMF, colloquially referred to as "electrosmog".

Some historical examples of EHS from as early as 1932 (82, 83) are given in the chapter "Neurological effects of radio-frequency radiation".

In a questionnaire survey in Switzerland in 2001, which was addressed to persons attributing specific health problems to EMF exposure, of the 394 respondents 58% suffered from sleep problems or disorders, 41% from headaches, 19% from nervousness, 18% from fatigue, and 16% from difficulties with concentration. The respondents attributed their symptoms to, e.g. mobile phone base stations (74%), mobile phones (36%), cordless phones (29%), and high-voltage power lines (27%). Two thirds of the respondents had taken measures to reduce their symptoms, the most frequent one being to avoid exposure (191).

In 2001, 63 persons who attributed health problems to environmental exposure were counseled in an interdisciplinary environmental medicine pilot project in Basel. An interdisciplinary expert team assessed the individual symptoms by a medical psychological-psychiatric and environmental examination, including visits and environmental measurements at home. With respect to the 25 persons with EHS, the expert team attested to the fact that in one third of them at least one symptom was plausibly related to electrosmog, although the EMF exposure was within the Swiss limits. They concluded that patients with EHS should be advised medically, psychologically, and environmentally (192, 193).

A questionnaire study of Finns (n=206), who describe themselves as suffering from electromagnetic hypersensitivity (EHS), revealed that the most common symptoms were related to the nervous system: stress (60%), sleeping disorders (59%) and fatigue (57%). The sources that were most often reported to have triggered EHS were: personal computers (51%) and mobile phones (47%). For 76% of the participants the reduction or avoidance of electromagnetic fields (EMF) helped in their full or partial recovery (194).

A representative telephone survey (n=2048; age>14 years) carried out in Switzerland in 2004 yielded a frequency of 5% (95% CI 4% to 6%) for having symptoms attributed to electrosmog, so-called EHS. In n=107 EHS persons, the most common symptoms being sleep problems (43%), headache (34%), and concentration difficulties (10%). Remarkably, only 13% consulted their family doctor. Individuals with a past history of symptoms attributable to EMF gave "turned off the source" as the answer to measures taken three times as often as the ones who still had symptoms (195).

In a Swiss questionnaire study of GPs in 2005, two-thirds of the doctors were consulted at least once a year because of symptoms attributed to EMF. Fifty-four percent of the doctors assessed a relation as possible. The doctors in this questionnaire asked for more general information about EMF and health and instructions on how to deal with patients with EHS (196).

In another questionnaire study, also mandated by the Swiss Federal Government and performed by the University of Bern in 2004, Swiss doctors working with complementary diagnostic and therapeutic tools reported that 71% of their consultations related to EMF. Remarkably, not only the patients but even more so the doctors suspected a possible relation between illness and EMF. The reduction or elimination of environmental sources was the main

therapeutic instrument in treating symptoms related to EMF (197).

A questionnaire study of Austrian doctors yielded similar results. In this study, the discrepancy between the physicians' opinions and established national and international health risk assessments was remarkable, considering that 96% of the physicians believed to some degree in or were totally convinced of a health-relevant role of environmental electromagnetic fields (198).

In a survey conducted 2009 in a Japanese EHS and multiple chemical sensitivity (MCS) self-help group (n = 75), 45% of the respondents had EHS as a medical diagnosis and 49% considered themselves EHS. Every second respondent had medically diagnosed MCS (49%) and 27% had self-diagnosed MCS. The main EHS-related symptoms were fatigue, headache, concentration problems, sleep disorders, and dizziness. The most frequent causes included base stations, other persons' mobile phones, PC, power lines, television, own mobile phone, public transportation, cordless phones, air conditioner, and car. Suspected EMF source of EHS onset were: mobile phone base stations, PC, electric home appliances, medical equipment, mobile phones, power lines, and induction cookers (199).

In 2010, Khurana et al. reported that eight out of ten epidemiological studies that assessed health effects of mobile phone base stations reported an increased prevalence of adverse neurobehavioral symptoms or cancer in populations living at distances within 500 m from base stations. None of the studies reported exposure levels above accepted international guidelines, suggesting that current guidelines may be inadequate in protecting the health of human populations (200).

Carpenter reported in 2015 (201) a series of healthy people that developed EHS after a brief, high-intensity microwave radiation exposure. Typical symptoms included, for example, chronic headaches, irritability, and emotional lability, decreased libido, and memory problems, which in some patients, lasted for years.

Hedendahl et al. (19) reported two 15-year-old male students and one 47-year-old female teacher who experienced health effects like headaches, difficulties concentrating, tachycardia, poor memory, or dizziness when exposed to Wi-Fi in school. This example is mentioned to point specifically to the potential health impacts from increasing RF exposure of students and teachers by Wi-Fi.

The question, whether EHS is causally associated with EMF exposure is controversially discussed. On the one hand, physicians judge a causal association between EMF exposures as plausible based on case reports, on the other hand, national and international health risk assessments mostly claim that there is no such causal association, because provocation studies under controlled blinded conditions mostly failed to show effects. However, these studies have severe shortcomings that must be addressed: sequences of exposure conditions were often contiguous neglecting aftereffects of exposure; the exposure duration and the examined effects were short-term; the sham exposure was frequently under conditions that could provoke arousal in sensitive individuals; the time frame neglected the temporal conditions of symptom occurrence and disappearance, and/or the recruitment of persons with EHS was not medically assessed.

The WHO does not consider EHS as a diagnosis and recommends to medical doctors that the treatment of affected individuals should focus on the health symptoms and the clinical picture, and not on a person's perceived need for reducing or eliminating EMF in the workplace or at home (202). Based on the existing evidence and practical knowledge this view ignores a causal approach; see also (203).

The paper "Electromagnetic hypersensitivity: fact or fiction" by Genuis and Lipp (204) offers an instructive review of studies of the last decades concerning EHS, including historical milestones, reviews, pathogenesis, biochemical markers, therapeutic management, as well as the debate about the legitimacy of EHS.

In facial skin samples of electrohypersensitive persons, a profound increase of mast cells has been found (205). From this and other earlier studies when EHS manifested itself often during exposure to EMFs from cathode ray tubes (CRT), it became clear that the number of mast cells in the upper dermis is increased in the EHS group. A different pattern of mast cell distribution also occurred in the EHS group. Finally, in the EHS group, the cytoplasmic granules were more densely distributed and more strongly stained than in the control group, and the size of the infiltrating mast cells was generally found to be larger in the EHS group as well. It should be noted that increases of a similar nature were later demonstrated in an experimental situation, employing normal healthy volunteers in front of CRT monitors, including ordinary household television sets (206).

A French research group headed by Belpomme (207) investigated prospectively, since 2009, self-reported cases of EHS and/or MCS clinically and biologically in an attempt to establish objective diagnostic criteria and to elucidate the pathophysiological aspects of these two disorders. Based on 727 evaluable cases, the investigation showed a number of new and important insights such as:

(a) None of the biomarkers so far identified in the study are specific for EHS and/or MCS.
(b) Several biomarkers like histamine, nitrotyrosine, and circulating antibodies against O-myelin were

increased. The 24-h urine melatonin/creatinine ratio was decreased.

(c) EHS and MCS are genuine somatic pathological entities.

(d) Under the influence of EMFs and/or chemicals a cerebral hypoperfusion/hypoxia-related neuroinflammation may occur.

(e) EHS and/or MCS patients might be potentially at risk of chronic neurodegenerative diseases and cancer.

While a 2006 study by Regel et al. (208) described no exposure effects, two provocation studies on exposure of "electrosensitive" individuals and control subjects to mobile phone base station signals (GSM, UMTS, or both) found a significant decline in well-being after UMTS exposure in the individuals reporting sensitivity (209, 210). Most so-called provocation studies with EHS show no effects. However, all these studies used a very limited number of exposure conditions and most have methodological weaknesses. Taking in account the strong dependence of EMF effects on a variety of physical and biological variables (27), available provocation studies are scientifically difficult to interpret and, in fact, are not suitable to disprove causality.

There is increasing evidence in the scientific literature of various subjective and objective physiological alterations, e.g. heart-rate variability (HRV) as apparent in some persons with EHS claiming to suffer after exposure to certain frequencies of RF like DECT or Wi-Fi (211–215). Analysis of the data available on the exposure of people living near mobile phone base stations has yielded clear indications of adverse health effects like fatigue, depression, difficulty in concentrating, headaches, dizziness, etc. (216–220). A synopsis of 30 studies on mobile phone base stations is given in the document "Leitfaden Senderbau" (221).

Residential EMF exposures in the VLF frequency range are often due to "dirty power"/"dirty electricity" originating from voltage and/or current perturbations from diverse sources like electronic power supplies for TVs, monitors, PCs, motor drives, inverters, dimmers, compact fluorescent lamps (CFLs), phase-angle control devices, as well as sparking and arcing from switching operations and from electric motors with brushes. The kHz waves/transients travel along the electric wiring and grounding systems (conducted emissions) and radiate electric and/or magnetic fields into free space (radiated emissions), leading to human exposures in the vicinity.

First epidemiological evidence links dirty electricity to most of the diseases of civilization including cancer, cardiovascular disease, diabetes, suicide, and attention deficit hyperactivity disorder in humans (222).

While the dependence of ELF effects on the local magnetic field has been reported by many research groups (13, 223), there are also a few studies which suggest that the RF effects are also dependent on slight changes in the local static magnetic field. In the review by Belyaev (224), a physical mechanism has been suggested to account for such effects (225). Slight changes in the local static magnetic field within 10 μT, which are usually observed within offices and homes due to ferromagnetic objects, were reported to induce biological effects that corresponded well to the predictions following from the mechanism of ion interference developed by Binhi (226).

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 (227).

In France, the first low-EMF zone has been established at Drôme in July 2009 (228). In Austria, the construction of a multi-family house has been planned for 2015, which was designed by a team of architects, building biology professionals, and environmental medicine health care professionals to provide a sustainable healthy living environment. Both the outdoor and indoor environments were explicitly chosen and designed to meet low-EMF requirements (229). The implementation of low-EMF zones for electrosensitive individuals is pursued in numerous countries. The realization of such projects greatly depends on the understanding, knowledge, and tolerance of the members of the chosen community.

Possible mechanism of EHS

Based on the scientific literature on interactions of EMF with biological systems, several mechanisms of interaction are possible (14, 13, 22, 26). A plausible mechanism at the intracellular and intercellular level, for instance, is an interaction via the formation of free radicals or oxidative and nitrosative stress (230–238). It has been shown in many reports reviewed by Georgiu (15) that reactive oxygen species (ROS) may be involved in radical pair reactions; thus, radical pairs may be considered as one of the mechanisms of transduction able to initiate EMF-induced oxidative stress. Furthermore, many of the changes observed in RF-exposed cells were prevented by (pre)treatment with antioxidants and radical scavengers (24). While the data from different studies should be interpreted with care in view of variations in physical and biological parameters, a majority of the studies have shown effects of ELF and RF on the oxidative stress (239).

The IARC monograph states: *"even small effects on radical concentration could potentially affect multiple biological functions"*, page 103 (24).

Yakymenko et al. (238) have summarized the current evidence: *"Analysis of the currently available peer-reviewed scientific literature reveals molecular effects induced by low-intensity RFR in living cells; this includes significant activation of key pathways generating reactive oxygen species* (*ROS*), *activation of peroxidation, oxidative damage of DNA and changes in the activity of antioxidant enzymes. It indicates that among 100 currently available peer-reviewed studies dealing with oxidative effects of low-intensity RFR, in general, 93 confirmed that RFR induces oxidative effects in biological systems. A wide pathogenic potential of the induced ROS and their involvement in cell signaling pathways explains a range of biological/health effects of low-intensity RFR, which include both cancer and non-cancer pathologies"*.

Reviews by Pall (12, 16, 240) provide evidence for a direct interaction between static and time-varying electric fields, static and time-varying magnetic fields and electromagnetic radiation with voltage-gated calcium channels (VGCCs). The increased intracellular Ca^{2+} produced by such VGCC activation may lead to multiple regulatory responses, including increased nitric oxide levels produced through the action of the two Ca^{2+}/calmodulin-dependent nitric oxide synthases, nNOS and eNOS. In most pathophysiological contexts, nitric oxide reacts with superoxide to form peroxynitrite, a potent non-radical oxidant, which can produce radical products, including hydroxyl and NO_2 radicals.

Peroxynitrite is by far the most damaging molecule that occurs during metabolism in our body. Although not a free radical, peroxynitrite is much more reactive than its parent molecules NO and O_2^-. The half-life of peroxynitrite is comparatively long (10–20 ms), sufficient to cross biological membranes, diffuse one to two cell diameters, and allow significant interactions with most critical biomolecules and structures (cell membranes, nucleus DNA, mitochondrial DNA, cell organelles), and a large number of essential metabolic processes (225). Elevated nitrogen monoxide, formation of peroxynitrite, and induction of oxidative stress can be associated with chronic inflammation, damage of mitochondrial function and structure, as well as loss of energy, e.g. via the reduction of adenosine triphosphate (ATP).

A significant increase of 3-nitrotyrosine was observed in the liver of Wistar rats exposed to ELF, suggesting a deteriorative effect on cellular proteins due to possible formation of peroxynitrite (241). Nitrotyrosin was found to be increased (>0.9 μg/mL) in 30% of the 259 tested EHS individuals (207).

A study by De Luca et al., in 2014 on 153 EHS and 132 controls showed metabolic pro-oxidant/pro-inflammatory alterations in EHS like decreased erythrocyte glutathione S-transferase (GST) activity, decreased reduced glutathione (GSH) levels, increased erythrocyte glutathione peroxidase (GPX) activity, an increased ratio of oxidized-CoQ10/total-CoQ10 in plasma, and a 10-fold increased risk associated with EHS for the detoxifying enzymes glutathione S transferase haplotype (null) GSTT1+(null) GSTM1 variants (242).

The importance of ATP has been shown for chronic fatigue syndrome (CFS) (243) and for stress control (244). Those patients describe the same symptoms as those suffering from CMI. This could indicate similarities in their pathomechanisms. Similar disturbances in neurotransmitter expression has been described both with chronic exposure to EMF (245) and in CMI patients (232, 246).

A study (247) proposed to investigate a possible association between RF exposure and myelin integrity via classical immunohistochemical markers for healthy and degenerated myelin, respectively, and for Schwann cells in general.

Complaints in chronic fatigue syndrome (CFS), fibromyalgia (FM), multiple chemical sensitivity (MCS), post-traumatic stress disorder (PTSD), and Gulf War syndrome (GWS) are almost the same. Meanwhile, they are summarized as chronic multisystem illnesses (CMI) (246). In all of them, various disturbances of functional cycles have been shown: activation of nitrogen oxide and peroxynitrite, chronic inflammation by activation of NF-kB, IFN-y, IL-1, IL-6, and interaction with neurotransmitter expression (232, 246, 248). We recommend classifying EHS as part of CMI (232, 249), but still recognizing that the underlying cause remains the environment (see Figure 1).

Other diseases that require attention with respect to EMF

Based on interactions between EMF exposure and biological responses that, e.g. lead to a disturbance of the oxidative/nitrosative homeostasis, a variety of diseases are possible and even expected to occur. Some examples are given here.

Havas reported in 2008 (250): *"Transient electromagnetic fields (dirty electricity), in the kilohertz range on electrical wiring, may be contributing to elevated blood sugar levels among diabetics and prediabetics. By closely following plasma glucose levels in four Type 1 and Type 2 diabetics, we find that they responded directly to the amount of dirty electricity in their environment. In an electromagnetically*

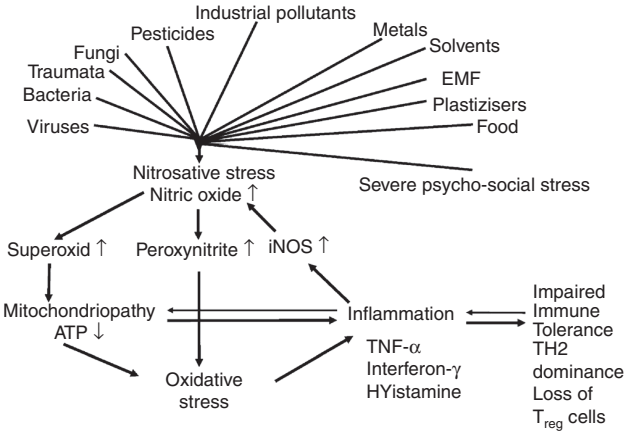

Figure 1: Pathogenesis of inflammation, mitochondriopathy, and nitrosative stress as a result of the exposure to trigger factors (248).

clean environment, Type 1 diabetics require less insulin and Type 2 diabetics have lower levels of plasma glucose. Dirty electricity, generated by electronic equipment and wireless devices, is ubiquitous in the environment. Exercise on a treadmill, which produces dirty electricity, increases plasma glucose. These findings may explain why brittle diabetics have difficulty regulating blood sugar. Based on estimates of people who suffer from symptoms of electrical hypersensitivity (3%–35%), as many as 5–60 million diabetics worldwide may be affected".

With respect to fetal and early childhood exposures to EMF, Sage in the BioInitiative Report 2012 (56) pointed out: *"Fetal (in-utero) and early childhood exposures to cell phone radiation and wireless technologies in general may be a risk factor for hyperactivity, learning disorders and behavioral problems in school." [&] "Common sense measures to limit both ELF EMF and RF EMF in these populations is needed, especially with respect to avoidable exposures like incubators that can be modified; and where education of the pregnant mother with respect to laptop computers, mobile phones and other sources of ELF EMF and RF EMF are easily instituted".*

In a 2013 review, Herbert and Sage (251, 252) reported remarkable similarities between pathophysiological phenomena found in autism spectrum conditions (ASCs) and the physiological impacts of ELF MF/RF, such as oxidative stress, free radical damage, malfunctioning membranes, mitochondrial dysfunction, inflammatory issues, neuropathological disruption and electrophysiological dysregulation, cellular stress proteins and deficiencies of antioxidants such as glutathione.

In a 6-year study, certain blood hormone levels were monitored in volunteers. Mobile phone use as well as close distances to mobile phone base stations were associated with decreased testosterone levels in males, as well as decreased ACTH, cortisol, T3 and T4 levels in males and females (253).

Recommendations for action

EUROPAEM has developed guidelines for differential diagnosis and potential treatment of EMF-related health problems with the aim to improve/restore individual health outcomes and to propose strategies for prevention. These recommendations are further outlined below.

These recommendations are preliminary and in large parts, although related to the whole body of evidence rooted in the experience of the team, cannot in every detail be strictly considered evidence-based.

Evidence of treatment strategies for EMF-related illness including EHS

There are only a few studies assessing therapeutic approaches to EHS. The interdisciplinary based assessing and counseling of EHS in the Swiss Environmental Pilot Project performed in 2001 showed, in an evaluation interview half a year after counseling, that 45% of the persons with EHS had benefitted from realizing certain advice, e.g. changing the bedroom (192, 193).

In the 2005 Swiss questionnaire study of physicians working with complementary therapeutic tools, two-thirds chose exposure reduction as a principal tool, whereas complementary therapeutics were only chosen as a supplement (197).

Since 2008, the Swiss Society of Doctors for the Environment has run a small interdisciplinary environmental medicine counseling structure for patients with EHS, which is embedded in everyday practice with a central coordination and consultation office as well as a network of general practitioners interested in environmental medicine who perform environmental medical assessments and consultations based on a standard protocol. If necessary, environmental experts are consulted and home inspections are conducted. The aim of the assessments is to detect or rule out common diseases and to analyze the impact of suspected environmental burdens on the complaints in order to find individual therapeutic approaches. The main instrument of the assessment is an extensive medical and psycho-social history with an additional environmental history, including a systematic questionnaire and environmental key questions.

In the first years, the project was scientifically assessed. In a questionnaire 1 year after counseling, 70% of the persons recommended the interdisciplinary based counseling structure and 32% of them considered the counseling as being helpful. Therefore, a model based on such an interdisciplinary concept, embedded in the family doctor's holistic and lasting concept of treatment, seems to be promising for a better therapeutic approach to EHS, also including accessibility measures targeted at the actual environment (254).

In Finland, psychotherapy is the officially recommended therapy for EHS. In a questionnaire study of EHS people in Finland, symptoms, perceived sources and treatments, the perceived efficacy of medical and complementary alternative treatments (CAM) in regards to EHS were evaluated by multiple choice questions. According to 76% of the 157 respondents, the reduction or avoidance of EMF helped in their full or partial recovery. The best treatments for EHS were given as weighted effects: dietary change (69.4%), nutritional supplements (67.8%), and increased physical exercise (61.6%). The official treatment recommendations of psychotherapy (2.6%) were not significantly helpful, or for medication (−4.2%) even detrimental. The avoidance of electromagnetic radiation and fields effectively removed or lessened the symptoms in persons with EHS (194, 255).

Response of physicians to this development

In cases of unspecific health problems (see Questionnaire) for which no clearly identifiable cause can be found – besides other factors like chemicals, non-physiological metals, molds – EMF exposure should, in principle, be taken into consideration as a potential cause or cofactor, especially if the person presumes it.

A central approach for a causal attribution of symptoms is the assessment of variation in health problems depending on time and location and individual susceptibility, which is particularly relevant for environmental causes such as EMF exposure.

Regarding such disorders as male infertility, miscarriage, Alzheimer's, ALS, blood sugar fluctuations, diabetes, cancer, hyperactivity, learning disorders and behavioral problems in school, it would be important to consider a possible link with EMF exposure. Some people with EHS might be misdiagnosed with multiple sclerosis (MS) since many of the symptoms are similar. This offers an opportunity to causally influence the course of the disease.

How to proceed if EMF-related health problems are suspected

The recommended approach to diagnosis and treatment is intended as an aid and should, of course, be modified to meet the needs of each individual case (see Figure 2).

1. History of health problems and EMF exposure
2. Medical examinations and findings
3. Measurement of EMF exposure
4. Reduction and prevention of EMF exposure
5. Diagnosis
6. Treatment of the patient including the environment

History of health problems and EMF exposure

In order to put later findings into a larger context, a general medical history is necessary. Part of this history should include:

- Electrical trauma: multiple shocks, electrocution, struck by lightning.
- Chemical trauma: exposure to pesticides, metals, chlorinated hydrocarbons (PCBs, DDT, etc.)

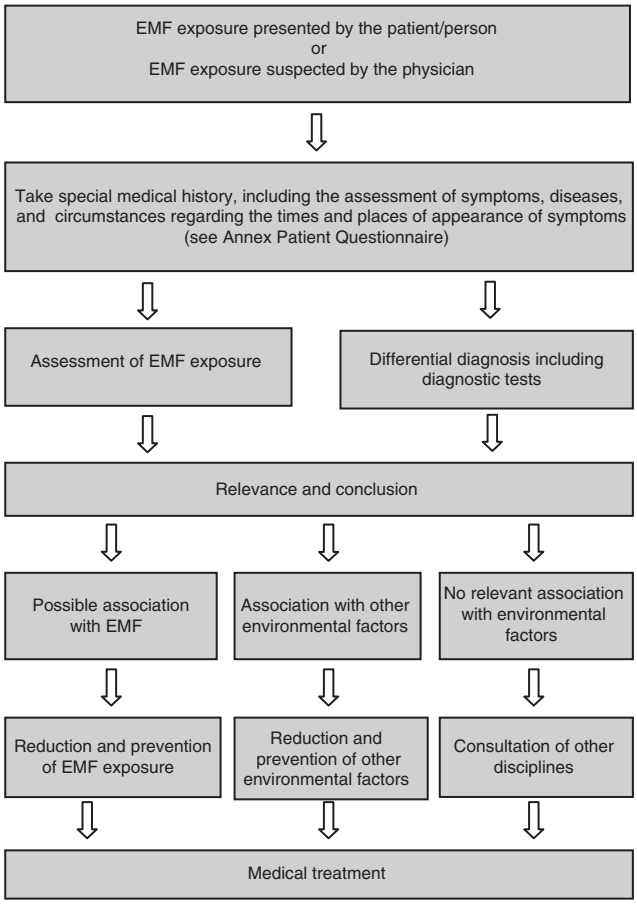

Figure 2: Flowchart for the handling of EMF-related health problems.

- Biological trauma in the form of a large load of parasites, fungal infections, viral infections, etc.
- Physical trauma to the central nervous system in the form of whiplash, other accidents, spinal problems
- Autoimmune disorders

In the next steps, we focus only on EMF-related health effects.

A questionnaire to take a systematic history of health problems and EMF exposure, compiled by the EUROPAEM EMF Working Group, is available in the Annex of this EMF Guideline.

The questionnaire consists of three sections:

(a) List of symptoms
(b) Variation of health problems depending on time, location, and circumstances
(c) Assessment of certain EMF exposures that can be evaluated by questionnaire

The list of symptoms in the questionnaire serves to systematically quantify health problems regardless of their causes. It also includes questions as to when the health problems first occurred. Most EMF-related symptoms are nonspecific and fall within the scope of health problems due to inadequate regulation (decompensation), e.g. sleep problems, fatigue, exhaustion, lack of energy, restlessness, heart palpitations, blood pressure problems, muscle and joint pain, headaches, increased risk for infections, depression, difficulty concentrating, disturbances of coordination, forgetfulness, anxiety, urinary urgency, anomia (difficulty finding words), dizziness, tinnitus, and sensations of pressure in the head and ears.

The health problems may range in severity from benign, temporary symptoms, such as slight headaches or paresthesia around the ear, e.g. when using a mobile phone, or flu-like symptoms after maybe some hours of whole-body EMF exposure, to severe, debilitating symptoms that drastically impair physical and mental health. It has to be stressed that, depending on the individual state of susceptibility, EHS symptoms often occur only occasionally, but over time they may increase in frequency and severity. On the other hand, if a detrimental EMF exposure is sufficiently reduced, the body has a chance to recover and EHS symptoms will be reduced or will vanish.

Variation of health problems depending on time, location, and circumstances

The answers to questions of when and where the health problems occur or recede, and when and where the symptoms increase or are particularly evident, provide only indications. They must be interpreted by the investigator (e.g. regarding the correct attribution between location/EMF sources and health problems). Special attention should be drawn to sleeping areas, because of the duration of influence and the vital role of sleep for regeneration.

Assessment of certain EMF exposures that can be evaluated by questionnaire

The assessment of EMF exposure usually starts with certain questions of usual EMF sources. Regardless of whether or not the patient suspects EMF exposure as a cause, these questions should be used to assess the existing exposure level, at least as a rough estimate. It is important to note that only certain types of EMF exposure can be assessed by means of questions, such as the use of compact fluorescent lamps, mobile phones, and cordless phones. Detection of other types of EMF exposure, e.g. due to RF transmitter sites or the electric or magnetic fields from electric wiring, generally requires measurements. In principle, questions should be asked to assess EMF exposure at home and at work and when on holidays and so on, keeping in mind that the degree of EMF exposure may vary at different times.

Medical examinations and findings

We do not have any clinical findings yet that are specific to EMF, which makes diagnosis and differential diagnosis a considerable challenge.

A method that has proven useful is to use stress-associated findings for diagnosis and follow-up and to evaluate them synoptically. Basic diagnostic tests should be carried out as a first step, followed by measurements of EMF exposure as a second step. The core diagnosis should focus on investigations of nitric oxide production (nitrotyrosine), mitochondriopathy (intracellular ATP), oxidative stress-lipid peroxidation (MDA-LDL), inflammation [TNF-alpha, IFN-gamma-inducible protein 10 (IP-10), IL-1b, histamine], and the melatonin status (24 h urine melatonin/creatinine ratio).

Then additional diagnostic tests can be considered. Due to the differences in normal ranges between labs and different practices as to the units of measurement in different countries, we do not provide levels to be considered relevant in EHS. It is recommended to interpret them in context, focusing not only on out-of-range values. For example, when several parameters are simultaneously close to the border of the normal ranges, this could be instructive for forming a therapeutic or diagnostic opinion.

Functional tests

Basic diagnostic tests

- Blood pressure and heart rate (in all cases resting heart rate in the morning while still in bed), including self-monitoring, possibly several times a day, e.g. at different locations and with journaling of subjective well-being for a week.

Additional diagnostic tests

- 24-h blood pressure monitoring (absence of nighttime decline)
- 24-h ECG (heart rhythm diagnosis)
- 24-h heart rate variability (HRV) (autonomous nervous system diagnosis)
- Ergometry under physical stress
- Sleep EEG at home

Laboratory tests

Basic diagnostic tests

- Blood
  - ACTH
  - Bilirubin
  - Blood count and differential blood count
  - BUN
  - Cholesterol, LDL, HDL, triglycerides
  - Coenzyme-Q10 ratio for oxidized-CoQ10/total-CoQ10
  - Creatinine kinases (CK-MB, CK-MM)
  - High-sensitivity C-reactive protein (hs-CRP)
  - Cystatin C (glomerular filtration rate)
  - Electrolytes
  - Fasting blood glucose
  - Ferritin
  - Glutathione S-transferase (GST)
  - Reduced glutathione (GSH)
  - Glutathione peroxidase (GPX)
  - HBA_{1c}
  - Histamine and diaminoxidase (DAO)
  - IFN-gamma-inducible protein 10 (IP-10)
  - Interleukin-1 (e.g. IL-1a, IL-1b)
  - Intracellular ATP
  - Liver enzymes (e.g. ALT, AST, GGT, LDH, AP)
  - Magnesium (whole blood)
  - Malondialdehyde (MDA)-LDL
  - Nitrotyrosine (NTT)
  - Potassium (whole blood)
  - Prolactin
  - Selenium (whole blood)
  - Testosterone
  - TSH
  - T3, T4
  - Tumor necrosis factor alpha (TNFα)
  - Vitamin D3
  - Zinc (whole blood)
- Standard urine
  - Leucocytes, erythrocytes, albumin, urobilinogen, pH, bacteria, glucose, microalbumin
- Second morning urine
  - Adrenaline
  - Dopamine
  - Noradrenaline
  - Noradrenaline/adrenaline ratio
  - Serotonin
  - Beta-phenylethyleamine (PEA)
- 24-h urine
  - 6-OH melatonin sulfate
  - Creatinine
  - 6-OH melatonin sulfate/creatinine ratio
- Saliva
  - Cortisol (8 a.m., 12 a.m., and 8 p.m.)

Additional diagnostic tests

- Urine
  - Metals (depending on case history, e.g. mercury, cadmium, lead, arsenic, aluminum)
- Second morning urine
  - Gamma-aminobutyric acid (GABA)
  - Glutamate
  - Cryptopyrrole
- Saliva
  - Dehydroepiandrosterone DHEA (8 a.m. and 8 p.m.)
  - Alpha-amylase
- Blood
  - 8-Hydroxydeoxyguanosine (DNA oxidation)
  - Biotin
  - Differential lipid profile
  - Folate
  - Holotranscobolamin
  - Homocysteine
  - Interferon-gamma (IFN-γ)
  - Interleukin-10 (IL-10)
  - Interleukin-17 (IL-17)
  - Interleukin-6 (IL-6)
  - Interleukin-8 (IL-8)
  - Intracellular glutathione (redox balance)
  - Lactate, pyruvate incl. ratio
  - Lipase
  - NF-kappa B
  - Vitamin B6 (whole blood)

Provocation tests

Special facilities with the use of a variety of signals, e.g. DECT or Wi-Fi exposure (e.g. 20–60 min, depending on

the individual regulation capacity, susceptibility, and observed response)

- Heart rate variability (HRV) (autonomous nervous system diagnosis)
- Microcirculation
- Oxidative stress (lipid peroxidation, malondialdehyde, oxo-LDL)
- For diabetics, plasma glucose
- Live blood analysis (red blood cell aggregation in the form of rouleaux, blood viscosity, macrophage activity, lysis of red blood cell membrane)
- For people with neurological problems and problems with fine or gross motor coordination, a video of them walking before and after provocation and a photograph taken of a sample of handwriting before and after provocation.

Individual susceptibility

- Blood (genetic parameters and actual function)
  - Glutathione S transferase M1 (GSTM1) – detoxification
  - Glutathione S transferase T1 (GSTT1) – detoxification
  - Superoxide dismutase 2 (SOD2) – protection of mitochondria
  - Catechol-O-methyltransferase (COMT) – stress control

Measurement of EMF exposure

The evolutionary development of the human species took place under the presence of the natural electromagnetic spectrum (Earth's magnetic field, Earth's electric field, spherics, Schumann resonance). Those influences have been part of our biosphere like the oxygen content in the air or the visible light spectrum, and they have been integrated into the biological functions (14).

By now, nearly all non-ionizing parts of the electromagnetic spectrum are filled with artificial, technical EMF sources due to electrification and (wireless) communication technologies, but are very rarely found in nature (see Figure 3). EMF measurements and/or exposure damages are usually not covered by statutory health care insurance.

In general, a wide variety of EMF exposure types (static fields, ELF, VLF, and RF) should be considered.

- ELF magnetic fields may originate from, e.g. 12 V transformers, transformer stations, net currents on the electric wiring, water pipes, and other conductive materials, infrared heaters, heating blankets and different types of power lines.
- ELF electric fields may originate from, e.g. electrical wiring, lamps, and appliances.
- VLF magnetic fields ("dirty power") and/or VLF electric fields ("dirty electricity") may be emitted from electronic

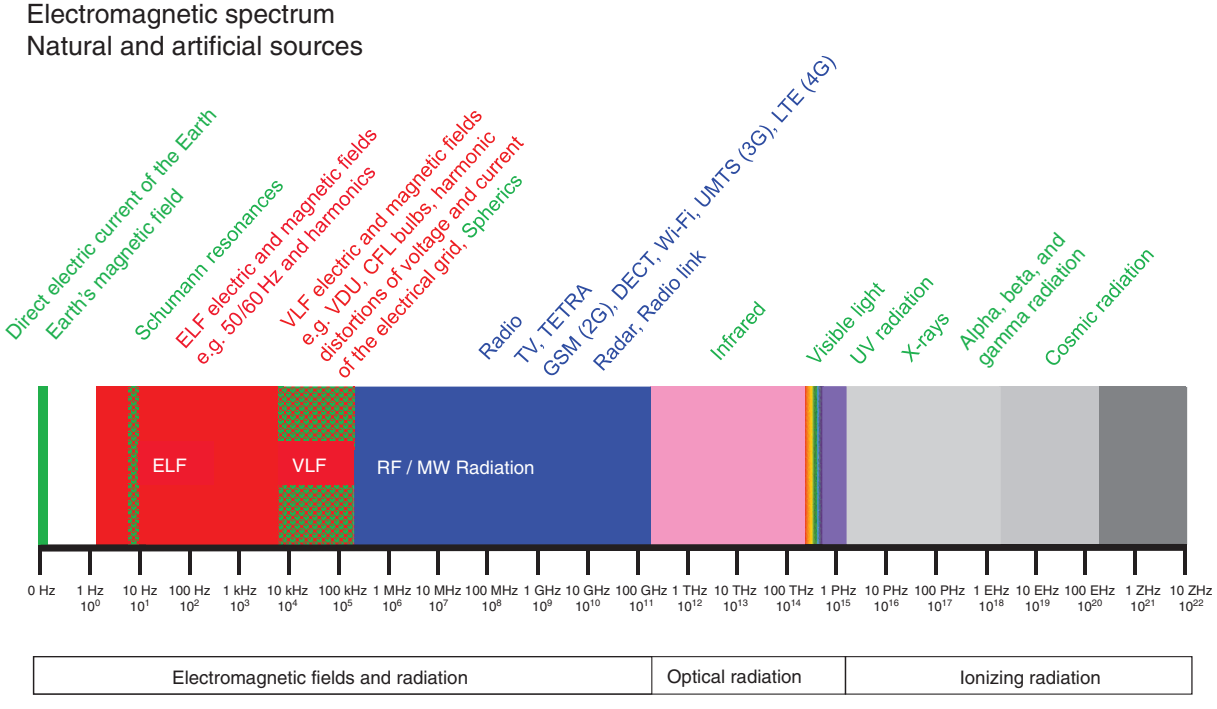

Figure 3: Examples of natural (green) and artificial (red and blue) EMF sources along the electromagnetic spectrum (256).

devices like energy-efficient lighting, electronic transformers, induction cooker, variable speed frequency drives, light dimmer switches, power line communication (PLC) connected to the electrical grid. These devices use current and/or voltage in short pulses that might produce harmonics and VLF transients on the electrical circuits, earthed materials and the ground.
- Typical RF radiation sources include, e.g. cordless phones (DECT), wireless Internet access (Wi-Fi), mobile phones and their base stations, radio and TV broadcast antennas, radar (military, airport, marine, and weather), Bluetooth, and the microwave ovens.

In the sleeping area, the most important exposure point is the head and trunk region followed by all other points with chronic or high exposure.

EMF measurements should be planned and carried out by specially trained and experienced testing specialists and always in accordance with relevant standards, e.g. the VDB Guidelines of the German Association of Building Biology Professionals (257). In addition to the measurement results, the measurement report should also include suggestions on how to possibly reduce the EMF exposure.

To clarify certain issues, personal dosimeters with a data logging function are available to measure ELF magnetic fields and radio-frequency radiation.

After the measurements have been commissioned by the person and carried out, the results should be discussed with a physician familiar with the EMF issue.

EMF guidance values

In each case, the following aspects should be individually taken into account when evaluating EMF measurement results (27, 26):
- A person's individual susceptibility, which, e.g. may be based on previous history of trauma (electrical, chemical, biological and physical).
- A person's individual total body burden (e.g. exposure to noise, chemicals like neurotoxins)
- Duration of EMF exposure
- EMF exposure during the night and day
- Multiple exposure to different EMF sources
- Signal intensity: watt/m^2 (W/m^2), volt/m (V/m), ampere/m (A/m)
- Signal characteristics were taken into account in the EMF guidance values – see Supplement 3 (258)
  - Frequency
  - Risetime (ΔT) of bursts, transients, etc.
  - Frequency and periodicity of bursts, e.g. certain GSM base stations (8.3 Hz), Wi-Fi networks (10 Hz), DECT cordless phones (100 Hz)
  - Type of modulation (frequency modulation, amplitude modulation, phase modulation)

Regardless of the ICNIRP recommendations for specific acute effects, the following guidance values (Tables 1–3, 5 and 6) apply to sensitive locations with long-term exposure of more than 20 h per week (259). They are based on epidemiological studies (9, 10, 27, 221, 260–262), empirical observations, and measurements relevant in practice (258, 263), as well as recommendations by the Seletun Statement (40) and the Parliamentary Assembly of the Council of Europe (42). The proposed guidance values are based on scientific data including a preventive component and aim to help restore health and well-being in already compromised patients. All levels provided are for incident intensities and whole-body exposure.

ELF magnetic fields (extremely low frequency) (ELF MF)

Measurement specifications

Frequency range: 50/60 Hz mains electricity, up to 2 kHz. 16.7 Hz railroad systems in Austria, Germany, Switzerland, Sweden, and Norway, 400 Hz on airplanes
Type of measurement: Magnetic induction or flux density [T; mT; μT; nT]
Field probe: Isotropic magnetic field probe (three orthogonal axes)
Detector mode: RMS (root mean square)
Measurement volume: Bed: Short-term measurements across entire sleeping area. Workplace: Short-term measurements across entire work area (e.g. sitting position). Long-term measurements: e.g. point close to the head/trunk in bed or at workplace
Measurement period: Short-term measurements to identify field sources. Long-term measurements during sleep and work shift
Basis for evaluation: Long-term measurements: maximum (MAX) and arithmetic mean (AVG)

Precautionary guidance values

In areas where people spend extended periods of time (>4 h per day), minimize exposure to ELF magnetic fields to levels as low as possible or below the precautionary guidance values specified below.

Table 1: Precautionary guidance values for ELF magnetic fields.

ELF magnetic field	Daytime exposure	Nighttime exposure	Sensitive populations
Arithmetic mean (AVG)	100 nT (1 mG)[1),2),3)]	100 nT (1 mG)[1),2),3)]	30 nT (0.3 mG)[5)]
Maximum (MAX)	1000 nT (10 mG)[2),4)]	1000 nT (10 mG)[2),4)]	300 nT (3 mG)[5)]

Based on: [1)]BioInitiative (9, 10); [2)]Oberfeld (262); [3)]Seletun Statement (40), [4)]NISV (264); [5)]Precautionary approach by a factor of 3 (field strength). See also IARC 2002 (30), Blank and Goodman (17), and TCO Development (265).

Evaluation guidelines specifically for sleeping areas

Higher frequencies than the mains electricity at 50/60 Hz and distinct harmonics should be evaluated more critically. See also the precautionary guidance values for the VLF frequency range further below. If applicable, mains current (50/60 Hz) and traction current (16.7 Hz) should be assessed separately but added (squared average). Long-term measurements should be carried out especially at nighttime, but at least for 24 h.

ELF electric fields (extremely low frequency) (ELF EF) Measurement specifications

Frequency range: 50/60 Hz mains electricity, up to 2 kHz.16.7 Hz railroad systems in Austria, Germany, Switzerland, Sweden, and Norway
Type of measurement: Electric field [V/m] without ground reference (potential-free)
Field probe: Isotropic electric field probe (three orthogonal axes)
Detector mode: RMS (root mean square)
Measurement volume: Bed: Nine points across sleeping area. Workplace: Across entire work area (e.g. sitting position three or six points)
Measurement period: Spot measurements to assess the exposure as well as to identify field sources. Since electric field exposure levels in the ELF frequency range usually do not change, long-term measurements are not needed.
Basis for evaluation: Spot measurements (maximum) at relevant points of exposure

Precautionary guidance values

In areas where people spend extended periods of time (> 4 h per day), minimize exposure to ELF electric fields to levels as low as possible or below the precautionary guidance values specified below.

Table 2: Precautionary guidance values for ELF electric fields.

ELF electric field	Daytime exposure	Nighttime exposure	Sensitive populations
Maximum (MAX)	10 V/m[1), 2)]	1 V/m[2)]	0.3 V/m[3)]

Based on: [1)]NCRP Draft Recommendations on EMF Exposure Guidelines: Option 2, 1995 (261); [2)]Oberfeld (262); [3)]Precautionary approach by a factor of 3 (field strength). See also TCO Development (265).

Evaluation guidelines specifically for sleeping areas

Higher frequencies than the mains electricity at 50/60 Hz and distinct harmonics should be evaluated more critically. See also the precautionary guidance values for the VLF frequency range further below.

Radio-frequency radiation (RF) Measurement specifications

Frequency range: Radio and TV broadcast antennas, mobile phone base stations, e.g. TETRA (400 MHz),GSM (900 and 1800 MHz), UMTS (2100 MHz),LTE (800, 900, 1800, 2500–2700 MHz), cordless phone base stations, e.g. DECT (1900), Wi-Fi access points and clients (2450 and 5600 MHz), WiMAX (3400–3600 MHz). Above frequencies in MHz refer to European networks.
Type of measurement: Usually electric field [V/m] -> calculated power density [W/m^2; mW/m^2; μW/m^2]; for conversion units see Table 4.
Field probe: Isotropic, biconical or logarithmic-periodic antennas
Detector mode: Peak detector with max hold
Measurement volume: Point of exposure across bed and workplace
Measurement period: Usually short-term measurements to identify RF field sources (e.g. acoustic analysis) and peak readings
Basis for evaluation: Band-specific or frequency-specific spot measurements (peak detector with max hold) of common signals at relevant points of exposure (e.g. with spectrum analyzer or at least band-specific RF meter)

Precautionary guidance values for selected RF sources

In areas where people spend extended periods of time (>4 h per day), minimize exposure to radio-frequency radiation to levels as low as possible or below the precautionary guidance values specified below. Frequencies to be measured should be adapted to each individual case. The specific guidance values take the signal characteristics of risetime (ΔT) and periodic ELF "pulsing" into account (258). *Note: Rectangular signals show short risetimes and consist of a broad spectrum of frequencies. The current density induced in the human body increases with increasing frequency in an approximately linear relationship* (266).

Table 3: Precautionary guidance values for radio-frequency radiation.

RF source Max Peak/ Peak Hold	Daytime exposure	Nighttime exposure	Sensitive populations[1)]
Radio broadcast (FM)	10,000 μW/m^2	1000 μW/m^2	100 μW/m^2
TETRA	1000 μW/m^2	100 μW/m^2	10 μW/m^2
DVBT	1000 μW/m^2	100 μW/m^2	10 μW/m^2
GSM (2G) 900/1800 MHz	100 μW/m^2	10 μW/m^2	1 μW/m^2
DECT (cordless phone)	100 μW/m^2	10 μW/m^2	1 μW/m^2
UMTS (3G)	100 μW/m^2	10 μW/m^2	1 μW/m^2
LTE (4G)	100 μW/m^2	10 μW/m^2	1 μW/m^2
GPRS (2.5G) with PTCCH* (8.33 Hz pulsing)	10 μW/m^2	1 μW/m^2	0.1 μW/m^2
DAB+ (10.4 Hz pulsing)	10 μW/m^2	1 μW/m^2	0.1 μW/m^2
Wi-Fi 2.4/5.6 GHz (10 Hz pulsing)	10 μW/m^2	1 μW/m^2	0.1 μW/m^2

*PTCCH, packet timing advance control channel.
Based on: BioInitiative (9, 10); Kundi and Hutter (260); Leitfaden Senderbau (221); PACE (42); Seletun Statement (40). [1)]Precautionary approach by a factor of 3 (field strength)= a factor of 10 (power density). See also IARC 2013 (24) and Margaritis et al. (267).

Table 4: Conversion of radio-frequency radiation measurement units.

Conversion	mW/m²	10	1	0.1	0.01	0.001	0.0001
of RF	μW/m²	10,000	1000	100	10	1	0.1
Measurement	μW/cm²	1	0.1	0.01	0.001	0.0001	0.00001
units	V/m	1.9	0.6	0.19	0.06	0.019	0.006

Magnetic fields in the VLF range (VLF MF) Measurement specifications

Frequency range: 3 kHz–3 MHz. Frequency-specific measurements (spectrum analyzer/EMF meter), e.g. "dirty power", powerline communication (PLC), radio-frequency identification transmitters (RFID), compact fluorescent lamps (CFL)
Type of measurement: Magnetic field [A/m] – > calculated magnetic induction [T; mT; μT; nT]
Field probe: Isotropic or anisotropic magnetic field probe
Detector mode: RMS (root mean square)
Measurement volume: Point of exposure across bed and workplace
Measurement period: Short-term measurements to identify field sources. Long-term measurements during sleep and work shift
Basis for evaluation: Long-term measurements: RMS detector, arithmetic mean and maximum at relevant points of exposure
Note: If an elevated exposure is detected, power quality analyzers and oscilloscopes can be used on the actual wiring to trace the source of the dirty power.

Precautionary guidance values

In areas where people spend extended periods of time (>4 h per day), minimize exposure to VLF magnetic fields to levels as low as possible or below the precautionary guidance values specified below.

Table 5: Precautionary guidance values for VLF magnetic fields.

VLF magnetic field	Daytime exposure	Nighttime exposure	Sensitive populations
Arithmetic mean (AVG)	1 nT (0.01 mG)[1)]	1 nT (0.01 mG)[1)]	0.3 nT (0.003 mG)[2)]
Maximum (MAX)	10 nT (0.1 mG)[1)]	10 nT (0.1 mG)[1)]	3 nT (0.03 mG)[2)]

Based on: [1)]The current density induced in the human body increases with increasing frequency in an approximately linear relationship (266). Therefore, the guidance value of the magnetic field in the VLF frequency range should be lower than the one of the 50/60 Hz magnetic field, e.g. for 100 nT RMS/100=1 nT. For the rationale of 100 nT (avg) and 1 μT (max), see section ELF magnetic fields. [2)]Precautionary approach by a factor of 3 (field strength). See also TCO Development (265).

Electric fields in the VLF range (VLF EF) Measurement specifications

Frequency range: 3 kHz–3 MHz. Frequency-specific measurements (spectrum analyzer/EMF meter), e.g. "dirty electricity", powerline communication (PLC), radio-frequency identification transmitters (RFID), compact fluorescent lamps (CFL)
Type of measurement: Electric field [V/m]
Field probe: Isotropic, biconical, logarithmic-periodic electric field probe
Detector mode: RMS arithmetic mean
Measurement volume: Point of exposure across bed and workplace
Measurement period: Short-term measurements to identify field sources. Long-term measurements during sleep and work shift
Basis for evaluation: Long-term measurements: arithmetic mean at relevant points of exposure
Note: If an elevated exposure is detected, power quality analyzers and oscilloscopes can be used on the actual wiring to trace the source of the dirty power.

Precautionary guidance values

In areas where people spend extended periods of time (>4 h per day), minimize exposure to VLF electric fields to levels as low as possible or below the precautionary guidance values specified below.

Table 6: Precautionary guidance values for VLF electric fields.

VLF electric field	Daytime exposure	Nighttime exposure	Sensitive populations
Arithmetic mean (AVG)	0.1 V/m[1)]	0.01 V/m[1)]	0.003 V/m[2)]

Based on: [1)]The current density induced in the human body increases with increasing frequency in an approximately linear relationship (266). Therefore, the guidance value of the electric field in the VLF frequency range should be lower than the one of the 50/60 Hz electric field, e.g. for 10 V/m/100 = 0.1 V/m. For the rationale of 10 V/m and 1 V/m, see section ELF electric fields. [2)]Precautionary approach by a factor of 3 (field strength). See also TCO Development (265).

Reduction and prevention of EMF exposure

Preventing or reducing EMF exposure after consulting a testing specialist is advantageous for several reasons:
(a) To prevent and reduce risks to individual and public health,
(b) To identify any links to health problems,
(c) To causally treat the EMF-related health problems.

There are numerous potential causes of relevant EMF exposures, and this EMF guideline can only give a few examples. Further information can be found, for instance, in the document "Options to Minimize EMF/ RF/Static Field Exposures in Office Environments" (268) and "Elektrosmog im Alltag"

(269). For detailed information on physics, properties, and measurement of EMF, see Virnich (270); regarding reduction of radio-frequency radiation (RF) in homes and offices, see Pauli and Moldan (271).

In most cases, it will be necessary to consult an expert (e.g. qualified EMF/RF engineer/ consultant) and/or electrician who will advise the person on what measures could be taken to reduce EMF exposure.

EMF exposure reduction – first steps

As a first step, recommendations are given (also as preventive measures) to eliminate or reduce typical EMF exposures, which may help alleviate health problems within days or weeks. The following actions may be suggested:

Preventing exposure to radio-frequency radiation (RF)

- Keep mobile phone/smartphone and cordless phone calls short; use the speakerphone function or a hands-free kit.
- Avoid wearing the mobile phone/smartphone close to the body.
- Deactivate all non-essential wireless mobile phone apps, which cause periodic radiation exposure.
- Keep mobile phones/smartphones in "airplane mode" whenever possible or deactivate mobile data, Wi-Fi, Bluetooth and near field communication (NFC) in the smartphone settings.
- Disconnect (unplug) the power supply of all DECT cordless phone base stations. So called "ECO Mode" or "zero-emission" DECT phones are only conditionally recommended because the exposure by the handset is still present. A "traditional" corded phone is recommended instead.
- Disconnect (unplug) the power supply to all Wi-Fi access points or Wi-Fi routers. Many LAN routers now come equipped with additional Wi-Fi. Call the provider of the LAN router and ask to have the Wi-Fi deactivated. It is usually also possible to do so online by following the provider's instructions.
- In case of external RF radiation sources, rooms – especially bedrooms – facing away from the source should be chosen.
- Avoid powerline communication for Internet access (dLAN) and instead use a hardwired Ethernet cable (LAN).
- Avoid exposure to RF radiation (e.g. wireless devices like, home entertainment, headsets, baby monitors, computer games, printers, keyboards, mouse, home surveillance systems) at home, in offices, and in cars.
- Avoid exposure to energy-efficient lighting (compact fluorescent lamps as well as some LEDs generate high frequency transients). These types of lamps can be replaced with incandescent or line-voltage halogen incandescent lamps until good-quality lighting energy-efficient lamps become commercially available.

Preventing exposure to ELF electric and magnetic fields

- Move the bed or desk away from the wiring in the walls and power cords. A minimum distance of 30 cm (1 ft) from the wall is recommended.
- As magnetic fields can pass through walls, make certain that there are no magnetic sources immediately beneath or above a bed or in an adjacent room.
- Another simple complementary action is to disconnect the power supply to the bedroom (turn off circuit breaker or fuse) for the nighttime while sleeping; try it for a test phase of, e.g. 2 weeks. In general, this measure is not always successful because circuits of adjacent rooms contribute to the electric field levels. ELF electric field measurements are required to know exactly which circuit breakers need to be disconnected. The benefits should be weighed against the potential risk of accidents; therefore, the use of a flashlight for the test phase should be recommended.
- Disconnect the power supply to all non-essential electric circuits, possibly in the entire apartment or house. (N.B. See note above.)
- Avoid using an electric blanket during sleep; not only turn it off, but also disconnect it.
- Avoid extended exposures close to running electric motors. As a first step, keep a minimum distance of 1.5 m (5 ft). As a second step, establish a safe distance based on magnetic field measurements.

Preventing exposure to static magnetic/static electric fields

- Sleep in a bed and mattress without metal.
- Avoid sleeping close to iron materials (radiator, steel, etc.)
- Wearing synthetic clothing and, e.g. rubber-soled shoes and not regularly being in contact with the earth can result in build up of static electricity. Cotton clothing and leather-soled shoes will help avoid static electricity.

EMF exposure reduction – second steps

As a second step, EMF measurements and mitigation measures should be carried out. Typical examples are:

- Measure the ELF electric field in the bed. Based on the measurement results, install automatic demand switches in those circuits that increase the exposure.
- Measure the ELF electric field at all other places that are used for extended periods at home and at work. If necessary, choose lamps used close to the body with a shielded electric cable and a grounded lamp fixture (metal). Especially in lightweight construction (wood, gypsum board), electrical wiring without grounding (two-slot outlets) might have to be replaced with grounded electrical wiring or shielded electrical wiring. In special cases, shielded wiring and shielded outlets may have to be installed in the whole building.
- Measure the ELF magnetic field close to the bed, e.g. for 24 h. If net currents are detected, the electrical wiring and grounding system of the building must be corrected to reduce the magnetic fields.
- Install a residual current device (RCD) or ground-fault circuit interrupter (GFCI) to prevent electric shocks (safety measure).
- Measure radio-frequency radiation and mitigate high exposure levels by installing certain RF shielding materials for the affected walls, windows, doors, ceilings, and floors. For example, in a multiunit setting (condominiums or highrise apartments, townhomes), proximity to neighbors can contribute to inhome exposure.
- Measure dirty electricity/dirty power (electric and magnetic fields in the VLF frequency range) and identify the sources in order to remove them. If this is not possible, appropriate power filters in line with the source may be used.

Diagnosis

We will have to distinguish between EHS and other EMF-related health problems like certain cancers, Alzheimer's, ALS, male infertility, etc. that might have been induced, promoted, or aggravated by EMF exposure. An investigation of EHS and other EMF-related health problems will largely be based on a comprehensive case history, focusing, in particular, on correlations between health problems and times, places, and circumstances of EMF exposure, as well as the progression of symptoms over time and the individual susceptibility. In addition, measurements of EMF exposure and the results of additional diagnostic tests (laboratory tests, cardiovascular system) serve to support the diagnosis. Moreover, all other potential causes should be excluded as far as possible.

In 2000 the Nordic Council of Ministers (Finland, Sweden, and Norway) adopted the following unspecific ICD-10 code for EHS: Chapter XVIII, Symptoms, signs and abnormal clinical and laboratory findings, not elsewhere classified, code R68.8 "Other specified general symptoms and signs" (Nordic ICD-10 Adaptation, 2000) (272).

Regarding the current International Classification of Diseases (ICD), ICD-10-WHO 2015, we recommend at the moment:

(a) Electromagnetic hypersensitivity (EHS): to use the existing diagnostic codes for the different symptoms **plus** code R68.8 "Other specified general symptoms and signs" **plus** code Z58.4 "Exposure to radiation" and/or Z57.1 "Occupational exposure to radiation."
(b) EMF-related health problems (except EHS): to use the existing diagnostic codes for the different diseases/symptoms **plus code** Z58.4 "Exposure to radiation" and/or Z57.1 "Occupational exposure to radiation."

Regarding the next ICD update to be published in 2018 (ICD-11 WHO), we recommend:

(a) To create ICD codes for all environmentally induced chronic multisystem illnesses (CMI) like multiple chemical sensitivity (MCS), chronic fatigue syndrome (CFS), fibromyalgia (FM), and electromagnetic hypersensitivity (EHS) on the basis of their clinical and pathological description (187, 192).
(b) To expand chapter XIX, Injury, Poisoning and Certain Other Consequences of External Causes (T66-T78), to include/distinguish effects of EMF (static magnetic field, static electric field, ELF magnetic field, ELF electric field, VLF magnetic field, VLF electric field, radio-frequency radiation), infrared radiation, visible light, UV radiation and ionizing radiation.
(c) To expand chapter XXI, Factors Influencing Health Status and Contact with Health Services (Z00-Z99), to include/distinguish factors as EMF (static magnetic field, static electric field, ELF magnetic field, ELF electric field, VLF magnetic field, VLF electric field, radio-frequency radiation), infrared radiation, visible light, UV radiation, and ionizing radiation.

Treatment of the patient including the environment

The primary method of treatment should mainly focus on the prevention or reduction of EMF exposure that is reducing or eliminating all sources of EMF at home and in the workplace. The reduction of EMF exposure should also be extended to schools, hospitals, public transport, public places like libraries, etc. in order to enable EHS persons an unhindered use (accessibility measure). Many examples have shown that such measures can prove effective.

With respect to total body load of other environmental influences, they must also be regarded.

Beside EMF reduction, other measures can and must be considered. These include a balanced homeostasis in order to increase the "resistance" to EMF. There is increasing evidence that a main effect of EMF on humans is the reduction of their oxidative and nitrosative regulation capacity. This hypothesis also explains observations of changing EMF sensitivity and the large number of symptoms reported in the context of EMF exposure. Based on currently available knowledge it appears useful to recommend a treatment approach, as those gaining ground for multisystem illnesses, that aims at minimizing adverse peroxynitrite effects. Measures that enhance the immune system and reduce stress in combination with detoxification will promote EHS recovery.

It should be stressed, that psychotherapy has the same significance as in other diseases. Products that are offered in the form of plaques and the like to "neutralize" or "harmonize" electrosmog should be evaluated with great restraint. Psychological stress generated by a lack of understanding or support by family, friends and physicians can exacerbate the symptoms of EHS as can stressing about exposure. For rapid recovery, the treatments need to apply to the body, mind and spirit of the individual.

In summary, the following treatment and accessibility measures appear advantageous, depending on the individual case:

Reduction of EMF exposure

This should include all types of EMF exposures relevant to the person, especially during sleep and at work – see Chapter "Reduction of EMF Exposure". For more information, see e.g. "Options to Minimize EMF/RF/Static Field Exposures in Office Environment" (268) and "Elektrosmog im Alltag" (269).

Environmental medicine treatments

Until now, no specific treatment of EHS has been established. The following paragraphs are recommendations based on the combined experience of the team. They can be considered either as an attempt to restore the full regulative capacity of the patients, as general advice for healthy living (that could and should be adapted to the cultural and individual situation of the patient), or as a more targeted approach to address the specific problems of EHS individuals according to the experience of the team.

Controlled clinical trials would be necessary to assess optimal treatment and accessibility measures. Actual data indicate that the functional deficits, which can be found in patients with EHS, correspond to those we can find in CMI such as MCS, CFS, and FM. The target of the therapy is the regulation of the physiological dysfunction detected by diagnostic steps (see chapter 2 "Examination and Findings"). The main therapeutic target includes both general and adjuvant procedures and specific treatments. The latter are challenging and need special knowledge and experience in clinical environmental medicine treatments. Main therapeutic targets include:

- **Control of total body burden**
  Besides the reduction of EMF exposure, the reduction of the total body burden by various environmental pollutants (home, workplace, school, hobby), food additives, and dental materials is indicated.
- **Reduction of oxidative and/or nitrosative stress**
  Reactive oxygen species (ROS) and reactive nitrogen species (RNS) are free radicals naturally produced in cells. Scavengers guarantee the balance between the production of free radicals and the rate of their removal. Many biologically important compounds with antioxidant (AO) function have been identified as endogenous and exogenous scavengers. Among the endogenous AO, we distinguish between enzymatic AO (catalase, glutathione peroxidase, glutathione reductase, superoxide dismutase) and non-enzymatic AO [bilirubin, ferritin, melatonin, glutathione, metallothionin, N-acetyl cysteine (NAC), NADH, NADPH, thioredoxin, 1,4,-bezoquinine, ubiquinone, uric acid]. They interact with exogenous dietary and/or synthetic AO (carotenoids, retinoids, flavonoids, polyphenols, glutathione, ascorbic acid, tocopherols). The complex regulation and use of these substances is the therapeutic challenge (232, 273).
- **Regulation of intestinal dysfunction**
  Endogenous and exogenous scavengers act synergistically to maintain the redox homeostasis. Therefore, dietary or natural antioxidants play an important role to stabilize this interaction.
  Treatment of a leaky gut, food intolerance, and food allergy is a prerequisite for maintaining redox homeostasis (274) and also requires special knowledge and experience.
- **Optimizing nutrition**
  Bioactive food is the main source of antioxidant components such as vitamin C, vitamin E, NAC, carotenoids, CoQ10, alpha-lipoic acid, lycopene, selenium, and flavonoids (275, 276). For instance, the regeneration of vitamin E by glutathione or vitamin C is needed to prevent lipid peroxidation. The dietary antioxidants only can have beneficial effects on the redox system if they are present in sufficient concentration

levels (273). Alpha-lipoic acid acts directly and indirectly as a scavenger of free radicals including, singlet oxygen, superoxide, peroxyl radicals, and the breakdown radicals of peroxynitrite (232). It has been shown that the number of free electrons in micronutrients determines how effective they are. In organic food, the number of free electrons is higher than in conventionally produced food (277). Especially in the case of food intolerances, the tailored substitution of micronutrients in the form of supplements is necessary.

– **Control of (silent) inflammation**
Elevated nitric oxide levels and the reaction with superoxide always leads to elevated peroxynitrate levels, which induce ROS levels as no other substance does ($NO/ONOO^-$ cycle). As a result, the nuclear factor κB (NF-κB) is activated, inducing inflammatory cytokines such as tumor necrosis factor α (TNF-α), interleukin-1β (IL-1β), interleukin-6 (IL-6), interleukin-8 (IL-8), and interferon gamma (IFN-γ) and activating various NO synthases (232). Tocopherols (278, 279), carotenoids at low concentration levels (280), vitamin C (281, 282), NAC (283), curcumin (284), resveratrol (285, 286), flavonoids (287) have shown to interrupt this inflammatory cascade at various points.

– **Normalization of mitochondrial function**
Mitochondrial function may be disturbed in two ways. First: the high amount of free radicals may block production of adenosine triphosphate (ATP), leading to muscle pain and fatigue. Second: in the case of silent (smoldering) inflammation, the demand for more energy is elevated by 25% (236), causing a high consumption of ATP. In this case, NADH, L-carnitine, and CoQ10 are essential for ATP synthesis.
Due to the lack of ATP, the stress regulation of catecholamines especially norepinephrine (NE) is reduced because catabolism of NE by S-adenosylmethionine is ATP dependent (288–290). Furthermore, stress regulation has a high demand for folate, vitamin B6, and methylcobalamine. Genetic polymorphisms of COMT and MTHFR influence the individual need for those substances (244, 291).

– **Detoxification**
In humans, the accumulation of environmental toxins has an individual profile of many different inorganic and organic chemicals, which make up the total body load (292).
Among the inorganic substances, metals and their salts play the dominant role and might be of importance to patients with EHS. Elemental mercury (Hg°) and other heavy metals such as lead (Pb) accumulate in the brain (293), especially at chronic low dose exposure. They may have toxic effects and can induce various immune reactions (294, 295). Whereas no specific active substance generally exists for the detoxification of chemicals, there are two groups of substances with more specific effects that can be used for the detoxification of metals.

1. Substances with nonspecific physiological effects: glutathione, NAC, alpha-lipoic acid, vitamin C, and selenium.
2. Chelating agents for detoxification of metals (296–298): the most important chelating agents are sodium thiosulfate 10%, DMPS (2,3-dimercapto-1-propanesulfonic acid), DMSA (mesodimercaptosuccinic acid), and EDTA (2,22,23,232-ethane-1,2-diyldinitrotetraacetic acid).

It should be noted that these substances should be used only by those designated as experts in this particular field.

– **Adjuvant therapies**

1. Drinking water
For detoxification reasons, a higher intake of high-quality drinking water with low mineral content and no CO_2 is needed. The intake quantity should range from 2.5 to 3.0 L (10–12 8-oz glasses) daily.

2. Light
Most of the people in central and northern Europe are depleted of vitamin D. Sufficient natural daylight exposure during the vitamin D-producing months (spring to fall) is one important factor. At the same time, prevention of actinic damage to the skin is necessary. In addition to natural sunlight, light therapy and low level lasers can promote healing, reduce inflammation, promote circulation, and enhance cellular ATP production.

3. Sauna
Sauna and therapeutic hyperthermia is an adjuvant therapy for the detoxification of almost all xenobiotics. These therapies have to be carefully used. An interaction with detoxifying drugs takes place. Sauna helps to regenerate tetrahydrobiopterin from dihydrobiopterin, which is essential for the metabolism of catecholamines and serotonin (299). However, not all saunas are alike. Traditional saunas or infrared saunas with low electric and low magnetic fields that do not use toxic glues and chemically treated wood are recommended.

4. Oxygen
A part of patients with EHS suffer from mitochondrial dysfunction. Sufficient natural oxygen is helpful. As both hypoxia and hyperbaric oxygen can produce oxidative stress, hyperbaric oxygen therapy should only be performed if the patients are treated with sufficient antioxidants at the same time.

5. Exercise
The optimal amount of exercise is still being debated. A person's physical capacity should be assessed by ergometry in order to prescribe an individual exercise regime. Environmental medicine experience indicates that for sick people only low-impact aerobic exercise should be used. In general, start with a workload of 20–30 watts that often can be finished at 60–70 watts. Exercise on an ergometer allows better control of the consumption of energy compared to walking or running. No fatigue should result from exercising, at least after half an hour.

6. Sleep
Sleep problems are very common in patients with EHS. Sleep disturbance is associated with a reduced melatonin level. In the case of chronic inflammation, the activation of IDO (indolamine-2,3-dioxygenase) reduces the production of serotonin and, in turn, it also reduces melatonin levels. EMF exposure might block the parasympathetic activity while sympathetic activity persists. Concerning sleep disturbances, any therapy has to follow the pathogenic causes. Optimal sleep is necessary to save energy and to regulate the functions of the immune and neuroendocrine systems.

7. Protection from blue light
Wavelengths of visible light below 500 nm are called "blue light". Low doses of blue light can increase feelings of well-being, but larger amounts can be harmful to the eyes. In natural daylight, the harmful effects of "blue light" are balanced out by the regenerative effect of the red and infrared content. The escalating use of electronic light sources – such as fluorescent tubes and compact fluorescent lamps (CFL), computer screens, laptops, tablets, smartphones, and certain LED bulbs – has increased our exposure to "blue light", which at this level is suspected of playing a role in the development of age-related macular degeneration and circadian misalignment via melatonin suppression, which is associated with an increased risk of sleep disturbance, obesity, diabetes mellitus, depression, ischemic heart disease, stroke, and cancer. Extended exposure to artificial "blue light" in the evening should therefore be limited. Antioxidants, especially melatonin (300, 301), and blue light screen filters (302–304) could be helpful.

8. Exposure to the natural electromagnetic fields of the Earth.
Most people in urban centers are disconnected from the Earth's natural grounding/magnetic fields by walking with rubber-soled shoes, wearing synthetic clothing, driving in metal boxes with rubber wheels, and living and working in concrete buildings that are permeated with artificial electromagnetic fields and radiation. Spending time in the woods, walking barefoot along a beach, lying on the grass, sitting on rocks, or strolling outside after a rain shower help ground a person and help balance the often enhanced positively charged ions that are associated with ill health.

Dental medicine
Dental medicine still works with toxic or immunoreactive materials, e.g. mercury, lead oxide, gold, and titanium. Environmental dental medicine demands that these materials not be used (305–308). The removal of toxic dental materials must take place under maximum safety conditions (avoid inhalation!). The elimination of particularly heavy metals from the body might be indicated. In general terms, endoprosthetic materials should be inert with respect to immunoreactivity. Based on our current knowledge, zirconium dioxide seems to be a neutral material. However, mechanical abrasion of the coated surface by the dentist should be avoided.

Immunotoxic metals show a similar pathophysiology with respect to oxidative stress, mitochondriopathy, and inflammation.

Lifestyle coaching
Lifestyle coaching may include balanced exercise, nutrition, reduction of addictive substances, change of sleep habits, etc. and stress reduction measures (reduction of general stress and work stress), as well as methods to increase stress resistance via, e.g. autogenic training, yoga, progressive muscle relaxation, breathing techniques, meditation, tai chi, and qigong.

Treatment of symptoms
A well-balanced treatment of symptoms is justified until the causes have been identified and eliminated. However,

it is of paramount importance to realize that the reduction of symptoms may put the person at risk for an increased environmental EMF load, thus generating possible future, long-term health effects, including neurological damage and cancer. The treating physician faces a very difficult ethical task when doing so, and the associated risks must be pointed out – in an equally well-balanced way – to the patient in question. From an ethical perspective, treating the symptoms is, of course, a very good start to provide immediate relief, but – without a concurrent environmental exposure reduction and lifestyle coaching – it may prove counter-productive in the long run. For a conventionally trained physician, this might seem a very new way of reasoning, but it is the only way to successfully and effectively alleviate symptoms and to achieve complete clinical recovery when dealing with chronic multisystem illnesses (CMI) and EHS. Though even if the causes are not known at the outset, it is already important at this stage to provide advice on how to reduce a person's exposure to electromagnetic fields and other environmental stressors to prevent further damage and promote healing.

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Reliable disease biomarkers characterizing and identifying electrohypersensitivity and multiple chemical sensitivity as two etiopathogenic aspects of a unique pathological disorder

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Abstract: Much of the controversy over the causes of electrohypersensitivity (EHS) and multiple chemical sensitivity (MCS) lies in the absence of both recognized clinical criteria and objective biomarkers for widely accepted diagnosis. Since 2009, we have prospectively investigated, clinically and biologically, 1216 consecutive EHS and/or MCS-self reporting cases, in an attempt to answer both questions. We report here our preliminary data, based on 727 evaluable of 839 enrolled cases: 521 (71.6%) were diagnosed with EHS, 52 (7.2%) with MCS, and 154 (21.2%) with both EHS and MCS. Two out of three patients with EHS and/or MCS were female; mean age (years) was 47. As inflammation appears to be a key process resulting from electromagnetic field (EMF) and/or chemical effects on tissues, and histamine release is potentially a major mediator of inflammation, we systematically measured histamine in the blood of patients. Near 40% had a increase in histaminemia (especially when both conditions were present), indicating a chronic inflammatory response can be detected in these patients. Oxidative stress is part of inflammation and is a key contributor to damage and response. Nitrotyrosin, a marker of both peroxynitrite ($ONOO^{\circ}$-) production and opening of the blood-brain barrier (BBB), was increased in 28% the cases. Protein S100B, another marker of BBB opening was increased in 15%. Circulating autoantibodies against O-myelin were detected in 23%, indicating EHS and MCS may be associated with autoimmune response. Confirming animal experiments showing the increase of Hsp27 and/or Hsp70 chaperone proteins under the influence of EMF, we found increased Hsp27 and/or Hsp70 in 33% of the patients. As most patients reported chronic insomnia and fatigue, we determined the 24 h urine 6-hydroxymelatonin sulfate (6-OHMS)/creatinin ratio and found it was decreased (<0.8) in all investigated cases. Finally, considering the self-reported symptoms of EHS and MCS, we serially measured the brain blood flow (BBF) in the temporal lobes of each case with pulsed cerebral ultrasound computed tomosphygmography. Both disorders were associated with hypoperfusion in the capsulothalamic area, suggesting that the inflammatory process involve the limbic system and the thalamus. Our data strongly suggest that EHS and MCS can be objectively characterized and routinely diagnosed by commercially available simple tests. Both disorders appear to involve inflammation-related hyper-histaminemia, oxidative stress, autoimmune response, capsulothalamic hypoperfusion and BBB opening, and a deficit in melatonin metabolic availability; suggesting a risk of chronic neurodegenerative disease. Finally the common co-occurrence of EHS and MCS strongly suggests a common pathological mechanism.

Keywords: biomarkers; cerebral hypoperfusion; electrohypersensitivity; limbic system; multiple chemical sensitivity.

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Introduction

In 1962, Randolph first described clinically (1) what is today commonly called multiple chemical sensitivity (MCS) (2); a human pathological disorder that has been identified and defined in 1999 during an international consensus meeting on the basis of the six following criteria: "1. The symptoms are reproducible with [repeated chemical] exposure; 2. The condition is chronic; 3. Low levels of exposure [lower than previously or commonly tolerated] result in manifestations

of the syndrome; 4. The symptoms improve or resolve when the inciting agents are removed; 5. Responses occur to multiple chemically unrelated substances; 6. [Added in 1999]: Symptoms involve multiple organ systems" (3). Although the precise worldwide prevalence of MCS remains unclear, it is expected that due to the vastly increased number of the various chemical products that have been put on the market during the last few decades, MCS is becoming an increasing prevalent pathological disorder (4).

The recent rise of wireless telecommunication worldwide also confronts scientists with the question of whether anthropogenic electromagnetic fields (EMFs) such as emitted by cell phones, wireless internet, and high voltage power lines, can cause adverse health effects as it is the case for chemicals. In 1991 Rea first described what he called electromagnetic field sensitivity (5). Six years later, Bergqvist et al., in a report prepared by a European group of experts for the European Commission coined the term electrohypersensitivity (EHS) to encompass in a unique concept the clinical conditions in which EHS self-reporting patients complain of symptoms they attribute to EMF exposure (6). Since 1998, Santini et al. in France, reported symptoms experienced by users of digital cellular phones and the health risk of people living near cellular phone base stations (7, 8).

In 2004, because of the increasing worldwide prevalence of EHS, the World Health Organization (WHO) organized an international scientific workshop in Prague (Czech Republic) in order to define and characterize EHS. Although not acknowledging EHS as being caused by EMF exposure, the Prague working group defined EHS as "a phenomenon where individuals experience adverse health effects while using or being in the vicinity of devices emanating electric, magnetic, or electromagnetic fields … whatever its cause, EHS is a real and sometimes a debilitating problem for the affected persons" (9). However, following this meeting, WHO proposed to use the alternative term "idiopathic environmental intolerance (IEI) attributed to electromagnetic fields" (IEI – EMF), indicating there is no proven causality between the occurrence of IEI – EMF (formerly EHS) and EMF exposure (9).

In view of the poor knowledge of pathogenesis and etiology of EHS and MCS, most mainstream medical, sanitary and societal bodies maintain there is not sufficient scientific proof to support the concept that clinical symptoms experienced by EHS and/or MCS self-reporting patients are really caused by EMF and/or chemical exposure, respectively. This is particularly the case for EHS patients, for whom in comparison to sham controls, the reproduction of clinical symptoms in the presence of EMFs have globally failed to demonstrate a causal link, in blind or double-blind studies (10).

Moreover, the lack of recognized disease biomarkers objectively characterizing EHS and MCS has resulted in clinical symptoms being dismissed as psychogenic; and/or EHS and MCS are conflated with psychosomatic or psychiatric diseases, and not recognized as true organic disorders caused by the environment (11–16). This is particularly the case for radiofrequency EMF, for which some scientists believe that EHS is an uncertain and confusing concept (17); whereas some others, on the basis of their own clinical experience agree that excessive exposure may cause EHS (5, 18, 19).

Here, we present our own experiences based on the preliminary analysis of a series of 1216 consecutive investigated cases of self-claimed EHS and/or MCS, in the framework of an ongoing prospective clinical study aiming at identifying and characterizing EHS and MCS both clinically and biologically; through the use of biomarkers detected and measured in the peripheral blood and the urine of patients. Our data clearly shows that EHS and MCS should be recognized as genuine somatic pathological entities; that patients with EHS and/or MCS are non-psychosomatic nor psychiatric patients; and probably that EHS and MCS are two etiopathogenic aspects of a single pathological disorder.

Search for reliable disease biomarkers

The identification and measurement of reliable biomarkers is a crucial step for identifying and characterizing diseases. This is *a fortiori* the case for any new pathological entity or clinical syndrome such as MCS, EHS or other environmental intolerance syndrome. However, to our knowledge, such an approach has proven inconclusive for MCS (20) and EHS (21).

We thus searched for characteristic biomarkers and selected a battery of biological tests which could be routinely used clinically in environmental medicine practice for taking care of EHS and/or MCS self-reporting patients.

In addition, due to the reported clinical symptoms, we systematically measured the brain blood flow (BBF) in both cerebral hemispheres of these patients by using echodoppler of the middle cerebral artery (22) and measured centimeter by centimeter brain pulsatility by using pulsed ultrasound-based cerebral computerized tomosphygmography, which allows centimetric resolution pulsed ultrasound recording of cerebral pulsatility (23–25), to localize more precisely the BBF in the different areas of the two temporal lobes. Our working hypothesis was that under

the influence of environmental factors such as EMFs and/or chemicals, some neuro-inflammation and oxidative stress might occur in the brain, with blood-brain barrier (BBB) disruption as a consequence.

We thus routinely measured the inflammation-associated high-sensitivity C reactive protein (hs-CRP) in the peripheral blood; and levels of vitamin D2-D3, as it has been suggested that low levels of its metabolite, the secosteroid 25 hydroxy-vitamin D (25-D) could be a consequence rather than a cause of inflammatory and/or autoimmune processes (26), and that vitamin D deficiency is associated with abnormal development and functioning of the central nervous system (CNS) (27, 28). Since it has been shown that upon brain injury, degeneration or infection, the inflammatory response may trigger degranulation of mast cells, leading to a massive release of histamine in the blood (29), we systematically measured the levels of histamine in the peripheral blood. In addition, as the best known mast cell degranulation mechanism involve crosslinking of the high affinity surface IgE receptor (30), we also measured total IgE levels in the peripheral blood. It is well known that histamine is a potent mediator of inflammation and is able to increase BBB permeability through oxidative and/or nitrosative stress (31, 32). So we looked for possible oxidative and/or nitrosative stress-related biomarkers of BBB disruption; and identified nitrotyrosine (NTT), because it results from the toxic effects of peroxynitrite ($ONOO^{\circ-}$) on proteins (33–36). Such a BBB opening marker has also been shown for the calcium-binding protein S100B, produced and released predominantly by peri-vascular astrocytes (37–40). During the inflammatory process, it is well known that cells produce excessive amount of superoxide (O_2°) and nitric oxide (NO°), and that although NO° is a weak free radical resulting from the action of nitric oxide synthase, its excessive intracellular production is associated with cytotoxic properties because of the formation of extremely reactive nitrogen species such as peroxynitrite. The biochemical reaction in the form of $O_2^{\circ}+NO^{\circ}=>ONOO^{\circ-}$ may thus explain why NTT (which results from oxidative and nitrosative stresses) is associated with BBB disruption (32, 41). Dosage of free NTT and protein-combined NTT as well as protein S100B in the peripheral blood of EHS and/or MCS patients was thus an important element of the battery of biological tests we used.

We also considered that non thermal radiofrequency often is a repetitive stress leading *inter alia* to continuous heat shock protein (HSP) over-expression and release in exposed tissues, particularly in the brain (42–46). HSPs are a family of highly conserved proteins with chaperone functions acting to maintain the structural conformation of cellular proteins. Their over-expression under stress conditions which promotes an inflammatory response is well known (47–49). We thus speculated that the major inducible stress protein HSP70, which has been shown to oppose to neuronal apoptosis (50, 51) and to BBB disruption (51, 52), so eliciting some neuroprotection could be involved as it could be also the case for HSP27 (53, 54). However, under chronic EMF exposure it was reported that, as compared to controls, intracellular HSP70 levels may decline (55). We thus systematically measured HSP70 and HSP27 levels in the peripheral blood of EHS and/or MCS patients in order to try to determine whether these chaperone proteins are a marker of EMF and/or chemicals chronic exposure; as it has been shown for non-thermal EMF exposure in experimental studies (42–46).

Moreover, during oxidative and nitrosative stress proteins may be extensively modified and denatured and so acquire new epitopes which can explain their loss of specificity and biological activity, hence the synthesis of autoantibodies (56, 57). This is the case for EMF exposure which has been shown to alter DNA replication and mitosis and form abnormal proteins (42, 58, 59) and so to produce electro-oxidation-related IgE autoantibodies (60). We consequently hypothesized that under the influence of environmental EMFs and/or chemicals, CNS proteins such as O-myelin may be so denatured that they acquire autoantigenic properties. Consequently we thus systematically searched for and measured autoantibodies against O-myelin in the blood of patients.

Finally, since some effects of EMF exposure have been reported to be mediated by the pineal hormone, melatonin (61), and given the fact that in our series many patients had sleep disturbance, we also systematically measured melatonin metabolism in these patients. However, as measurement of endogenous melatonin in urine is not useful because of its low unmetabolized levels (62), we measured levels of its metabolite 6-hydroxymelatonin sulfate (6-OHMS) and creatinine in 24 h urine, to determine the 6-OHMS/creatinine ratio. Note that since creatinine is excreted in a relatively constant amount in each patients, we used this ratio to reduce the variability of 6-OHMS measurement attributed to urine dilution.

The test battery for identifying and characterizing EHS and MCS is summarized in Table 1. Technical information about the methods we used for carrying out all biological tests and the BBF analysis are summarized as follows:

For the biomarker study, all patients were investigated by using commercially available biochemical tests and values for each patient were compared to the normal reference values obtained from the commercial companies. Sensitivity, specificity and reproducibility of these tests were thus those defined by these companies. Each

Table 1: Disease biomarkers investigated in self-reporting EHS and/or MCS patients with their normal values.

Biomarker	Normal range
High-sensitivity C reactive protein (hs-CRP)	≤3 mg/L
Vitamin D2-D3	≥30 ng/mL
Histamine	≤10 nmol/L
IgE	≤100 UI/mL
Protein S100B	≤0.105 μg/L
Nitrotyrosine (NTT)	≥0.6 μg/L and ≤0.9 μg/mL
Heat shock protein 70 (HSP70)	≤5 ng/mL
Heat shock protein 27 (HSP27)	≤5 ng/mL
Anti-O-myelin autoantibodies	Negative
Hydroxy-melatonin sulfate (6-OHMS)	≥5 ng/L and ≤40 ng/L
6-OHMS/creatinine	≥0.8 and ≤8

assay was performed according to the manufacturer's method. Hs-CRP and 25-OH vitamin D were measured by using an automated immunoassay [Architect Ci 4100 (Abbott Laboratories, Abbott Park, Chicago, IL, USA)]; for Histamine measurement we used an ELISA specific test; for protein S100B, a quantitative automated chemiluminescent immunoassays [Liason S100 (DiaSorin Deutschland GmbH, Dietzenbach, Germany)]; for NTT, a competitive ELISA test (Cell Biolabs Inc., San Diego, CA, USA); for anti-O-myelin antibody detection, a Western Blot qualitative analysis (IMMCO Diagnostics, Buffalo, NY, USA); for HSP 27 and HSP 70, specific high sensitivity enzymatic immunoassays (Stressgen Biotechnologies Corporation, San Diego, CA, USA); and for 5-hydroxy-melatonin-sulfate, a urine ELISA test (IBL International GmbH, Hamburg, Germany).

In addition, to these biochemical tests we used a non-invasive ultrasonic cerebral tomosphygmography method that we specifically set-up to investigate the blood flow in the patient temporal lobes and determined for each patient a pulsometric index (PI) that we measured centimeter by centimeter from the cortex to the diencephalic medial area (see Figure 1). This index varies between the territories studied. In this study, Pi determination for each cerebral territory in 727 EHS and/or MCS patients was compared to a retrospective series of 141 normal subjects which allowed to establish the normal median reference values of PI (see Figure 2). Finally since our study is still ongoing we did not reported any statistical analysis. This will follow in specific further papers.

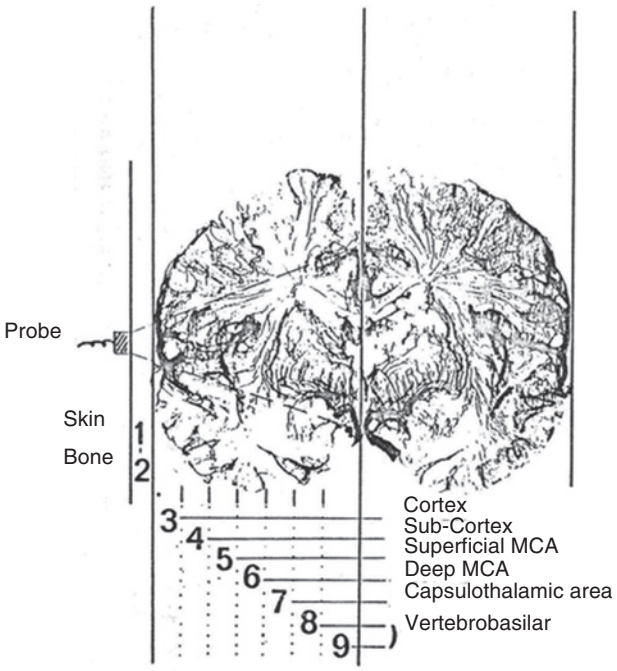

Figure 1: Pulsometric index (PI) obtained by a computerized ultrasonic cerebral tomosphygmography (UCTS) in the different area of temporal lobes.
Data are expressed as mean pulsometric index (PI). PI varies between territories studied: 3+4 correspond to cortico sub-cortical area; 3+4+5, to the superficial area of the middle cerebal artery (MCA); 5+6+7, to the deep area of the MCA; 7, to the capsulothalamic area; 3+4+5+6+7, to the complete area depending of the MCA; 8+9, to the vertebrobasilar area; 3+4+5+6+7+8+9, to the complete temporal lobe.

Search for clinical diagnosis criteria

In 2009, at the time we initiated this prospective cohort study, we were aware there was no available recognized biological markers for defining objectively EHS and MCS; this led us to use clinical criteria as inclusion criteria. For MCS, as already above mentioned, we used the six criteria that had been reported in the 1999 international workshop (3) and for EHS, we used similar criteria. However, as in an unpublished feasibility study we showed that many EHS patients when they are in the vicinity of chemicals may present with olfactory abnormalities consisting in subjective odor disruption; we systematically added a seventh clinical criteria to the six ones already defined during the 1999 consensus meeting on MCS, in order to further characterize clinically MCS and distinguish it from EHS. Accordingly patients with MCS, unlike EHS patients, were characterized not only by the simple odor intolerance, but more specifically by symptoms of mucous inflammation in the nose, the oropharynx and/or the laryngo-tracheo-bronchus tract; manifesting clinically as rhinitis, oropharyngeal dysesthesia or laryngitis and/or bronchospasms, respectively.

To further avoid any confounding pathology, all patients of the present prospective series have been

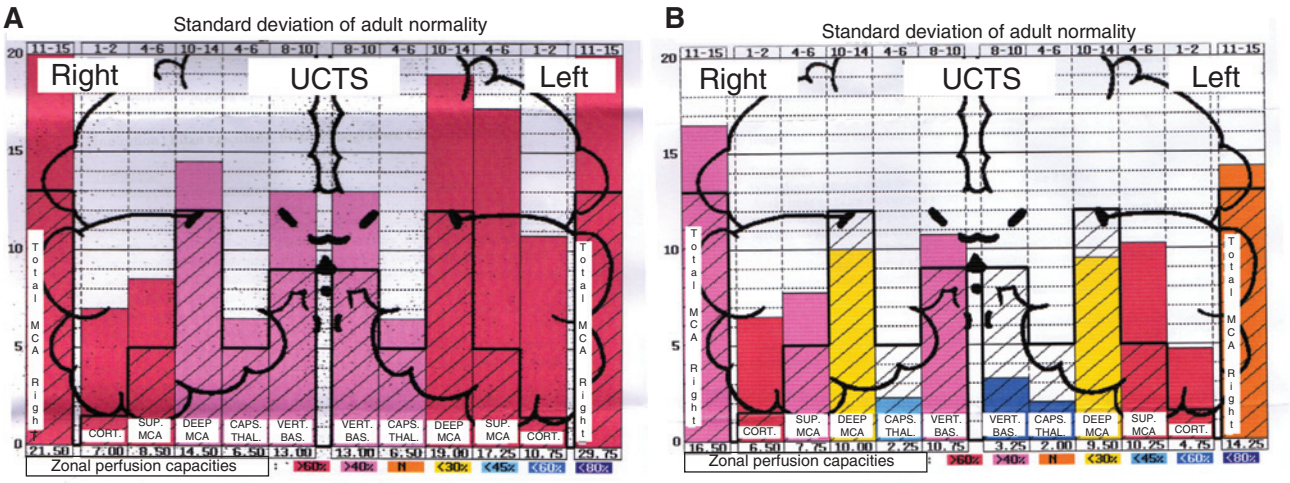

Figure 2: Example of diagrams obtained by using UCTS exploring the global centimetric ultrasound pulsatility in the two temporal lobes of a normal subject (A) and in a EHS self-reporting patient (B).
Measurements are expressed in Pulsometric index (PI). Note that in A and B mean values of PI in each explored area recorded is from the cortex to the internal part of each temporal lobe; so on the left part of the two diagrams A and B for the right lobe from the left to the right; and on the right part of these diagrams for the left lobe from the right to the left. Note also that in A (normal subject) all values are over the normal median values whereas in B (EHS-self reporting patients) values in the capsulothalamic areas (the fifth and the second column for the right and left temporal lobe, respectively) are under the normal median values.

interviewed face to face at length during their medical consultation and questioned systematically about their past medical history and the type and conditions of occurrence of their clinical symptoms, thanks to the use of a validated pre-established questionnaire. In addition, all patients have been carefully physically examined. Also, before inclusion, all patients were systematically investigated by usual routine blood tests and medical imaging including Brain MRI and/or scanner and carotid echodoppler in order to eliminate any known unrelated CNS pathology.

Finally, based on the above clinical finding for both EHS and MCS patients we used the following inclusion criteria:

1. Absence of known pathology accounting for the observed clinical symptoms;
2. Reproducibility of symptom occurrence under the influence of EMFs and/or multiple chemicals whatever their incriminated source;
3. Regression or disappearance of symptoms in the case of EMF and/or multiple chemical avoidance;
4. Chronic evolution;
5. Symptoms such as headache, superficial and/or deep sensibility abnormalities, skin lesions, sympathetic-nerve dysfunction, reduced cognitive ability including loss of immediate memory and attention and/or concentration deficiencies, insomnia, chronic fatigue and depressive tendency, all main clinical symptoms reported as non-specific symptoms in the scientific literature (13, 19), but which when grouped together may evoke clinically the diagnosis of EHS (data not shown);
6. No serious pre-existing pathology such as atherosclerosis, diabetes, cancer; and/or neurodegenerative or psychiatric diseases which have been associated with EHS and/or MCS in the past or at the inclusion time but would render difficult the interpretation of clinical symptoms and biomarker data (see Section "EHS/MCS as a possible sentinel pathological disorder"); and finally
7. For each patient written informed consent.
Study of this large cohort of patients was not a case-control study neither a randomized study so there was no specific control group.

As depicted in Table 2, on a total of 1216 investigated consecutive cases, 839 are presently analyzed of whom 727 are evaluable, 521 with EHS (71.7%), 52 with MCS (7.1%) and 154 with both EHS and MCS (21.2%), regardless of whether MCS occurred before or after EHS. Only 29 patients, i.e. 3% claimed to suffer from EHS and/or MCS but did not meet the inclusion criteria. In fact most of these patients claimed to be electrohypersensitive. Although many of them were associated with a putative neurologic or psychiatric disorder, EHS could not be clearly established. Also excluded were patients with EHS and/or MCS who were in addition, diagnosed as suffering from heavy pathology evidenced after inclusion, or who were lost to follow-up, or for whom results of the biological investigation were not available at the time of analysis.

Table 2: Summary of the present ongoing prospective clinic-biological study of EHS and/or MCS-self reporting patients.

Patients groups	Total	EHS	MCS	EHS/MCS
Total investigated	1216			
Total presently analyzed	839			
Neither EHS nor MCS	29			
Not evaluable	83			
Evaluable	727	521	52	154
Sex ratio	495 W/232 M	344 W/177 M	34 W/18 M	117 W/37 M
	68%/32%	66%/34%	65%/35%	76%/24%
Mean age	47.9±12.4	48.2±12.9	48.5±10.3	46.7±11.2
Median age [range][a]	47 [16–83]	48 [16–83]	47 [31–70]	46 [22–76]

[a]The range of values is indicated in square brackets, e.g. [minimum-maximum].

Demographic panorama

This large cohort of investigated patients originated from many different European countries, and from other countries worldwide such as the US, Canada, Australia, Russia, China, Middle East and Africa. This allows some estimation the demographic picture of so called EHS and/or MCS patients. The demographic data are depicted in Table 2 and Figure 3.

A noteworthy finding which was observed in many countries is that women appear to be much more susceptible to EHS and/or MCS than men, since in our series two thirds are female, with no difference between EHS and MCS rates. Note however, that the female predominance appears to be more pronounced for patients with both EHS and MCS, where three out of four are female (Table 2).

In this series, median age is about 47 years and does not differ according to EHS, MCS and EHS/MCS diagnosis. As indicated in Figure 3, all age categories are represented and mainly include young and old adults, but it appears that adolescents may be also associated with EHS. This may be due to their excessive use of wireless technology (essentially mobile phones and other devices) at this age. In fact, outside of the present series, we have observed that infants and children could also be suffering from EHS.

Analysis of biochemical markers

Biomarker results are indicated in Tables 3–5 and in Figure 4.

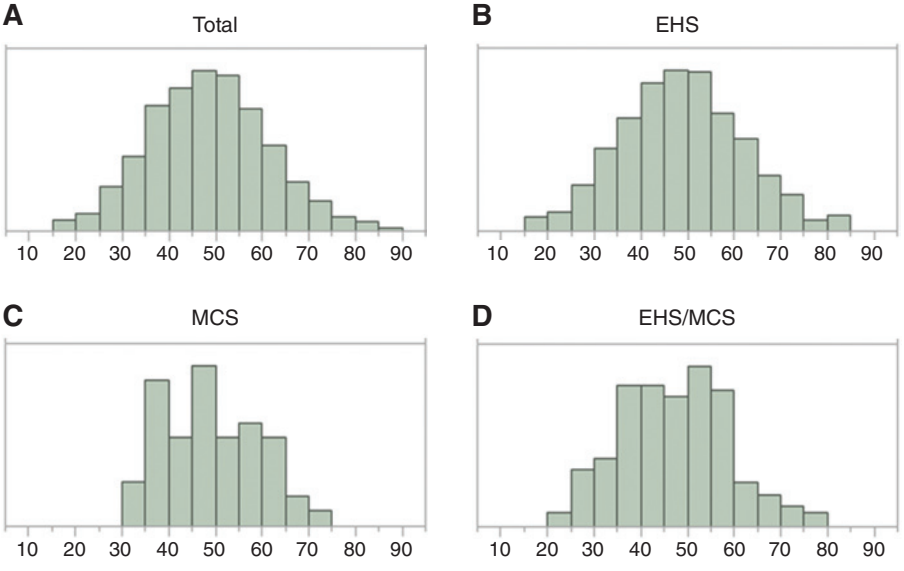

Figure 3: Age categories according to the total number of evaluable patients (A) and to the three EHS (B), MCS (C) and EHS/MCS (D) analyzed groups of patients.

Table 3: High-sensitivity C reactive protein (hs-CRP), immunoglobulin E (IgE), vitamin D2-D3 and histamine in the peripheral blood of EHS and/or MCS self-reporting patients.

Patients groups	EHS	MCS	EHS/MCS
n	521	52	154
hs-CRP	78 (14.97%)	3 (13.46%)	22 (14.28%)
>3 mg/L	[3.27–51.91]	[3.5–10]	[3.27–21.61]
Vitamine D	33 (6.33%)	5 (9.62%)	16 (10.39%)
<10 ng/mL	[4.81–9.70]	[4.80–8.00]	[7.10–9.90]
Vitamine D	300 (57.58%)	25 (48.07%)	92 (59.74%)
≥10 ng/mL and <30 ng/mL	[10.40–29.70]	[10.70–27.90]	[15.00–28.60]
Histamine	182/491 (37%)	18/44 (36.7%)	59/142 (41.5%)
>10 nmol/L	[10.08–360.00]	[10.80–90.00]	[10.10–1797.50]
IgE	115 (22.07%)	8 (15.38%)	38 (24.68%)
>100 UI/mL	[101–1387.60]	[131.10–294.87]	[103.30–1200.00]

Note that for each biomarker the range of values is indicated in square brackets, e.g. [minimum-maximum].

Table 4: Protein S100B and nitrotyrosin (NTT) in the peripheral blood of EHS and/or MCS self-reporting patients.

Patients groups	EHS	MCS	EHS/MCS
n	521	52	154
S100B	73/495 (14.7%)	6/51 (19.7%)	28/142 (10.7%)
>0.105 µg/L	[0.105–2.090]	[0.110–0.500]	[0.110–0.470]
NTT	77/259 (29.7%)	6/29 (26%)	22/76 (28.9%)
>0.9 µg/mL	[0.92–8.20]	[1.10–3.10]	[0.91–3.10]
Increased S100B and/or NTT	133/250 (53.2%)	12/22 (54.5%)	46/73 (63%)
Increased histamine, S100B and/or NTT	220/327 (71.8%)	27/36 (75%)	91/125 (79.1%)

Note that for each marker the range of values is indicated in square brackets, e.g. [minimum-maximum].

Table 5: HSP70 and HSP27 chaperone proteins and anti-O-myelin autoantibodies in the peripheral blood of EHS and/or MCS self-reporting patients.

Patients groups	EHS	MCS	EHS/MCS
n	521	52	154
Hsp 70	91/486 (18.7%)	4/52 (7.7%)	36/142 (7.6%)
>5 ng/mL	[5.90–11.20]	[7.10–7.70]	[5.20–32.20]
Hsp 27	123/476 (25.8%)	6/52 (11.5%)	42/132 (11.5%)
>5 ng/mL	[5.20–11.20]	[5.90–9.20]	[5.10–25.00]
Hsp70 and/or Hsp27	162/487 (33.3%)	9/52 (25%)	56/142 (39.4%)
Anti-O-myelin autoantibodies	109/477 (28.8%)	8/47 (17%)	33/140 (23.4%)

Note that for each marker the range of values is indicated in square brackets, e.g. [minimum–maximum].

High-sensitivity C reactive protein (hs-CRP)

An increase in hs-CRP levels was found globally in 107 patients (14.7% of the cases), and more precisely in 78 patients (15%), seven patients (13.5%) and 22 patients (14.3%), respectively in the three EHS, MCS, EHS/MCS individualized groups (Table 3); suggesting that in such cases, patients were associated with some type of systemic inflammation. We thus systematically looked for unrelated causes of inflammation and/or infection in these patients, but with the exception of three cases, we did not found any. Furthermore, since hs-CRP is considered as a biomarker of age-related cognitive decline or dementia, and more particularly of Alzheimer's disease (63, 64), we systematically searched for Alzheimer's disease in these patients. In two cases, Alzheimer's disease was discovered after inclusion and considered as possibly the results of excessive past EMF exposure (see Section "EHS/MCS as

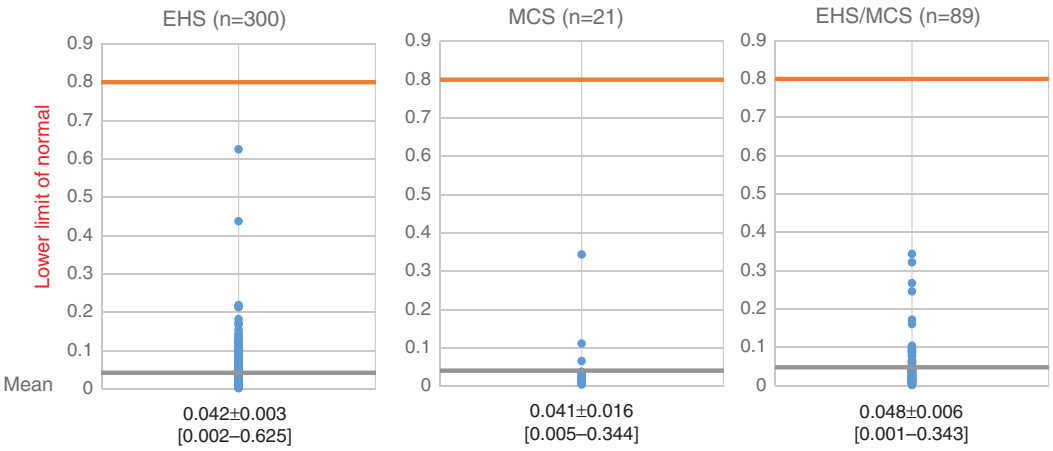

Figure 4: 24 H urine 6-OHMS/creatinine ratio in EHS and/or MCS self-reporting patients.

a possible sentinel pathological disorder"). But, because chronologically, Alzheimer's disease appeared to follow the initial occurrence of EHS, we considered that for these two patients, Alzheimer's disease might have been the consequence of EHS rather than simply associated with it. Nevertheless, these two cases were categorized as non-evaluable cases in the present analysis.

Vitamin D2–D3

As indicated in Table 3, a profound decrease in the levels of the secosteroid 25-D is found globally in 184 patients (25.3% of the cases), and in 121 patients (23.2%), 12 patients (23.1%) and 51 patients (33.1%) in the three groups, respectively. As already discussed (see Section "Search for reliable disease biomarkers"), these data agree with the concept that decrease in vitamin D2–D3 levels appear to be a consequence rather than a cause of inflammation and so need to be therapeutically normalized.

Histamine

An important finding in our study is the discovery that histamine in the peripheral blood is increased in nearly 40% of the patients and that this increase does not differ between the three groups investigated (Table 3). This finding suggests that histamine is not only a natural clinical biomarker of EHS and MCS, but also may play a crucial role in the pathogenesis of both clinical entities, since it has been shown to be not only a neurotransmitter produced and released by the CNS, but also an inflammatory mediator produced and released by mast cells in many inflammatory processes including neuro-inflammation (see Section "Pathophysiological relevance").

IgE

Levels of circulating IgE were found to be increased in 22%, 15.4% and 24.7% of the three EHS, MCS and MCS/EHS groups, respectively. Since histamine release from mast cells involve the high affinity IgE mast cell surface receptor and IgE (30, 65), we searched for a correlation between histamine and IgE levels in the peripheral blood of the patients. As it will be further discussed, it seemed not to be the case (see Section "Pathophysiological relevance").

Protein S100B

Levels of circulating protein S100B have been found to be globally increased in 107 patients (15.5%), with no differences between the three groups (Table 4). As we will discussed (see Section "Some insight into etiopathogeny") this finding confirms previously reported data showing the glia-derived S100B protein is a biomarker of hypoperfusion-associated brain damage or dysfunction (39, 40, 66–68), and more particularly of neurodegenerative diseases such as Alzheimer's disease (69) and amyotrophic lateral sclerosis (70); but differs from the negative results obtained in non EHS healthy subjects for whom protein S100B levels has been shown to be normal within the 2 h following GSM mobile phone use (71–73).

Nitrotyrosin

Likewise, increased NTT blood levels have been detected globally in 105 patients (29%), with no difference between the three groups. Moreover, as indicated in Table 4, it appears that increased levels of protein S100B and/or NTT can be detected in approximately 55%–60% of the cases.

Since, as previously indicated, protein S100B and NTT could be potential markers of BBB disruption, we consider that such disruption could be evidenced clinically in over 50% of the patients, whatever their EHS and/or MCS clinical presentation.

HSP70 and HSP27

As indicated in Table 5, depending of the group considered, increased levels of the HSP70 and HSP27 chaperone proteins were detected in the peripheral blood in about 7%–19% and about 11%–26% of patients, respectively. Collectively, 25%–40% of the patients were found to be associated with increased levels of HSP70 and/or HSP27, without difference between the 3 so far individualized groups, meaning that HSP70 and HSP27 are circulating biomarkers not only of EMF chronic exposure as it is the case in animal experimental studies (42–46) but also of chemical chronic exposure. HSP70 and HSP27 seem to be more frequent in EHS patients than in MCS patients.

Autoantibodies against O-myelin

As indicated in Table 5, autoantibodies against O-myelin have been detected globally in 17% to nearly 29% of the patients studied with no difference between the three groups, suggesting that in these patients EHS and/or MCS were associated with some type of autoimmune response. Here too, it is more frequent in EHS than in MCS.

Melatonin

6-OHMS and creatinine were measured in the 24 h urine of a number of patients. As indicated in Figure 4, all investigated patients had a decrease in the 6-OHMS/creatinine ratio; suggesting that these patients have decreased antioxidant defenses (74, 75), and so may be at risk of chronic diseases (see Sections "Pathophysiological relevance" and "EHS/MCS as a possible sentinel pathological disorder"). Moreover, this decrease might explain why such patients present sleep disturbance.

Clinical forms of EHS and/or MCS without detectable biomarkers

Increase in hs-CRP and vitamin D2–D3 blood levels are non-specific biological parameters. On the other hand, although none of our biomarkers are per se specific (see Section "Some insight into etiopathogeny") the increased serum level of histamine, protein S100B and NTT in the peripheral blood seems more characteristic of EHS and MCS, because of their pathophysiological relevance. However, as indicated in Table 4, increased levels of histamine, protein S100B and/or NTT were found in only 70%–80% of the patients, meaning that in 20%–30% of the cases in our series, EHS and MCS could not be objectively characterized by these biomarkers. However, in such patients in addition, to the clinical picture the objective diagnosis of EHS and/or MCS could still be made based on the abnormal recording of brain pulsed ultrasound computed tomosphygmography.

Pathophysiological relevance

In our study we have shown that EHS and MCS both are associated with the same biological abnormalities. This strongly suggests that both pathological entities share a unique common pathophysiological mechanism.

Since histamine was found to be increased in the peripheral blood of nearly 40% of the patients, this molecule appears to be a key pathogenic mediator, whatever the environmental stressors. Indeed, the fact that histamine levels were not found to be increased in all patients doesn't mean that patients for whom there is no histamine blood level increase have no local histamine production and release in their tissues or at other times. Moreover, we will outline below that histamine is not just a neuro-inflammation mediator. Histamine plays a critical pathophysiological role as a neurotransmitter in the brain. For example neuronal histamine has been shown to be involved in the sleep cycle, motor activity, synaptic plasticity and memory (76–79): all types of neurologic and/or psychologic altered functions or symptoms that we have observed clinically in EHS and/or MCS bearing patients (data not shown). In addition, histamine release from sympathetic nerves can be experimentally induced by nerve stimulation (80) and it has been shown that H1 receptor may play a major role in the regulation of sympathetic nerve activity (81). This may explain why EHS and/or MCS patients may present clinically with some transitory sympathetic-related symptoms such as tachycardia, tachyarrhythmia and/or arterial pressure instability (data not shown) when exposed to EMF and/or chemical stressors (82). Moreover, following ischemic-hypoxic damage, histamine release from nerve endings has been found to be enhanced, possibly contributing to some neuroprotection (83).

However, histamine is also a unique molecule which fulfils all criteria that have been historically established for defining an inflammatory mediator (84). Histamine is mainly produced and stored in perivascular tissue resident mast cells and circulating basophils, and released in inflammatory tissues through established mechanisms predominantly involving cell surface receptors. Regarding histamine release from skin mast cells, the best known degranulation mechanism involves IgE and the high affinity IgE cell surface receptor (30).

In our study, we found elevated levels of circulating IgE in about 20% of the patients, whatever the EHS and/or MCS group considered. However, in such cases, we didn't find any positive correlation between the levels of circulating histamine and the levels of circulating IgE nor the presence of skin lesions. This suggests that skin lesions and circulating histamine level increase in EHS and/or MCS patients are not related to an allergic process.

Also it has been shown that advanced glycation end products (AGEs) can activate mast cells through RAGE, the receptor of AGEs, and may contribute to initiating a vicious circle involving increased AGE formation and ROS production, hence increased low-grade chronic inflammation (85). Similar biological effects may also be obtained with protein S100B which has been shown to engage RAGE in macrophage/microglia and endothelial cells; and so depending of its extracellular concentration, to contribute either to chronic inflammation via NFκB activation or to anti-apoptotic effects and trophic protection in the course of pathological conditions such as brain insult or diabetes (86). Since AGEs have been shown to be involved in diabetes mellitus (87) although all included patients had no diabetes type II at inclusion time, we systematically search for a possible occurrence of diabetes type II in EHS and/or MCS patients during the follow up of this study, but with the exception of two cases, all patients were free from diabetes.

Predominantly found at host/environment interfaces such as skin, respiratory and gastrointestinal tracts (88) and closely associated with blood vessels, mast cells play a crucial sentinel role in host defense (89). Consequently, more precise investigations remain to be done in EHS and/or MCS patients to determine what mast cell-associated tissue histamine release come from.

However, since brain mast cells have been shown to be critical regulators of the pathogenesis of CNS diseases including stroke, traumatic injury and neurodegenerative diseases (83, 90) (see also Section "EHS/MCS as a possible sentinel pathological disorder") we systematically looked for brain pathologic alterations in EHS and /or MCS patients. Routine cerebral MRI and/or scanner as well as carotid echography were critically considered to be normal in all evaluable cases. We thus measured the BBF-related pulsatility in the patient hemispheres by using echodoppler of the middle cerebral artery, and found that resistance index and systolic and diastolic velocity indexes were associated with cerebral hypoperfusion in one or the two hemisphere in 50.5% of the cases, whatever the patient group considered (data not shown). More precisely, by using pulsed ultrasound computed tomosphygmography, we found that in comparison to normal subjects, cerebral pulsatility in EHS and /or MCS patients was decreased or even completely abolished in one or the two temporal lobes (Figure 2), suggesting that BBF might be specifically decreased or abolished in this brain area. We found that this abnormality, although being not specific, was so frequently observed in these patients that it may represent a typical brain alteration similar to that found in Alzheimer's disease and other neurodegenerative diseases (see Section "EHS/MCS as a possible sentinel pathological disorder"). This finding therefore, strongly suggests that brain could be the main target of environmental EMFs and/or chemicals in EHS and/or MCS patients, and that both cerebral hypoperfusion and subsequent histamine release whatever its neuronal or mast cell origin could be main contributing factors to BBB disruption. Furthermore, we found that cerebral blood pulsatility was quasi-constantly decreased in the capsulothalamic area of the temporal lobes, which includes the *limbic system* and the *thalamus*, and so correspond to particularly vulnerable areas to environmental stressors in the brain.

Confirming this capsulothalamic hypothesis, it has been shown that experimentally-induced brain ischemia-hypoxia can increase BBB permeability (91–94) and that hippocampal pathology arising after chronic hypoperfusion can give rise to cognitive impairment and more particularly memory deficit (95), a pathophysiological mechanism that supports both the key role of cerebral hypoperfusion/hypoxia in neurodegenerative diseases such as Alzheimer's disease (96) and our clinical observation of frequent cognitive defects in EHS and/or MCS patients. How cerebral hypoperfusion/hypoxia may arise from the neuro-inflammation process remains however, unclear. Cerebral blood flow restriction and consequently impaired oxygen supply may occur due to local oedematous swelling, artery and/or capillary vasoconstriction and/or increased BBB permeability induced by histamine or other neuro-inflammation mediators (97, 98). While hypoxia itself rather than ischemia can induce histamine release (99). In addition, less efficient oxygen utilization due to mitochondrial uncoupling may be associated with impaired oxygen supply (100). As a consequence of hypoxia and impairment of mitochondrial functioning, reduced sensorial excitability, hence transitory loss of

motor, sensory and cognitive function may occur during EHS and/or MCS processes; but this loss of function may progress to permanence and universality in the case of chronic neurodegenerative diseases (97, 101).

Under the influence of environmental stressors, not only mast cells (102, 103), but also microglia cells and astrocytes (31, 104–106) play a crucial role in BBB disruption. Indeed the resident CNS tissue macrophages glial cells such as microglia cells and astrocytes, and the resident CNS mast cells are probably the first cells to respond to any neuro-inflammatory stimuli. In addition, it has been shown that tachykinin peptides such as substance P, can trigger microglial activation and subsequent release of proinflammatory molecules, thereby contributing in addition, to mast cells to the development of microglia-mediated inflammation and BBB break down (107–109). It is indeed well known that under the influence of neuro-inflammatory stressors, such as EMF and particularly during mobile device (GSM) prolonged exposure, microglia cells can migrate to the site of injury, proliferate and recruit astrocytes (110), what is commonly called gliosis – a first cellular neuro-inflammation response which produces and releases NO°, ROS and inflammatory mediators (105, 111). Moreover, astrocytes express histamine receptors (112) which after activation can trigger release of cytokines, which are themselves able to induce histamine release through mast cell degranulation in positive feedback loop (113). Finally, our finding of both cerebral hypoperfusion and histamine release, supports previous data according to which BBB disruption is obtained more efficiently when these two factors are combined (91).

At a molecular level it has been evidenced that histamine and other neuro-inflammation mediators induce oxidative and nitrosative stress and so change the molecular composition and functional state of the BBB endothelial tight junctions, hence increasing permeability of the BBB (32, 104, 114, 115). As a consequence of this process circulating inflammatory cells may thus transmigrate into the CNS and so amplify the neuro-inflammation response (116, 117). Note that such oxidative/nitrosative stress-induced BBB disruption has not only been evidenced as a consequence of chronic cerebral hypoperfusion (118) but also proved to occur under the influence of EMF exposure at non thermal as well as thermal levels in several animal studies (104, 119–122).

Melatonin suppression as a consequence of EMF exposure has been experimentally evidenced both in animals and humans (123–125). We found that 6-OHMS 24 h-urine excretion was decreased in all the investigated cases, whatever the EHS and/or MCS patient group considered. Although this finding suggests that melatonin production might have been decreased in these patients, EMF exposure have been reported to be incapable of altering melatonin synthesis and secretion (126). So an alternative plausible explanation is that decrease in 6-OHMS excretion may reflect decreased melatonin metabolic availability, due to an increased uptake and utilization of melatonin as a free radical scavenger (127, 128). Such reduction in melatonin bioavailability may thus contribute to decrease host defence mechanisms and may account for the fact that patients submitted to prolonged and intensive EMF exposure may be at risk of neurodegenerative diseases and cancer (129), particularly of breast cancer (130) (see Section "EHS/MCS as a possible sentinel pathological disorder").

The development of the oxidative/nitrosative stress-related autoimmune response may also contribute to weaken the protective effect of the chaperone proteins HSP70 and HSP27 (131) as has been evidenced for example in stroke patients (132). Indeed the role of histamine in modulating the immune system (133), the disturbance of the immune system by EMFs (134) and the progressive increase in oxidative and nitrosative stress as long as chronic exposure to EMFs and/or chemicals persists may explain why the physiological defence mechanisms of these patients may finally collapse.

On the basis of our data we therefore, propose the following pathophysiological model of co-MCS/EHS exposure: 1) Under the influence of EMFs and/or chemicals a cerebral hypoperfusion/hypoxia-related neuro-inflammation may occur; 2) Due to the release of histamine and other mediators BBB disruption and permeability increase may be induced through resulting oxidative and/or nitrosative stress; 3) Circulating inflammatory cells could then enter the brain to initiate a vicious circle which may considerably amplify the neuro-inflammation process; and finally 4) Because of oxidative and nitrosative stress and subsequent decreased melatonin bioavailability and autoimmune response, physiological defence mechanisms are weakened making EHS and/or MCS patients potentially at risk of chronic neurodegenerative diseases and cancer.

Part of this model has been proposed separately for histamine release from mast cells in EHS (135) and for the NO/NOOH- nitrosative stress cycle in MCS (136). Our proposed EHS/MCS common pathogenic model is summarized in Figure 5.

Some insight into etiopathogeny

Certainly this study does not prove a causal link between EMFs and EHS, or between chemicals and MCS, but it does strengthen the evidence for such a possibility. To our

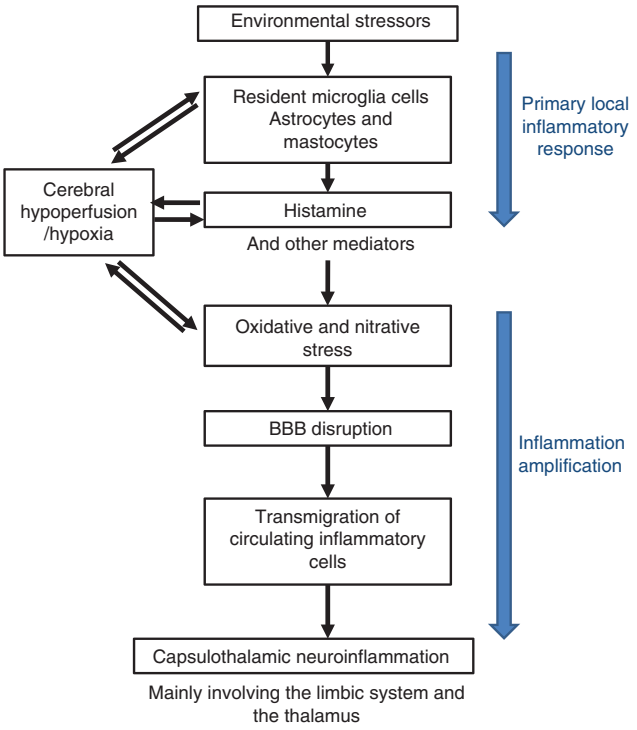

Figure 5: Proposed hypothetic EHS/MCS common pathogenic model based on EHS/MCS induced-neuroinflammation, cerebral hypoperfusion, histamine release, oxidative/nitrosative stress and BBB disruption.

knowledge this is the first time that EHS and/or MCS have been objectively characterized by the use of several different types of biomarkers and in a large prospective series of patients. This finding should avoid the frequent erroneous interpretation that EHS and/or MCS patients are psychosomatic patients (11–14, 17, 137) and so strongly suggests that EHS and MCS are genuine somatic pathological entities. Furthermore, our study revealed that with the exception of the two cases of Alzheimer's disease which were detected soon after inclusion, and several other cases of neurodegenerative diseases which were diagnosed during the follow-up (these cases have been considered as non-evaluable cases) (see Section "EHS/MCS as a possible sentinel pathological disorder"), all EHS and/or MCS patients had no detectable psychiatric disease.

As previously mentioned we should however, note that none of the biomarkers so far identified in our study are specific of EHS and/or MCS. This is the case for histamine which is known to be increased in the serum of patients with typical migraine (138–140) and/or allergy (30) and for HSP70 and HSP27 which has been shown to be increased in several neurodegenerative diseases (141, 142); and for protein S100B which acts normally as a physiological intracellular regulator and extracellular signal and so has been shown to be expressed and released not only by damaged CNS cells such as glial cells and neurons, but also by different non CNS cells such as chondrocytes, adipocytes, melanocytes, myofibers and other non CNS cells (67, 86, 143). This explains why the detection of increased levels of protein S100B in the serum of patients does not mean they are necessarily EHS and/or MCS patients. Other pathological disorders such as neurodegenerative diseases, psychiatric diseases such as bipolar disorder or cancer (70, 144, 145) may be indeed also concerned by such S100B protein levels. Likewise NTT is not only a general marker of inflammation but also more particularly a marker of atherosclerosis (146). Increased levels of NTT are thus also non-specific. As already indicated (see Section "Search for reliable disease biomarkers") we therefore, paid attention for excluding from our series all cases associated with neuropsychiatric diseases and/or other serious pathologies such as atherosclerosis and type 2 diabetes in order to eliminate any confounding factors.

Unlike the reported negative result of histamine increase in MCS patients (147), we found increased histamine levels globally in about 40% of MCS, EHS or MCS/EHS patients. Since it has been shown that increased histamine levels may in fact appear only when MCS patients are submitted to environmental stressors such as volatile organic compounds (VOC) (147), we thus wonder whether the 60% of patients in our series who were not associated with detectable increased histamine levels may in fact be patients who were not exposed to environmental EMF and/or chemical stressors just before histamine measurement. Such interpretation may also involve the fact that in our series we detected increased S100B protein levels in only 15% of the patients, since the increased levels of protein S100B following brain injury are fleeting (39, 40, 66–68).

However, since EHS and MCS share similar biological abnormalities and so may share a common pathophysiological mechanism (see Section "Analysis of biochemical markers"), these two so far clinically individualized entities may represent two etiopathogenic aspects of a unique common pathological disorder. Arguments in support are the following: 1. EHS and MCS are associated with a similar symptomatic clinical picture; 2. Both entities share identical biological abnormalities including histamine release, oxidative and nitrosative stress, and BBB opening; 3. Both entities are characterized by a similar BBF decrease, and this cerebral hypoperfusion take place in the majority of cases predominantly in the same areas, i.e. mostly in the temporal lobes, more precisely in the capsulothalamic area; 4. either EHS or MCS occur first; 5. Using the same therapeutic protocol, similar positive clinical results can be obtained in both cases (data not shown).

Because EHS and MCS were historically identified clinically and distinguished from each other on the basis of individual potentially environmental stressors, some confusion has emerged. That is, unlike EHS and/or MCS which are still considered as subjective entities because of a lack of etiological substratum, many other internationally recognized diseases were medically characterized before discovery of their etiopathological mechanisms. In fact, the acknowledgment of EHS and MCS as resulting from environmental causes oppose to powerful socioeconomic interests and may explain why they are still not recognized as genuine pathological disorders by national or international bodies and health institutions (137).

Moreover, it is well known that diseases are multifactorial and this may explain why current research failed to attribute a causal origin to EHS and/or MCS. Case-control epidemiologic studies and provocation studies, globally have failed to demonstrate a causal link between EMF and EHS (13, 137), as it may also be the case for chemicals and MCS. These negative results however, do not exclude the possibility of a causal link, as observational studies are difficult to conduct and objective inclusion/exclusion criteria and endpoint evaluation criteria were not clearly defined because of a lack of objective reliable biomarkers. Moreover, if we accept the concept that EHS and/or MCS are part of a common multifactorial disease, clearly those findings may also have been biased by multiple related or unrelated confounding exposure factors and so may have been associated with a reduction of signal-to-noise ratio, thereby obscuring evidence of a possible causal link. Moreover, black box epidemiology and provocation studies focus on risk factors without satisfactory understanding pathogenesis.

There are in fact several arguments for a causal role of EMFs and/or multiple chemicals in the genesis of the so far individualized EHS/MCS pathological disorder: 1. Self-reporting occurrence of clinical symptoms depending on electromagnetic and/or chemical sources, 2. Efficient removing or lessening of clinical symptoms in EHS patients and/or MCS patients in case of avoidance of EMFs and/or chemicals, respectively (19); 3. Appearance of biological abnormalities (positive detection of biomarkers) when patients are exposed to electromagnetic and/or chemical sources, and regression or disappearance of these biological abnormalities (normalization of biomarkers) when patients are withdrawn from electromagnetic and/or chemical sources, a finding that confirm objectively self-reporting patient symptoms (data not shown); 4. a possible common underlying pathophysiological mechanism involving oxidative and/or nitrosative stress-associated neuro-inflammation and BBB opening (see Sections "Demographic panorama" and "Analysis of biochemical markers"); and finally 5. Identical or similar biological abnormalities detected in humans as compared to those evidenced experimentally in animals submitted to EMF and/or chemicals exposure. Although our data account for clinical symptoms and biological abnormalities associated with an intolerance syndrome and highlight its pathogenesis, they do not account for susceptibility and more particularly, hypersensitivity which in addition, to intolerance both characterize EHS and MCS. Virtually all diseases result from the interaction of genes and the environment, hence the concept of genetic susceptibility via constitutive genes which can further the pathogenic role of environmental stressors (148). Theoretically such susceptibility could explain why some subjects are particularly suffering from EHS and/or MCS and not others. A genetic predisposition including gene variants of drug-metabolizing enzymes has been reported for MCS (149–151) but this has not been confirmed (152, 153), suggesting that to define MCS biologically, redox state and cytokine profiling should be considered instead (153).

Our data reveal that women are more susceptible than men to EHS or MCS and this susceptibility concerns both EHS and MCS (see Section "Search for clinical diagnosis criteria"). This suggests some still undetermined sex-related genetic susceptibility. To our knowledge there is no reported study on genetic predisposition in EHS patients. As magnetosomes are detectable in the human brain and meninges (pia mater and dura mater) (154), and because some EMF-related biological effects are achieved through magneto-reception (155), we speculated that some type of innate genetic predisposition to EHS might result from the presence of a high number of magnetosomes in the brain and meninges of susceptible patients. This may reveal to be true particularly for non-thermal EMFs (156). Other hypothesis may include acquired susceptibility through epigenetic mechanisms related to EHS and/or MCS prolonged exposure and some biological synergistic potential between EMF exposure and low dose organic or inorganic chemical contamination (157, 158). This may be particularly the case for heavy metals which, as for EMF, have been shown to release proinflammatory cytokines (159, 160).

It is worthy of note that metallic dental alloys are associated with release of heavy metals such as mercury, lead and cadmium into oral cavity (161, 162) and so may contribute to EHS (158). It has been shown that EMFs such as GSM frequencies emitted from mobile phone may induce or accelerate the mercury vapor release from dental amalgam (163) and consequently may contribute not only to EHS but also to MCS (164).

An intriguing unknown pathophysiological mechanism referred to as sensitivity-related illness (SRI) (4) or

as toxicant-induced loss of tolerance (TILT) (165) has been put forward in order to account for the fact that patients with EHS and/or MCS cannot tolerate weak intensity of EMFs and/or low concentration of chemicals. We define acquisition of such a hypersensitivity state with two criteria: 1. Decrease in the tolerance threshold for EMFs or chemicals; and 2. Extension of this decreased tolerance threshold to the whole electromagnetic spectrum or to multiple structurally unrelated chemicals, as disease progress. Although our data may suggest a role of the limbic system and the thalamus, to our knowledge no clear pathophysiological explanation of this intriguing brain-related hypersensitivity condition has yet been given.

EHS/MCS as a possible sentinel pathological disorder

The BBB protects the brain against potentially harmful toxic chemicals which may have contaminated the blood and thereby is currently regarded as a physiological structure that plays a crucial role in maintaining brain homeostasis (166–169). However, the BBB cannot protect the brain against EMFs (170). This may explain why EMFs are probably a major stressor associated with BBB disruption and brain inflammation, and why oxidative stress and more particularly oxidative/nitrosative stress-induced BBB breakdown may be causally involved in neurodegenerative diseases (171, 172), such as Alzheimer's disease (AD) (173–176), Parkinson's disease (PD) (177), multiple sclerosis (MS) (178), Huntington's disease and amyotrophic lateral sclerosis (70) and even possibly psychiatric diseases such as schizophrenia, autism and bipolar disorder (179–182).

Since the first reports on EMF exposure-related BBB disruption (119, 183) conflicting data have emerged (122) leading to search for new tests for evidencing BBB disruption in EHS and/or MCS patients. BBB permeability imaging (184) in addition, to search of peripheral biomarkers could be helpful. Using protein S100B and NTT as biomarkers our data tend to show that BBB opening could be detected in 55%–60% of patients; but this result does not mean the remaining cases could not have been associated with BBB opening we were unable to detect.

There is indeed compelling evidence that chronic neuro-inflammation is a long lasting and potentially self-perpetuating process including an initially long-standing release of inflammatory mediators, leading to increased oxidative and nitrosative stress. This process may thus persist long after the initial environmental trigger and consequently can contribute to neurodegeneration through free radical attack on neural cells (185). This is particularly the case in AD and PD for which toxicity of free radicals have been demonstrated to contribute to protein and DNA injury, inflammation, tissue damage and subsequent neuronal degeneration and apoptosis (175, 176, 183, 185–187).

We have shown that patients with EHS and/or MCS often have cerebral hypoperfusion and histamine release, two factors that in addition, to the production of autoantibodies have been evidenced to occur in AD (173, 174) and PD (188–192); hence contributing to neuro-inflammation and BBB dysfunction. Moreover, several studies have shown that prolonged occupational exposures to low or extremely low frequency EMFs are associated with AD (193–196) and such a link has recently been confirmed in a meta-analysis based on more than twenty epidemiological studies (197). Although it has been shown in a single study that long term high frequency EMF exposure could protect against and even reverse cognitive impairment in mice bearing a so called animal equivalent of AD (198), there is currently no scientific reason to believe that in humans prolonged radiofrequency EMF exposure as it is the case with excessive cell phone and/or mobile phone use will be not also causally related to AD occurrence (199). Moreover, it has been shown that neurodegenerative diseases are in fact multifactorial and that, as it has been hypothesized, ferrimagnetic metals in food chain may contribute to initiate these neurodegenerative diseases under the influence of EMF exposure (200).

Typically AD starts with mild memory deficits, primarily affecting short term memory and gradually progresses to loss of retrospective memory and dementia. An important finding in our still ongoing study is that most of EHS and/or MCS patients had decreased cognitive ability manifested by loss of immediate memory and attention and concentration deficiency (see Sections "Search for reliable disease biomarkers" and "Analysis of biochemical markers"). Since EHS and/or MCS pathogenesis appears to be associated with brain pathophysiological abnormalities similar to that occurring in neurodegenerative disorders, a question is whether EHS and/or MCS are either a pre-neurodegenerative state or an unrelated pathological disorder whose environmental causal origin might however, be similar to that of neurodegenerative diseases. Nevertheless, whichever these two possible etiopathologic alternatives, EHS and/or MCS might be considered as some type of environmental sentinel pathological disorder.

It is worthy of note that in our series, in addition, to the two cases of AD, which were diagnosed a few months after inclusion, another case of AD and two cases of PD were discovered in association with EHS during the patient follow up. Moreover, at inclusion time we excluded two cases of AD, two cases of PD, three cases of multiple sclerosis,

and one case of Huntington disease, which were found to be associated with EHS. In addition, we excluded seven EHS or EHS/MCS cases because they were associated with previous or simultaneous carcinoma: breast carcinoma (3 cases), brain tumor (2 cases) and lymphoma (1 case). We also excluded three MCS cases because they were associated with lymphoma (1 case) and thyroid endocrinopathy (2 cases).

Certainly long term longitudinal analysis and replication of this ongoing prospective study will be necessary to establish whether EHS and/or MCS could be related to neurodegenerative disease and/or cancer, and thus may announce or reflect occurrence of these pathologies.

The growing worldwide health problem

Whatever the causal origin of EHS and/or MCS, there is compelling evidence that EHS and/or MCS self-reporting patients constitute an unsolved, large and growing health problem worldwide.

As far as EHS is concerned, about 1%–10% of the investigated population, e.g. 5% in Switzerland (13), 5% in Ireland, 9% in Sweden, 9% in Germany and 11% in England are presently estimated to be EHS self-reporting persons (201). Given the seven billion persons worldwide using cordless and/or mobile phone it is expected these percentages may increase in the 50 next years. However, because at the time these estimations were made there was no objective criteria for identifying EHS (21), these data require confirmation by more objective investigations.

By using the battery of biomarkers we have investigated in this study it now seems possible to objectively characterize and identify EHS and MCS. Although termed "idiopathic", IEI has been defined as abnormal responses possibly triggered by exposure to organic chemicals and/or metals. It is believed that in addition, to MCS several pathological disorders such as fibromyalgia and chronic fatigue syndrome, because they may share a similar environment-related intolerance condition, could be part of IEI. We have shown multiple lines of evidence that EHS and MCS share a similar pathogenesis and so might be the same pathological disorder whatever their putative causal stressors. This strongly reinforces the concept that both EHS and MCS must be part of the so called IEI syndrome.

Since the WHO publication in 1993 on EMFs (202), much progress have been made in the identification and understanding of EMF effects on the organism, while EHS has still not been clearly characterized and acknowledged by WHO.

Present research vainly focus on the causal role of EMFs and chemicals as possible triggers of EHS and MCS, respectively and not enough on the actually unmet health care needs at a socioeconomic and public health setting for persons with environmental sensitivity (203), as it is particularly the case for EHS and/or MCS persons.

We therefore, strongly propose that whatever their proofs for their causal origins, EHS and MCS should clearly be added to the next version of the WHO international classification of diseases (ICD) on the basis on their clinical and pathological description; as has been the case for many other diseases.

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De biologische effecten van zwakke elektromagnetische velden

Problemen en oplossingen

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Voorwoord

Ik ben voormalig docent aan het Imperial College in Londen, na Oxford en Cambridge de derde universiteit van het Verenigd Koninkrijk en gerenommeerd om haar expertise op het gebied van elektrotechniek en gezondheid. Ik heb vele jaren besteed aan het bestuderen van de calciumhuishouding in levende cellen en hoe cellen, weefsels en organismen worden beïnvloed door elektrische en elektromagnetische velden.

In dit artikel wil ik in lekentaal proberen uit te leggen hij uit hoe zwakke elektromagnetische velden van mobiele telefoons, draadloze telefoons en WiFi ernstige gevolgen kunnen hebben voor de gezondheid van mens en dier. Dit houdt schade in aan klieren, met als gevolg obesitas en aanverwante stoornissen, chronische vermoeidheid, autisme, toename van allergieën en meervoudige chemische gevoeligheden, vroegtijdige dementie, DNA-schade, verlies van vruchtbaarheid en kanker.

Dit alles gebeurt op niveaus van straling waarvan onze overheden en de telefoonbedrijven zeggen dat ze veilig zijn, omdat de straling te zwak is om significante verwarming te veroorzaken. **Dit is het enige criterium dat ze gebruiken om de veiligheid te beoordelen**. In feite brengt het directe elektrische effect op onze cellen, organen en weefsels veel meer schade aan bij energieniveaus die honderden of duizenden malen lager kunnen zijn dan die door significante oververhitting. Dit noemen we de niet-thermische effecten. **Tot op heden doen onze regering en onze gezondheidsautoriteiten niets om ons hier tegen te beschermen.**

Samenvatting

Veel van de gemelde biologische effecten van niet-ioniserende elektromagnetische velden treden op bij niveaus die te laag zijn om significante verwarming te veroorzaken, dat wil zeggen ze zijn niet-thermisch. De meeste kunnen worden verklaard door elektrische effecten op levende cellen en hun membranen. De wisselende velden genereren wisselende elektrische stromen die door de cellen en

weefsels vloeien en structureel belangrijke calciumionen uit celmembranen verwijderen, waardoor die gaan lekken.

Elektromagnetisch behandeld water (zoals gegenereerd door elektronische water-conditioners, die worden gebruikt om kalkaanslag te verwijderen) heeft vergelijkbare effecten. Dit houdt in dat de effecten van de velden ook kunnen worden uitgeoefend in de bloedbaan. Vrijwel alle niet-thermische effecten van elektromagnetische straling kunnen worden verklaard door het lekken van celmembranen.

Meestal heeft dit naar binnen lekken van vrije calciumionen een enorme elektrochemische gradiënt tot gevolg, waardoor calcium-gevoelige enzymsystemen worden beïnvloed. Dit is het normale mechanisme waarmee cellen mechanische membraanschade voelen. Ze reageren normaal door reactiemechanismen die de groei en reparatie stimuleren, met inbegrip van de MAP-kinase cascades, die het signaal versterken.

Als de schade niet te groot of te langdurig is, zien we een stimulering van de groei en het effect lijkt positief, maar als de blootstelling voortduurt, worden deze mechanismen overwonnen en het resultaat is uiteindelijk schadelijk. Dit fenomeen treedt zowel op bij ioniserende als bij niet-ioniserende straling en wordt straling-hormese genoemd. Cellen van klieren zijn hier een goed voorbeeld van, aangezien kortdurende blootstellingen hun activiteit stimuleren, maar blootstelling gedurende langere tijd veroorzaken zichtbare schade en functieverlies. Schade aan de schildklier door het wonen binnen 100 meter van een GSM basisstation veroorzaakte hypothyreoïdie en kan gedeeltelijk verantwoordelijk zijn voor de huidige uitbraak van obesitas en chronische vermoeidheid.

Secundaire gevolgen van overgewicht zijn diabetes, koudvuur, hartproblemen, nierfalen en kanker. Straling van GSM basisstations beïnvloedt ook de bijnieren en de aanmaak van adrenaline en cortisol. Overtollige adrenaline veroorzaakt hoofdpijn, hartritmestoornissen, hoge bloeddruk, tremoren en slaapproblemen, die allemaal zijn gemeld door mensen die dicht bij basisstations wonen. De productie van cortisol verzwakt het immuunsysteem en kan omwonenden van basisstations meer vatbaar maken voor ziekten en kanker.

Naar binnen lekken van calcium in de neuronen van de hersenen stimuleert hyperactiviteit en maakt ze minder goed in staat om zich te concentreren op taken, wat kan resulteren in “attention deficit hyperactivity disorder” (ADHD). Wanneer dit gebeurt in de hersenen van ongeboren baby's en jonge kinderen, vermindert dit hun vermogen om zich te concentreren op het leren van sociale vaardigheden en kan dit autisme veroorzaken. Lekkage van de cellen van het perifere zenuwstelsel bij volwassenen zorgt voor foutieve signalen naar de hersenen. Dit resulteert in de symptomen van elektromagnetische intolerantie (elektromagnetische overgevoeligheid). Sommige vormen van elektromagnetische intolerantie kunnen het gevolg zijn van beschadiging door de mobiele telefoon van de bijschildklier, die het calcium in het bloed controleert en celmembranen meer “lekgevoelig” maakt. Verdere blootstelling kan dan resulteren in symptomen van elektromagnetische intolerantie.

GSM straling beschadigt het DNA indirect, hetzij door de lekkage van spijsverteringsenzymen uit lysosomen of door de productie van reactieve zuurstof soorten (ROS) van beschadigde mitochondriale en plasma membranen. De gevolgen zijn vergelijkbaar met die van blootstelling aan gammastraling van radioactief isotoop.

Effecten van DNA schade houden een verhoogd risico op kanker en een verlies van vruchtbaarheid in. Beide gevolgen zijn geconstateerd in epidemiologische studies. De effecten van de mobiele telefoon en WiFi-straling zijn ook experimenteel vastgesteld met behulp spermavocht. De resultaten toonden de productie van ROS en een verlies aan kwaliteit van het sperma en, in sommige gevallen, DNA fragmentatie.

Het naar binnen lekken van calciumionen door elektromagnetische velden opent ook de verschillende strikte afscheidingen in ons lichaam, die ons normaal beschermen tegen allergenen en giftige stoffen in het milieu en die voorkomen dat giftige stoffen in de bloedbaan gevoelige delen van het lichaam, zoals de hersenen, binnengaan. De opening van de bloed-hersen barrière heeft aangetoond het afsterven van neuronen te kunnen veroorzaken, waardoor aandoeningen als vroegtijdige dementie en Alzheimer verwacht kunnen worden. De opening van de barrière in ons respiratoire epitheel door elektromagnetische velden heeft aangetoond het risico van astma bij kinderen te vergroten; de opening van de bloed-lever barrière kan gedeeltelijk verantwoordelijk zijn voor de huidige uitbraak van leverziektes. De opening van andere barrières, zoals de darmbarrière, kan vreemde stoffen uit de darmen in de bloedbaan toelaten. Hierdoor kunnen allergieën ontstaan; ook zijn er connecties gelegd met auto-immuun ziekten.

Celmembranen fungeren ook als elektrische isolatoren voor de natuurlijke gelijkstromen die ze gebruiken om energie te transporteren. Mitochondriale membranen gebruiken de stroom van waterstofionen voor het koppelen van het verbranden van voedsel aan de productie van ATP. Het buitenste celmembraan gebruikt de stroom van natriumionen voor het koppelen van het geproduceerde ATP aan de opname van voedingsstoffen. Als een van deze twee lekken of permanent zijn beschadigd, zullen beide mechanismen worden verstoord; dit kan leiden tot een verlies van beschikbare energie. Dit levert volgens sommigen een bijdrage op aan het chronische vermoeidheidssyndroom.

Het mechanisme dat ten grondslag ligt aan door elektromagnetische velden geïnduceerde membraan lekkage is, dat zwakke ELF (“extreme low frequency”) stromen die door weefsels vloeien, bij voorkeur structureel belangrijke calciumionen verwijderen, maar ze hebben aangetoond dat dit alleen gebeurt binnen bepaalde amplitude grenzen, waarboven en waaronder er weinig of geen effect optreedt. Dit betekent dat er geen eenvoudige dosis-response curve bestaat. Dit vinden veel mensen verwarrend maar een plausibel theoretisch model wordt hieronder beschreven. Het mechanisme verklaart ook waarom bepaalde frequenties, vooral 16 Hz, bijzonder effectief zijn.

Levende cellen hebben zich ontwikkeld als verdedigingsmechanismen tegen niet-ioniserende straling. Dit omvat het wegpompen van een overschot aan calcium die in het cytosol is gelekt, de sluiting van de overgangen om de beschadigde cellen te isoleren, de productie van ornithine decarboxylase om DNA te stabiliseren en de productie van warmte-shock eiwitten, die werken als “chaperones” om belangrijke enzymen te beschermen. Dit kost echter veel energie en hulpbronnen en leidt tot een verlies van cellulaire efficiency. Als de blootstelling aan de straling wordt verlengd of vaak wordt herhaald, wordt elke stimulering van de groei die wordt veroorzaakt door het initieel binnendringen van calcium onmogelijk gemaakt en wordt de groei en het herstel tegengegaan. Als het herstel uitblijft, kan de cel afsterven of permanent worden beschadigd.

Tot op zekere hoogte kunnen we onze eigen elektromagnetische omgeving veiliger te maken door het vermijden van ELF elektrische en magnetische velden en radiogolven die zijn gepulseerd of amplitude

gemoduleerd met ELF frequenties. De ELF-frequenties die schadelijke biologische effecten veroorzaken, zoals gemeten bij calcium vrijlating uit hersendelen en ornithine decarboxylase productie in weefsel culturen, liggen tussen 6 Hz en 600 Hz. Het is jammer dat vrijwel alle digitale mobiele telecommunicatiesystemen gebruik maken van pulsen in dit gebied. De industrie heeft duidelijk haar huiswerk niet goed gedaan, voordat deze technologieën werden losgelaten op het grote publiek en dit verzuim kan al vele levens hebben gekost.

Zelfs nu, kan het mogelijk zijn hun effecten om te keren door het “begraven” van de pulsen in willekeurige magnetische ruis, zoals voorgesteld door Litovitz in de jaren 1990, of door het neutraliseren van de pulsen door middel van een “gebalanceerde signaal technologie” maar, op dit moment, lijkt de industrie daar geen belangstelling voor te hebben.

Totdat de mobiele telecommunicatie industrie haar producten meer biologisch vriendelijk maakt, hebben we weinig andere keuze dan onze persoonlijke blootstelling zoveel mogelijk te beperken. Dit kan door het gebruiken van mobiele telefoons alleen in noodgevallen, het vermijden van DECT draadloze telefoons en het vervangen van WiFi door Ethernet communicatie. De enige DECT telefoons die nog enigszins aanvaardbaar zijn die, waarvan het basisstation automatisch wordt uitgeschakeld als geen verbinding wordt gemaakt (“normale” DECT telefoons stralen 24 uur/dag en 7 dagen/week); bijvoorbeeld de Gigaset C595, ingesteld in Eco Plus-modus. Wie zeer gevoelig is voor elektromagnetische straling kan zijn huis, of tenminste zijn bed, afschermen tegen binnenkomende microgolfstraling en zo ver mogelijk uit de buurt slapen van bekende bronnen van ELF.

INTRODUCTIE

Er zijn vele voorbeelden van schadelijke effecten door elektromagnetische velden van mobiele telefoons, DECT-telefoons (draadloze telefoons in huis), WiFi, hoogspanningsleidingen en elektrische bedrading in huizen en gebouwen. Die houden een verhoogd risico in op kanker, verlies van vruchtbaarheid, effecten op de hersenen en symptomen van elektromagnetische intolerantie. Veel mensen geloven nog steeds dat, omdat de energie van de velden te laag is om aanzienlijke verwarming te veroorzaken, ze geen biologische effecten veroorzaken. Echter, de bewijzen dat wisselende elektromagnetische velden niet-thermische biologische effecten kunnen hebben, zijn nu overweldigend. Zie o.a. op www.bioinitiative.org en www.neilcherry.com. De verklaring is dat het niet het verhittingseffect, maar vooral het elektrisch effect op de gevoelige structuur van de elektrisch geladen celmembranen is waarvan alle levende cellen afhankelijk zijn.

Wisselende elektromagnetische velden kunnen wisselstromen induceren, die door levende cellen en weefsels stromen. Deze kunnen interfereren met de normale gelijkstromen en -spanningen die essentieel zijn voor de stofwisseling van alle cellen. Vrijwel elke levende cel is een kolkende massa van elektrische stromen en elektrische en biochemische versterkers, die essentieel zijn voor hun normaal functioneren. Sommige hebben een enorme versterkende capaciteit; bijvoorbeeld wordt beweerd dat een aan het donker aangepast menselijk oog een enkele foton (de kleinst mogelijke eenheid van licht) kan detecteren en dat het menselijk oor kan geluiden met een vermogen van slechts een miljardste watt kan horen. We moeten daarom niet al te verbaasd zijn als we merken dat onze cellen elektromagnetische velden kunnen detecteren en daarop reageren, die ordes van grootte beneden het niveau liggen dat nodig is om een betekenisvolle hoeveelheid warmte te genereren.

Mijn voornaamste doel hier is om te laten zien hoe het grootste deel van de schadelijke gezondheidseffecten van elektromagnetische velden kan worden toegeschreven aan een enkele oorzaak; die is dat ze structureel belangrijke calciumionen (elektrisch geladen calcium atomen) verwijderen uit celmembranen; die gaan vervolgens lekken. Ik zal de wetenschappelijke bewijzen die tot deze conclusie leiden uitleggen en ook hoe we een en ander kunnen herstellen, zonder af te zien van het gebruik van mobiele telefoons en andere draadloze communicatie. Ik heb ook belangrijke referenties, die de meer nieuwsgierige lezers in staat moeten stellen om dieper graven, toegevoegd. In veel gevallen moet u een samenvatting van de betreffende publicatie op internet terug kunnen vinden.

Elektromagnetische velden zijn van invloed op vele, maar niet op alle mensen
Veel experimenten op het gebied van de biologische effecten van elektromagnetische wisselvelden blijken wisselende resultaten op te leveren. Daar zijn vele redenen voor, zoals verschillen in de genetische make-up, fysiologische toestand en de geschiedenis van het testmateriaal. Bij mensen, houden gerapporteerde effecten een verhoogd risico in op kanker, effecten op de hersenfunctie, verlies van vruchtbaarheid, metabolische veranderingen, vermoeidheid, verstoring van het immuunsysteem en verschillende symptomen van elektromagnetische intolerantie.

Niet iedereen wordt op dezelfde manier beïnvloed en sommigen kunnen helemaal niet worden aangetast. Echter, er is steeds meer bewijs dat de situatie erger wordt. Onze blootstelling aan elektromagnetische velden neemt snel toe en voorheen gezonde mensen worden nu elektrogevoelig. In deze studie heb ik me geconcentreerd op de gevallen waarin duidelijke effecten te zien waren. Dit is de meest efficiënte manier om te weten te komen wat er fout gaat en wat kan worden gedaan om dit te voorkomen.

De frequentie van de velden is belangrijk
De velden die de meeste problemen geven liggen in het extreem lage frequentiebereik (ELF) en ook de radiofrequenties die zijn gepulst of amplitude gemoduleerd met ELF (amplitudemodulatie vindt plaats als een draaggolf informatie verstuurt door in sterkte toe- en af te nemen met een lagere frequentie, die de informatie draagt) leveren problemen op.

Waarom microgolven in het bijzonder schadelijk zijn
De frequentie van de draaggolf is ook belangrijk. Hogere frequenties, zoals de microgolven die worden gebruikt in mobiele telefoons, WiFi en DECT-telefoons, zijn het meest schadelijk. Onze huidige blootstelling aan kunstmatige microgolven is ongeveer een miljoen miljard miljard (één, gevolgd door vierentwintig nullen) keer groter dan onze natuurlijke blootstelling aan deze frequenties. We zijn niet geëvolueerd in zo'n omgeving en we moeten dus niet al te verbaasd zijn om te ervaren dat tenminste sommige mensen hier niet genetisch aan zijn aangepast. Zoals bij de meeste bevolkingsgroepen die worden geconfronteerd met veranderingen in het milieu, worden diegenen die niet zijn aangepast ofwel ziek, sterven voortijdig of zorgen niet of onvoldoende voor nageslacht. Ironisch genoeg zijn diegenen die elektromagnetisch intolerant zijn beter uitgerust om te overleven, omdat ze gedreven worden om alles te doen wat in hun vermogen ligt om de straling te vermijden.

De belangrijkste reden waarom microgolven in het bijzonder schadelijk zijn is waarschijnlijk vanwege het gemak waarmee de stromen die ze opwekken celmembranen doorboren. Celmembranen hebben een zeer hoge weerstand tegen gelijkstromen maar, omdat ze zo dun zijn (ongeveer 10 nanometer), gedragen ze zich als condensatoren; hierdoor kunnen de hoogfrequente wisselstromen ze gemakkelijk passeren. Aangezien de effectieve weerstand van een condensator voor wisselstromen (de reactantie)

omgekeerd evenredig is aan de frequentie, gaan microgolfstromen nog gemakkelijker door de celmembranen en weefsels heen dan radiogolven van lagere frequenties; ze kunnen daarom meer schade aanrichten aan de inhoud van de cel.

Calcium verlies van celmembranen verklaart het grootste deel van de schadelijke gevolgen voor de gezondheid

Ik raakte geïnteresseerd in dit onderwerp toen ik werkte aan de biologische effecten van fysisch (magnetisch) geconditioneerd water, dat op grote schaal wordt gebruikt om kalkaanslag van ketels en sanitair te verwijderen. Het wordt gemaakt door leidingwater snel te laten stromen tussen de polen van een krachtige magneet of door het bloot te stellen aan een zwak gepulseerd elektromagnetisch veld van een elektronische water conditioner. Water dat op deze manier is behandeld kan calcium ionen (elektrisch geladen calcium atomen) verwijderen van oppervlakken en het effect op het water kan enkele dagen aanhouden. Ik volgde een aantal Russische en Israëlische studies op waaruit bleek dat magnetisch geconditioneerd water de groei van gewassen zou kunnen bevorderen, maar het bleek veel belangrijker te zijn dan dat. Het onderliggende principe kon ook de mechanismen verklaren, waardoor zwakke elektromagnetische velden schade aan levende cellen kunnen toebrengen; het verklaart ook wat kan worden gedaan om dit te stoppen.

Magnetisch geconditioneerd water en elektromagnetische velden hebben soortgelijke effecten

Waarschijnlijk was onze belangrijkste ontdekking dat als leidingwater werd geconditioneerd door zwakke elektromagnetische velden, het behandelde water soortgelijke effecten gaf in gist als wanneer het gist zelf was bestraald, waaronder een verhoogde permeabiliteit van de celmembranen voor giftige stoffen (Goldsworthy et al.. 1999). Omdat al bekend was sinds het werk van Bawin et al. (1975) dat zwakke elektromagnetische velden calciumionen uit de oppervlakken van de hersencellen konden verwijderen, leek het waarschijnlijk dat zowel het geconditioneerde water als de elektromagnetische velden op dezelfde manier werkten; **dat wil zeggen door het verwijderen van structureel belangrijke calciumionen uit celmembranen, die daardoor lekken gingen vertonen.** We weten nu dat dit lekken van membranen het merendeel van de biologische effecten van zowel geconditioneerd water als van directe blootstelling aan elektromagnetische velden kan verklaren.

De effecten op de groei hangen af van de duur van de conditionerende behandeling

We toonden ook aan dat de effecten van geconditioneerd water op de groei van gist culturen afhankelijk waren van de duur van de conditionering. Minder dan 30 seconden van conditionering stimuleerde de groei, maar meer dan 30 seconden remde de groei. Het was alsof het conditioneringsproces geleidelijk aan een of meer chemische stoffen in het water aanbracht. Een lage dosis als gevolg van de kortere conditioneringsperiode stimuleerde de groei, maar langere conditioneringsperiodes leverden een hogere dosis op, die de groei afremde. Dit toxische effect van zwaar geconditioneerd water, waarbij het water continu door de conditioner wordt gerecycled, wordt nu commercieel geëxploiteerd door draadalgen in vijvers te vergiftigen (www.lifescience.co.uk /domestic_blanketweed.htm). Op dezelfde manier kan het bloed, dat continu en gedurende langere tijd circuleert onder invloed van de pulserende velden van een mobiele telefoon of een vergelijkbaar apparaat, giftig worden voor de rest van het lichaam. Dit betekent dat geen enkel deel van het lichaam, van de hersenen tot aan de lever en gonaden, veilig kan worden beschouwd voor de toxische invloeden van gepulste elektromagnetische velden.

Straling-hormese

Veel mensen hebben soortgelijke dubbele effecten ondervonden van directe blootstelling aan zowel

ioniserende als niet-ioniserende straling. Kleine doses van anders schadelijke straling stimuleren vaak de groei en blijken gunstig (een fenomeen bekend als straling-hormese) maar grotere doses zijn schadelijk. Dit verklaart ook waarom lage doses van gepulseerde magnetische velden effectief zijn bij de behandeling van sommige medische aandoeningen zoals gebroken botten (Bassett et al.. 1974), maar langdurige blootstelling (zoals we later zullen zien) schadelijk is.

Het verklaart ook enkele van de schijnbare tegenstrijdigheden die worden gevonden bij het vergelijken van verschillende experimenten, en waarom meta-analyses van de gegevens met voorzichtigheid moeten worden behandeld. Duidelijke positieve en duidelijke negatieve resultaten (afhankelijk van de dosis en de toestand van het materiaal) samengevoegd, kunnen foutief worden gekenmerkt als geen effect, maar met een hoge mate van variabiliteit.

Cellen hebben enorme krachten om zwakke signalen te versterken en daarop te reageren
We weten nu dat elektromagnetische groeibevordering vrijwel zeker een gevolg is van elektrochemische versterking, gevolgd door de activering van de MAP kinase cascades door vrije calciumionen, die lekken in het cytosol (het grootste deel van de cel). Het naar binnen lekken van calciumionen is het normale mechanisme waardoor een cel voelt dat hij beschadigd is en de noodzakelijke reparatie-mechanismen activeert. Het gaat om enorme versterkingsprocessen, zodat zelfs kleine lekken (bijvoorbeeld door membraanperforatie of zwakke elektromagnetische velden) snelle en vaak massale reacties teweeg kunnen brengen.

De eerste fase van de versterking is het gevolg van de calcium gradiënt zelf. Er is hier een enorm (meer dan een duizendvoudig) concentratieverschil voor vrij calcium tussen de binnen-en buitenkant van levende cellen. Daarnaast is er een spanningsverschil van vele tientallen millivolts dat in dezelfde richting werkt. Dit betekent dat zelfs een kleine verandering in het lekken van het celmembraan een zeer grote instroom van calciumionen tot gevolg kan hebben. Het is als bij een transistor, waarbij een kleine verandering in de lading in de basis een enorme stroom kan veroorzaken, onder invloed van een relatief hoog spanningsverschil tussen de emitter en de collector.

De volgende stap van de versterking wordt veroorzaakt door de extreem lage calciumconcentratie in het cytosol, waardoor zelfs het binnendringen van weinig calciumionen een groot verschil maakt; vele enzymen in de cel zijn hier gevoelig voor.

Nog meer versterking komt van de MAP-kinase cascades. Dit zijn biochemische versterkers die het mogelijk maken dat kleine hoeveelheden groeifactoren of hormonen (misschien zelfs een enkele molecule) zeer grote effecten tot gevolg hebben. Ze bestaan uit ketens van enzymen die achtereenvolgens actief zijn; het eerste enzym activeert talrijke moleculen van het tweede enzym, dat op zijn beurt nog meer moleculen van het derde enzym activeert, etc. De laatste stap activeert de proteïne synthese machinerie, die nodig is voor celgroei en -reparatie.

Tenminste enkele van deze cascades hebben calciumionen nodig om hun werk te doen (Cho et al.. 1992), zodat het naar binnen lekken van calcium door beschadigde celmembranen de snelheid van deze processen die de groei en herstel stimuleren zullen verhogen. Echter, deze reparaties kunnen een grote aanslag doen op de beschikbare energie en hulpstoffen van de cel, en het vermogen om de schade te herstellen zal afhangen van de fysiologische en voedingstoestand van de cel. Dit betekent dat, indien de schade langdurig of blijvend is, de hulpstoffen vroeg of laat zijn uitgeput en de cel het opgeeft. Dit gebeurt in de remmende fase, wellicht gevolgd door apoptosis (afsterven van de cel) of door het verlies van een deel van de normale functies. We zien nu dit verlies van functie in toenemende

mate optreden na langdurige blootstelling aan de straling van mobiele telefoon basisstations; een voorbeeld hiervan is het verlies van de schildklier functie na zes jaren van blootstelling (Eskander et al., 2012.).

Effecten op Klieren

Cellen van klieren zijn vooral gevoelig voor straling

Cellen van klieren kunnen bijzonder gevoelig zijn voor straling, omdat hun afscheiding normaal wordt geproduceerd in interne membraansystemen, die ook kunnen worden beschadigd. Hun afscheiding wordt meestal uitgescheiden in de vorm van blaasjes (membraanbelletjes), die samensmelten met het externe celmembraan en hun inhoud naar buiten uitstoten (exocytose). Het membraanblaasje wordt dan een deel van het externe membraan. De resulterende overmaat aan uitwendig membraan wordt gecompenseerd door het omgekeerde proces (endocytose) waarbij het externe membraan blaasjes afgeeft aan het inwendige van de cel; die smelten vervolgens samen met de interne membranen. Op deze wijze kan een actieve cel van een klier het equivalent van zijn gehele membraanoppervlak ongeveer elk half uur naar binnen brengen. Dit betekent dat, als het membraanoppervlak direct wordt beschadigd door de velden of door elektromagnetisch geconditioneerd bloed, het beschadigde membraan snel onderdeel wordt van het inwendige membraansysteem, waarvan de normale activiteit afhangt. Indien de schade te ernstig is, kan de hele klier zijn normale functie verliezen.

Elektromagnetische effecten op het endocriene systeem en obesitas

Hoewel elektromagnetische velden vaak de klieractiviteit op de korte termijn stimuleren, is langdurige blootstelling vaak schadelijk, doordat de klier niet meer goed werkt. Dit is vooral ernstig voor de klieren van het endocriene systeem (die klieren die onze lichaamsfuncties coördineren), omdat dit invloed kan hebben op vele aspecten van het metabolisme en het hele lichaam uit balans kan brengen. Dit kan bijvoorbeeld verantwoordelijk zijn, althans gedeeltelijk, voor de huidige uitbraak van obesitas en vele andere ziekten die daaruit voortvloeien.

Een goed voorbeeld hiervan is de schildklier, die in een kwetsbare positie aan de voorkant van de hals zit. Rajkovic et al.. (2003) toonden aan dat na drie maanden blootstelling aan de frequenties van het elektriciteitsnet, de schildklieren van ratten zichtbare tekenen van achteruitgang lieten zien. Ze verloren ook hun vermogen om de schildklierhormonen te produceren, wat niet terugkwam, ook niet nadat de velden waren uitgeschakeld. Esmekaya et al.. (2010) vond een soortgelijke zichtbare verslechtering van de schildklier bij ratten, die werden blootgesteld aan gesimuleerde 2G GSM-straling gedurende 20 minuten per dag, gedurende drie weken. Eskander et al.. (2012) vonden bij mensen die gedurende zes jaar binnen 100 meter van een GSM basisstation woonden een significante vermindering van de uitstoot in het bloed van een aantal hormonen, waaronder ACTH uit de hypofyse, cortisol uit de bijnierklieren, en prolactine en testosteron van organen elders. Echter, het meest significante verlies was hun vermogen om de schildklierhormonen aan te maken. Het verwachte gevolg hiervan is hypothyreoïdie, waarvan de meest voorkomende symptomen vermoeidheid en obesitas zijn. Het kan geen toeval zijn dat ongeveer een kwart miljoen Britse burgers nu lijdt aan wat wordt gediagnosticeerd als chronisch vermoeidheidssyndroom en ongeveer acht van de tien hebben overgewicht of zijn klinisch zwaarlijvig.

De incidentie van obesitas kan worden verergerd door effecten op de productie van de eetlust regulerende hormonen ghreline en peptide YY. Ghreline wordt gesynthetiseerd in de maagwand en

geeft ons een gevoel van honger, terwijl peptide YY wordt gemaakt in de darmwand en ons een vol gevoel geeft. Bij normale mensen is het niveau van ghreline in het bloed hoog vóór de maaltijd en gaat daarna omlaag, terwijl peptide YY omhoog gaat We gaan dus we van een hongergevoel naar een vol gevoel, waardoor we ons niet overeten.

Echter, bij zwaarlijvige mensen blijft het niveau van beide hormonen steeds ongeveer hetzelfde, zodat ze zich nooit helemaal vol voelen en op een ongereguleerde manier eten (Le Roux et al.. 2005, Le Roux et al.. 2006). Als voortdurende blootstelling aan elektromagnetische velden de afgifte van deze hormonen op dezelfde manier beperkt als hij invloed heeft op de afgifte van ACTH, cortisol, prolactine, testosteron en schildklierhormonen, dan kan dit verklaren waarom zoveel mensen het moeilijk vinden om met eten te stoppen en uiteindelijk klinisch zwaarlijvig worden.

Wie hier last van heeft, kan hierdoor gedwongen worden om op een levenslang dieet te gaan, een maag-bypass operatie te ondergaan om de grootte van zijn maag drastisch te verkleinen of de vele ernstige ziekten riskeren die het gevolg kunnen zijn van overgewicht en dit kan niet eens AAN UZELF TE WIJTEN ZIJN. Denk twee keer na voordat u een mobiele telefoon gebruikt of een draadloze telefoon of WiFi installeert. De gevolgen daarvan zijn nu pas zichtbaar aan het worden; noch de regering noch de telecommunicatie-industrie zal u vertellen wat die zijn, maar ze zijn niet goed.

Obesitas kan leiden tot vele andere ziekten

De gevolgen van obesitas omvatten diabetes, gangreen, hoge bloeddruk, hartproblemen, nierfalen en kanker. Daarmee veroorzaken ze groot menselijk leed en kosten de economie van het land veel geld. De jaarlijkse kosten van overgewicht en daaraan gerelateerde ziekten voor de Britse economie werden geraamd op circa £ 6,6 - 7,4 miljard (McCormick et al. . 2007).

De jaarlijkse kosten van het chronisch vermoeidheidssyndroom zijn ongeveer $ 20.000 per patiënt in de VS (Reynolds et al.. http://www.resource-allocation.com/content/2/1/4) en ongeveer £ 14.000 in het Verenigd Koninkrijk (McCrone et al.. 2003), dus een redelijke schatting van de totale jaarlijkse kosten van chronische vermoeidheid in het Verenigd Koninkrijk is ca. £ 3.500.000.000. De totale jaarlijkse kosten van de aandoeningen samen is ongeveer £ 10.000.000.000. Als een deel hiervan wordt veroorzaakt door microgolf telecommunicatie, dan moeten maatregelen worden genomen om hun effecten te minimaliseren, en zou het niet meer dan terecht zijn om de industrie hiervoor te laten betalen.

Elektromagnetische effecten op de bijnier

Cortisol: - Augner et al.. (2010) toonden in een dubbelblind onderzoek (als noch de patiënt noch de persoon die de resultaten registreert weet of de straling in- of uitgeschakeld is) aan dat kortdurende blootstelling aan de straling van een 2G (GSM) mobiele telefoon basisstation de cortisolspiegel in het speeksel van menselijke vrijwilligers verhoogde. Cortisol is een stresshormoon, dat normaal wordt geproduceerd in de cortex van de bijnieren en wordt gecontroleerd door de hoeveelheid calcium in de cellen (Davies et al.. 1985), dus elektromagnetisch geïnduceerde membraanlekkage die meer calcium in het cytosol laat zou ook dit effect moeten hebben.

Cortisol is onderdeel van een mechanisme dat het lichaam in een "vecht of vlucht"-modus brengt, waarbij meer suiker in de bloedbaan wordt gebracht, pijngevoeligheid wordt verminderd en het immuunsysteem wordt onderdrukt. In feite worden cortisol en aanverwante stoffen medicinaal gebruikt om pijn te verlichten en ook om het immuunsysteem te onderdrukken na transplantatie chirurgie. Echter, wanneer blootstelling aan straling van een basisstation dit doet, is dit geen goed

nieuws omdat de onderdrukking van het immuunsysteem ook het risico van infectie en op de ontwikkeling van tumoren uit pre-kankercellen, die anders vernietigd hadden kunnen worden.

Adrenaline:
Buchner en Eger (2011) onderzochten het effect van een nieuw geïnstalleerd 2G mobiele telefoon basisstation op bewoners van Beieren en vonden dat dit een levenslange toename van de productie van adrenaline veroorzaakte. Dit is een belangrijke neurotransmitter die werkt op adrenergische receptoren om de calciumconcentratie in het cytosol te verhogen. Het wordt ook gesynthetiseerd in de adrenale medulla als reactie op signalen van het sympathisch zenuwstelsel. Adrenaline zet ook het lichaam in strijd of vlucht modus door het wegleiden van de middelen van de gladde spieren van de darmen naar de hartspier en de skeletspieren, die nodig zijn voor de vlucht of de strijd. Daarnaast stimuleert het de productie van cortisol door de bijnieren, en reduceert indirect de activiteit van het immuunsysteem, ziekteresistentie en verhoogt het risico op kanker.

Sommige mensen beleven genoegen aan de "adrenaline stoot", die wordt veroorzaakt door het doen van energetische of gevaarlijke dingen, en dit kan een factor zijn die bijdraagt aan de verslavende werking van mobiele telefoons. Echter, de keerzijde is, dat bekende effecten van overtollige adrenaline hoofdpijn, hartritmestoornissen, hoge bloeddruk, tremor, angst en onvermogen om te slapen zijn. Deze resultaten bevestigen en verklaren een aantal van de bevindingen van Abdel-Rassoul et al.. (2007), die constateerden dat omwonenden van zendmasten (masten) een significante toename vertoonden van hoofdpijn, geheugenverlies, duizeligheid, trillen en slecht slapen.

Effecten op de hersenen

Calcium lekkage en hersenfunctie
Normaal functioneren van de hersens is afhankelijk van de ordelijke overdracht van signalen via een massa van ongeveer 100 miljard neuronen. Neuronen zijn sterk vertakte zenuwcellen. Ze hebben meestal één lange tak (het axon), die elektrische signalen als actiepotentialen (zenuwimpulsen) van of naar andere delen van het lichaam of tussen relatief afgelegen delen van de hersenen (een zenuw bevat veel samengebundelde axonen) verstuurt. De kortere takken communiceren met andere neuronen waarbij hun uiteinden grenzen aan synapsen. Ze geven, over de synapsen, informatie door met behulp van verschillende neurotransmitters, die chemisch worden uitgescheiden door het ene neuron en gedetecteerd door het andere.

Calcium ionen spelen een essentiële rol bij de hersenfunctie, omdat een kleine hoeveelheid calcium het cytosol van het neuron moet binnendringen, voordat zij hun neurotransmitters kunnen vrijgeven Alberts et al.. 2002). Elektromagnetisch geïnduceerde membraan lekkage zou het achtergrondniveau van calcium in de neuronen verhogen, zodat zij hun neurotransmitters eerder kunnen vrijgeven. Dit verbetert onze reactietijd voor eenvoudige stimuli, maar het kan ook leiden tot de spontane afgifte van neurotransmitters om noodsignalen uit te zenden die daar op dat moment niet horen te zijn. Die maken de hersens hyperactief en minder in staat om zich te concentreren.

Autisme
Mogelijkerwijs ontstaat de grootste schade aan de hersenen door microgolven als ze zich voor het eerst ontwikkelen in de foetus en bij het zeer jonge kind, waar het kan leiden tot autisme. Dr Dietrich

Klinghardt heeft een relatie aangetoond tussen microgolven en autisme; een samenvatting van zijn werk is te vinden op http://electromagnetichealth.org/media-stories/#Autism .

Wat is autisme?

Autisme is een groep van levenslange stoornissen (autistic spectrum disorders of ASD), die worden veroorzaakt door storingen in de hersenen. Ze worden geassocieerd met subtiele veranderingen in de anatomie van de hersenen (zie Amaral et al. . 2008 voor een overzicht). De belangrijkste symptomen zijn een onvermogen om adequaat te communiceren met anderen en omvatten abnormaal sociaal gedrag, slechte verbale en non-verbale communicatie, ongewone en beperkte interesses, en aanhoudend repetitief gedrag. Er zijn ook niet-kernsymptomen, zoals een verhoogd risico op epileptische aanvallen, angst en stemmingsstoornissen. ASD heeft een sterke genetische component, komt voornamelijk voor bij mannen en heeft de neiging om in gezinnen voor te komen.

Genetische ASD kan worden veroorzaakt door calcium dat neuronen binnendringt

Er wordt verondersteld dat bepaalde genetische vormen van ASD kunnen worden verklaard door bekende mutaties in de genen voor ionenkanalen, die resulteren in een verhoogde achtergrondconcentratie van calcium in neuronen. Dit kan leiden tot neuronale hyperactiviteit en de vorming van soms onnodige en onjuiste synapsen. Dit kan weer leiden tot ASD (Krey en Dolmetsch 2007).

Elektromagnetische velden laten ook calcium in neuronen binnendringen

Er heeft, in de afgelopen jaren, een 60-voudige toename van ASD plaatsgevonden, die niet kan worden verklaard door verbetering van diagnostische werkwijzen en alleen kan worden verklaard door veranderingen in het milieu. Deze verhoging komt in de tijd overeen met de verspreiding van mobiele telecommunicatie, WiFi, en magnetrons evenals extreem laagfrequente velden van huishoudelijke bedrading en huishoudelijke apparaten. We kunnen dit nu in ieder geval deels verklaren in termen van elektromagnetisch geïnduceerde membraanlekkage, die leidt tot hyperactiviteit en tot abnormale ontwikkeling van de hersenen.

Hoe membraan lekkage neuronen beïnvloedt

Neuronen geven informatie aan elkaar door als chemische neurotransmitters, die in de synapsen waarmee ze contact maken passeren. Hun ontwikkeling wordt gewoonlijk veroorzaakt door een korte puls van calcium die hun cytosol binnengaat. Als het membraan lekt als gevolg van blootstelling aan elektromagnetische straling, zal het al een hoge inwendige concentratie calcium bezitten, omdat calcium naar binnen lekt door de veel hogere calciumconcentratie buiten. Dit zet de cellen in de haar-trigger modus, zodat ze meer kans hebben om neurotransmitters vrij te maken en de hersenen als geheel kunnen hyperactief worden (Beason en Semm 2002; Krey en Dolmetsch 2007, Volkow et al. 2011). Dit betekent dat de hersenen worden overbelast met soms stoorsignalen, die leiden tot een verlies van concentratie en “attention deficit hyperactief disorder” (ADHD).

Hoe werkt dit effect op autisme?

Vóór en vlak na zijn geboorte, zijn de hersenen van een kind als een leeg doek en gaan ze door een intensieve periode van leren om zich bewust te maken van de betekenis van haar nieuwe sensorische input, bijvoorbeeld om het gezicht van hun moeder, haar uitdrukkingen en eventueel andere mensen en hun relatie met hem of haar te herkennen (Hawley en Gunner 2000). Tijdens dit proces maken de neuronen in de hersenen talloze nieuwe verbindingen, waarvan de patronen opslaan wat het kind heeft geleerd. Echter, in een tijdsbestek van enkele maanden worden verbindingen die zelden worden

gebruikt automatisch verwijderd (Huttenlocher en Dabholkar, 1997). Patronen die blijven, worden stevig verankerd in de psyche van het kind. De productie van te veel stoorsignalen als gevolg van elektromagnetische blootstelling tijdens deze periode zal frequente willekeurige verbindingen opleveren, die ook niet worden gewist, zelfs niet als ze geen zin hebben. Het kan belangrijk zijn dat autistische kinderen vaak iets grotere hoofden hebben, mogelijk om de uitgeschakelde neuronen te herbergen (Hill en Frith 2003).

Omdat het wisproces bij elektromagnetisch blootgestelde kinderen meer willekeurig kan zijn, kan dit bij het kind een defecte vastgelegde “mind-set” voor sociale interacties teweegbrengen; die kan vervolgens bijdragen aan de verschillende autistische spectrum stoornissen. Deze kinderen zijn niet per definitie minder intelligent; ze kunnen zelfs meer hersencellen hebben dan de rest van ons en sommigen kunnen zelfs geleerd zijn. Ze kunnen gewoon niet in staat zijn een normaal leven te leiden door een tekort in de specifiek vastgelegde neurale netwerken die nodig zijn voor een efficiënte communicatie.

Autisme kost de Britse economie meer dan de fiscale inkomsten uit mobiele telefoons
De ontwikkeling in het voorkomen van autisme liep parallel aan de toename van elektromagnetische vervuiling in de afgelopen dertig jaar. De kans op een kind met een autistische aandoening kan nu al een op vijftig zijn. Afgezien van de persoonlijke drama's voor de getroffen kinderen en hun families, is autisme van enorm economisch belang. In het Verenigd Koninkrijk alleen al, overtreffen de jaarlijkse kosten voor de staat voor de zorg en verloren productie hoger dan de jaarlijkse belastinginkomsten uit de gehele mobiele telefoon industrie; dit zijn ongeveer 20 miljard Britse ponden. (zie ook http://www2.lse.ac.uk/newsAndMedia/news /archives/2009/05/MartinKnappAutism.aspx). Als dit allemaal te wijten zou zijn aan mobiele telefoons, zou de regering de gehele industrie kunnen opdoeken en daarmee nog winst boeken! Er kunnen manieren zijn waarop de modulatie van het signaal kan worden gewijzigd om deze problemen te vermijden (zie later), maar in de tussentijd moeten we doen wat we kunnen om onze blootstelling aan informatie-dragende microgolven, inclusief die van mobiele telefoons, DECT telefoons, WiFi en slimme meters te minimaliseren. Doet u dit niet doet, dan kan dit veel kosten opleveren.

Elektromagnetische intolerantie (ofwel elektromagnetische hypergevoeligheid of EHS)
Elektromagnetische intolerantie is een aandoening waarbij sommige mensen een breed scala aan onaangename symptomen ervaren bij blootstelling aan zwakke niet-ioniserende straling. Ongeveer 3 procent van de bevolking lijdt hieraan op deze manier en op dit moment, hoewel slechts een klein deel hiervan zo zwaar belast is dat ze meteen kunnen vertellen of een stralend apparaat is ingeschakeld of uitgeschakeld. Aan de andere kant van de schaal, zijn er mensen die wel gevoelig zijn, maar dit nog niet weten omdat ze chronisch worden blootgesteld aan elektromagnetische velden en hun symptomen aanvaarden als volkomen normaal. Elektromagnetische intolerantie is in feite een continuüm zonder duidelijk uitschakelmoment. In sommige gevallen kunnen relatief milde klachten optreden bij of na het gebruik van een mobiele telefoon, maar in ernstige gevallen kan het betekenen dat mensen geen normaal leven kunnen leiden en dat ze gedwongen worden om te leven in bijna totale isolatie. Er is alle reden om te geloven dat langdurige blootstelling de ernst van de symptomen zal doen toenemen, dus wie er nu al last van heeft zou al het mogelijke moeten doen om verdere blootstelling te minimaliseren.

Symptomen van elektromagnetische intolerantie
Symptomen zijn onder meer huiduitslag, hartritmestoornissen, hoofdpijn (soms ernstig), pijn in spieren en gewrichten, gevoelens van warmte of koude, tintelingen, oorsuizen (tinnitus), duizeligheid en

misselijkheid. Een meer volledig overzicht is te vinden op http://www.es-uk.info/info/recognising.asp De meeste, zo niet alle van deze aandoeningen kunnen worden verklaard door de straling, die lekken van de celwanden tot gevolg heeft.

Wanneer huidcellen lekken,
Wanneer huidcellen lekken wordt door het lichaam waargenomen als schade aan het weefsel. Deze verhoogt de bloedtoevoer naar dit gebied om de schade te herstellen en veroorzaakt de uitslag.

Wanneer de cellen van de hartspier lekken
Als de cellen van de hartspier lekken verzwakt dit de elektrische signalen die normaal de contractie van het hart beheersen. Het hart raakt vervolgens uit controle en geeft hartritmestoornissen. Dit is potentieel levensbedreigend.

Wanneer sensorische cellen lekken
Als sensorische cellen lekken worden ze hyperactief en sturen foutieve signalen naar de hersenen. We hebben verschillende sensorische cellen, maar ze werken allemaal op dezelfde manier. Als ze voelen wat ze geacht worden te voelen, lekken ze doelbewust door het openen van ionenkanalen in hun membranen. Dit vermindert de natuurlijke spanning over deze membranen, waardoor ze zenuwimpulsen naar de hersenen sturen. Elektromagnetisch geïnduceerde cel lekkage zou hetzelfde effect hebben, maar in deze situatie veroorzaakt dit het sturen van verkeerde signalen naar de hersenen om de valse gevoelens van elektromagnetische intolerantie te geven. Dit kan nog worden verergerd door de betrokken zenuwcellen die hyperactief zijn gemaakt door het binnendringen van calcium.

Wanneer lekkage optreedt in de sensorische cellen van de huid
Als lekkage optreedt in de sensorische cellen van de huid kan dit sensaties opleveren van hitte, kou, tinteling, druk enz., afhankelijk van welke typen cel bij de betreffende persoon het gevoeligste zijn.

Wanneer lekkage optreedt in de sensorische haarcellen van het slakkenhuis van het oor
Lekkage van sensorische haarcellen in het oor veroorzaakt tinnitus. Hierdoor ontstaat een vals gevoel van geluid. Wanneer dit plaatsvindt in het vestibulaire systeem (het gedeelte van het binnenoor dat zich bezighoudt met balans en beweging) resulteert dit in symptomen van duizeligheid en bewegingsziekte, waaronder misselijkheid.

Hypocalciëmie, elektromagnetische intolerantie en de bijschildklier
Verschijnselen van hypocalciëmie zijn zeer vergelijkbaar met die van elektromagnetische intolerantie en omvatten huidaandoeningen, tintelingen, gevoelloosheid, gevoelens van verbranden, vermoeidheid, spierkrampen, hartritmestoornissen, gastro-intestinale problemen en vele anderen.
Een uitgebreidere lijst is te vinden op
http://www.endotext.org/parathyroid/parathyroid7/parathyroid7.htm .
Het is mogelijk dat sommige vormen van elektromagnetische intolerantie te wijten zijn aan lage niveaus van calcium in het bloed. Blootstelling aan elektromagnetische velden zou dan nog meer calcium uit hun celmembranen verwijderen om ze “over de rand te duwen” en de symptomen van elektromagnetische intolerantie veroorzaken.

De hoeveelheid calcium in het bloed wordt geregeld door het parathyroïd hormoon, dat wordt afgescheiden door de bijschildklier die in de nek zit, dichtbij waar de mobiele telefoon wordt gehouden bij het bellen. Deze grenst aan de schildklier en, indien hij door de straling op dezelfde wijze zou

worden beschadigd, zou de productie van het parathyroïd hormoon afnemen, de hoeveelheid calcium in het bloed worden verlaagd en zou de betrokken persoon elektromagnetisch intolerant worden.

Effecten op DNA

GSM straling kan DNA beschadigen

Lai en Singh (1995) waren de eersten die dit lieten zien in gekweekte hersencellen van ratten, maar het is sindsdien door vele andere wetenschappers bevestigd. Een uitgebreide studie hierover vond plaats in het Reflex-project, gesponsord door de Europese Commissie en gerepliceerd in laboratoria in verschillende Europese landen. Zij vonden dat straling zoals die van GSM (2G) mobiele telefoon toestellen zowel enkel- als dubbelstrengs breuken in het DNA van gekweekte menselijke en dierlijke cellen veroorzaakten. Niet alle celtypen werden even sterk getroffen en sommige, zoals lymfocyten, schenen helemaal niet te worden beïnvloed (Reflex Verslag 2004).

In gevoelige cellen hing de mate van beschadiging af van de duur van de blootstelling. Bij menselijke fibroblasten werd een maximale schade bereikt na ongeveer 16 uur (Diem et al.. 2005). Echter, het zou onverstandig zijn om aan te nemen dat blootstelling van minder dan 16 uur noodzakelijkerwijs veilig zou zijn, omdat DNA-schade genetisch afwijkende cellen kan opleveren, lang voordat dit duidelijk wordt onder de microscoop. Het zou ook onverstandig om aan te nemen dat de schade zou worden beperkt tot de directe omgeving van de telefoon, zoals eerder beschreven; de effecten van de straling kunnen worden overgedragen in de bloedsomloop, in de vorm van magnetisch geconditioneerd bloed; dus het is nergens veilig, zelfs niet bij de geslachtsorganen.

Hoe het DNA wordt beschadigd

Vanwege de zeer hoge stabiliteit van DNA-moleculen is het niet waarschijnlijk dat ze rechtstreeks worden beschadigd door zwakke straling. Het meest plausibele mechanisme is dat DNase (een enzym dat DNA vernietigt) en andere digestieve enzymen lekken door de membranen van lysosomen (organellen die afval verteren) die zijn beschadigd door de straling. Andere mechanismes kunnen zijn de lekkage van reactieve zuurstof deeltjes (ROS) zoals waterstofperoxide van beschadigde peroxisomen en vrije radicalen superoxide van beschadigde mitochondriale membranen en NADH oxidase in het plasmamembraan. Volgens Friedman et al.. (2007) is de eerste reactie op niet-thermische mobiele telefoon frequenties de NADH oxidase in het plasmamembraan, die binnen minuten na blootstelling wordt geactiveerd.

Toch kunnen al deze reactieve zuurstof deeltjes (ROS) peroxidatie kettingreacties initiëren in de meervoudig onverzadigde fosfolipiden van celmembranen (het zelfde verschijnsel dat vetten ranzig maakt), waardoor de membranen verder worden verstoord en het effect wordt verergerd. Slechts één molecule ROS is nodig om een domino effect teweeg te brengen, waarbij elke beschadigde lipidemolecule een vrije radicaal genereert die de volgende schade toebrengt. Het proces stopt normaal als het een anti-oxidant molecule bereikt die zichzelf opoffert door zich samen te voegen met de vrije radicaal, op een zodanige wijze dat het geen nieuwe genereert. De meeste van onze anti-oxidanten komen uit onze voeding (bv vitamine E), maar de belangrijkste, die we zelf maken, is melatonine. Het is jammer dat de productie van melatonine door de pijnappelklier ook wordt verstoord door elektromagnetische velden (Henshaw en Reiter, 2005); dit maakt de situatie nog erger.

De genoemde ROS zijn zeer reactief en kunnen DNA beschadigen. In feite wordt veel van de schade aan cellen door ioniserende straling, zoals gammastraling, veroorzaakt door schade aan celmembranen en DNA door vrije radicalen uit de radiolyse van water. Er kan dus weinig verschil zijn tussen het houden van een mobiele telefoon of het houden van een radioactieve bron met gammastraling aan je hoofd. Beide kunnen celmembranen beschadigen, leiden tot fragmentatie van DNA en ook aanzienlijke collaterale schade aan andere cellulaire componenten toebrengen, die ofwel de cellen kan doden, of maken dat ze hun normale functie na verloop van tijd verliezen.

Mobiele telefoons verhogen het risico op kanker

Als dergelijke DNA-fragmentatie zou voorkomen in het gehele organisme, zouden we een verhoogd risico op kanker kunnen verwachten, omdat essentiële genen die de celdeling regelen beschadigd raken of verloren gaan. Recente studies over het optreden van hersentumoren laten dit al zien. Intensief gebruik van de mobiele telefoon verdubbelt ruwweg het risico op het krijgen van hersentumoren bij volwassenen, aan de zijde van het hoofd waar ze de mobiele telefoon gebruiken. Voor jongere mensen stijgt het risico tot vijf keer meer (Hardell en Carlberg 2009). Omdat hersentumoren zich normaal in tientallen jaren ontwikkelen, is het nog te vroeg om de uiteindelijke impact van de straling te beoordelen, maar de Wereldgezondheidsorganisatie heeft mobiele telefoons al geclassificeerd als een Groep 2B carcinogeen (mogelijk kankerverwekkend), zoals ook het geval is met benzeen en DDT. Andere tumoren aan het hoofd komen ook meer voor, met inbegrip van tumoren aan de parotide speekselklier (naast de plek waar je de mobiele telefoon houdt bij het bellen) en de schildklier, die is in de hals is gelegen.

Mobiele telefoons verminderen de vruchtbaarheid bij mannen

We zouden DNA schade kunnen verwachten in de cellen van de kiemlijn (de lijn van cellen vanaf het embryo waaruit zich uiteindelijk eieren en sperma ontwikkelen) waardoor een verlies van vruchtbaarheid zou ontstaan. Een aantal epidemiologische studies hebben aanzienlijke verlagingen laten zien in de beweeglijkheid, levensvatbaarheid en hoeveelheid zaadcellen bij mannen, die meer dan een paar uur per dag hun mobiele telefoon gebruiken (Fejes ea. 2005; Agarwal . et al., 2006) en dit verschijnsel werd verder besproken door Desai et al. . (2009). Een gemeenschappelijke conclusie is dat deze effecten samenhangen met de productie van reactieve zuurstof species (ROS) die vele cellulaire componenten zoals celmembranen en DNA kunnen beschadigen.

Meer recent hebben Agarwal et al.. (2009) in experimenten aangetoond dat uitgestoten sperma van gezonde donoren verminderde levensvatbaarheid en motiliteit lieten zijn, evenals een toename van ROS na één uur blootstelling aan een mobiele telefoon in spreekmodus. Nog recenter, vonden Avandano et al.. (2012) dat blootstelling van spermavocht aan een WiFi laptop computer gedurende vier uur een afname gaf van sperma motiliteit en een toename van DNA-fragmentatie in vergelijking met monsters blootgesteld aan een soortgelijke computer waarvan WiFi was uitgeschakeld.

Een soortgelijke relatie tussen zaadkwaliteit en elektromagnetische blootstelling is ook gevonden voor laagfrequente magnetische wisselvelden (Li et al. . 2010). Het is daarom raadzaam voor mannen om sterke magnetische velden te vermijden, gebruik van hun mobiele telefoontjes tot een minimum te beperken en ze uitgeschakeld te houden (of in vliegtuig modus als dit mogelijk is). Anders zenden de telefoontjes regelmatig met vol vermogen hun signalen naar het basisstation, zelfs wanneer ze niet in gebruik zijn. Als ze, om welke reden dan ook, moeten worden ingeschakeld moet men ze in ieder geval niet in hun broekzak houden.

Mogelijke effecten op de vruchtbaarheid van vrouwen

We weten nog niet wat de effecten van de mobiele telefoon zijn op de vruchtbaarheid van vrouwen, Wel toonden Panagopoulos et al. . (2007) aan dat blootstelling van volwassen Drosophila melanogaster (fruitvliegjes, veelvuldig gebruikt bij genetische experimenten) aan een GSM signaal voor slechts zes minuten per dag gedurende zes dagen, zorgde voor gefragmenteerde DNA in de cellen waaruit hun eieren zich ontwikkelen, en de helft van deze eieren stierven af. Wij mensen moeten daarom voorzichtig te zijn omdat, hoewel onze zaadcellen worden geproduceerd in ontelbare miljarden hoeveelheden en het ongeveer drie maanden duurt om te rijpen, alle eieren die een vrouw ooit zal hebben al in haar eierstokken waren voordat ze geboren werd en worden blootgesteld aan de straling (en aan elektromagnetisch geconditioneerd bloed) gedurende haar hele leven. Aldus kan aanzienlijke cumulatieve schade ontstaan aan zowel de eieren als de follikel cellen die hen voeden en beschermen. Schade aan beide, te beginnen wanneer het kind in de baarmoeder is, kan naar verwachting een verlies aan vruchtbaarheid opleveren. Zwangere moeders moeten alle huidige vormen van microgolf communicatie, met inbegrip van mobiele telefoons en WiFi voorkomen. Haar kind zou kunnen worden beschadigd door de straling, maar ze zal dit niet weten totdat het haar puberteit bereikt en zelf een kind wil.

Effecten op “tight junction” barrières

“Tight junction” barrières zijn lagen cellen waarbij de doorgangen tussen de cellen zijn afgesloten, om te voorkomen dat stoffen rond hun zijkanten weglekken. Ze beschermen alle oppervlakken van ons lichaam tegen het binnendringen van ongewenste stoffen en beschermen vaak een deel van het lichaam tegen overmatige beïnvloeding door de andere delen. Bijvoorbeeld, de bloed-hersenbarrière voorkomt dat giftige stoffen vanuit de bloedsomloop de hersenen binnendringen. Normaliter worden deze barrières gesloten maar ze zijn geprogrammeerd om te openen als calciumionen hun cellen binnengaan. Dit werd aangetoond door Kan en Coleman (1988), die lieten zien dat de calcium ionofoor A23187 (een antibioticum dat bacteriën en schimmels doodt door calciumionen binnen te laten in hun cellen) “tight junction” barrières in de lever opende. Het elektromagnetisch openen van de bloed-lever barrière kan een bijdragende factor zijn om de huidige uitbraak van leverziekte in het Verenigd Koninkrijk bij mensen onder de veertig (de mobiele telefoon generatie), die momenteel wordt toegeschreven aan alcoholmisbruik, te verklaren. Aangezien alle “tight junction” barrières in principe dezelfde werking hebben ligt het voor de hand dat ongepland calcium, dat binnenkomt als gevolg van blootstelling aan elektromagnetische velden, ze allemaal te opent op vrijwel dezelfde manier. Het openen van “tight junction” barrières door elektromagnetische velden kan veel hedendaagse ziektes veroorzaken, van astma tot meerdere allergieën en de ziekte van Alzheimer.

De bloed-hersenbarrière en vroegtijdige dementie

De bloed-hersen barrière voorkomt normaal dat mogelijk toxische grote moleculen uit het bloed de hersenen binnenkomen. De straling van mobiele telefoons, zelfs op een honderdste van de toegestane SAR-waarde, kan de bloed-hersenbarrière bij ratten openen, zodat eiwitmoleculen zo groot als albumine hun hersenen kunnen binnenkomen (Persson et al.. 1997). Latere experimenten van Salford et al.. (2003) toonden aan dat dit met afsterven van neuronen samenhing. We zouden geen rechtstreeks effect hebben verwacht, omdat de hersenen reservecapaciteit bezitten, maar langdurige of herhaalde blootstelling aan mobiele telefoon of vergelijkbare straling zou naar verwachting een progressief verlies van functionele neuronen kunnen veroorzaken en resulteren in vroegtijdige

dementie en de ziekte van Alzheimer bij de mens. De extreme gevoeligheid van de bloed-hersen barrière voor de straling zou kunnen betekenen dat zelfs zitten dicht bij iemand die zijn mobiele telefoon gebruikt ook invloed op jezelf zou kunnen hebben. Het mag niet te verrassend zijn dat het vroeg ontstaan van “Alzheimer” vandaag de dag, in onze moderne samenleving, toeneemt.

De barrière bij de luchtwegen en astma

Di et al. . (2011) toonden aan dat blootstelling aan zwakke ELF elektromagnetische velden tijdens de zwangerschap het risico op astma bij de nakomelingen verhoogde (ze hebben de effecten van microgolf straling niet onderzocht). Dit kan worden verklaard doordat de straling structurele calcium verwijderde uit de cellen van de “tight junction” barrière langs de luchtwegen, die daarbij wordt geopend. Deze verklaring wordt ondersteund door de bevindingen van Chu et al.. (2001). Die lieten zien dat ofwel lage niveaus van extern calcium of het toevoegen van EGTA (die allebei structurele calciumionen uit celoppervlakken zouden verwijderen) een enorme toename in de elektrische geleidbaarheid (een maat voor de permeabiliteit voor ionen) en ook de doorlaatbaarheid voor veel grotere virusdeeltjes veroorzaakten. We zouden dan ook verwachten dat veel allergenen langs dezelfde route binnenkomen en het kind predisponeren om astma te krijgen. Er zijn ongeveer 5,4 miljoen mensen met astma in het Verenigd Koninkrijk en de geschatte jaarlijkse kosten voor de NHS alleen is ongeveer £ 1.000.000.000 (http://www.asthma.org.uk/news_media/news/new_data_reveals_hig.html)

De huidbarrière, allergieën en meervoudige chemische gevoeligheden (MCS)

De “tight junction” barrière bij de huid is gelegen in het stratum granulosum. Dat is de buitenste laag van levende huidcellen, net onder de vele lagen van dode cellen (Borgens et al.. 1989). Furuse et al. . (2002) toonden aan dat gemuteerde muizen met een tekort aan Claudin-1 (een essentieel onderdeel van het afsluitmechanisme) stierven binnen een dag na de geboorte en hun huid barrières waren doorlaatbaar voor moleculen met een grootte van 600D, wat groot genoeg is om veel ongewenste vreemde stoffen toe te laten, inclusief potentiële allergenen. Bij mensen zou dit de veroorzaker kunnen zijn van meervoudige chemische gevoeligheden, waarbij mensen allergisch zijn geworden voor een groot aantal chemicaliën, ofschoon die de meeste van ons onberoerd laten. Mensen die lijden aan meervoudige chemische gevoeligheid zijn vaak ook elektromagnetisch intolerant en veel van hun symptomen zijn zeer vergelijkbaar.

Vrijwel alle oppervlakken van ons lichaam worden beschermd door cellen met “tight junctions”, zoals de nasale mucosa (Hussar et al.. 2002), de longen (Weiss et al.. 2003) en de bekleding van de darmen (Arrieta et al.. 2006). Een elektromagnetisch geïnduceerde toename in de permeabiliteit van een van deze oppervlakken zou het sneller toelaten tot het lichaam van een hele reeks van vreemde stoffen, zoals allergenen, toxinen en carcinogenen, tot gevolg hebben.

Verlies van barrière dichtheid kan auto-immuunziekten veroorzaken

Een elektromagnetisch geïnduceerde toename in de permeabiliteit van “tight-junction” barrières wordt in verband gebracht met het optreden van auto-immuunziekten, waarbij de lymfocyten uit het immuunsysteem de eigen lichaamsdelen aanvallen, alsof het vreemde stoffen of pathogenen waren.

Het immuunsysteem is zeer ingewikkeld, maar in feite zijn lymfocyten (een soort witte bloedlichaampjes) getraind en geselecteerd voordat ze volgroeid zijn, om eigen cellen van het lichaam, die normaal in de bloedbaan aanwezig zijn, te herkennen op grond van chemische patronen op hun oppervlak (de belangrijke histocompatibility complexen).

B-lymfocyten maken specifieke antilichamen aan, die samensmelten met vreemde cellen en stoffen die dit patroon niet bezitten , waardoor ze gemerkt worden voor eventuele opname en vertering door fagocyten (een ander type witte bloedcel). T-lymfocyten doden de eigen cellen van het lichaam als ze geïnfecteerd zijn met een virus dat gewoonlijk wordt weergegeven op het celoppervlak. In beide gevallen kan de aanwezigheid van de vreemde stoffen of geïnfecteerde cellen de snelle vermenigvuldiging van een kloon van lymfocyten die ze herkennen teweegbrengen. Ze kunnen dan met volle kracht aanvallen.

Echter, als de betrokken stof tot het lichaam zelf behoort, maar normaal wordt verhinderd de bloedbaan door een “tight junction” barrière, zoals de bloed-hersenbarrière, binnen te gaan als de barrière open gaat, verhoogt dit de kans op het lekken van onbekende stoffen in de bloedbaan en zal dit resulteren in een auto-immuunreactie. Bijvoorbeeld, Grigoriev et al. (2010) toonden aan dat 30 dagen blootstelling aan ongemoduleerde 2450 MHz microgolfstraling een kleine, maar significante toename in anti-hersenen-antilichamen in het bloed van ratten veroorzaakte. Met andere woorden, de straling had het immuunsysteem gevoelig gemaakt voor een of meer componenten van zijn eigen hersenen, wat vervolgens kan resulteren in een auto-immuun aanval op de hersenen en/of het zenuwstelsel. Een voorbeeld van een auto-immuunziekte van de hersenen is de “Graves ziekte”, waarbij de hypofyse (gelegen aan de basis van de hersenen) wordt aangetast.

Verder wordt verhoging van de permeabiliteit van de darm barrière gekoppeld aan diverse andere auto-immuunziekten, waaronder type-1 diabetes, ziekte van Crohn, coeliakie, multiple sclerose en “irritable bowel syndrome” (Arrieta et al.. 2006).

Celmembranen als stroomgeneratoren en elektrische isolatoren

Celmembranen houden niet alleen stoffen van elkaar gescheiden die niet moeten worden toegestaan om zich te vermengen; ze fungeren ook als elektrische isolatoren voor de natuurlijke elektrische stromen waarvan al onze cellen afhankelijk zijn.

Natuurlijke elektrische stromen zijn belangrijk voor overdracht van energie en informatie

Bijna elke levende cel is een kolkende massa van elektrische stromen en versterkers. Bijvoorbeeld, deze stromingen zijn belangrijk voor energie productie in de mitochondriën (energiecentrales van de cellen) en voor de cel signalering (de overdracht van informatie binnen en tussen cellen). Zij worden vervoerd als stromen ionen, wat de normale manier is waarop elektriciteit wordt doorgevoerd in water en door levende cellen.

Deze natuurlijke stromen worden opgewekt door celmembranen.

Natuurlijke elektrische stromen worden gewoonlijk gegenereerd door moleculaire ionenpompen in celmembranen. Dit zijn eiwitten die metabolische energie gebruiken om specifieke ionen, gewoonlijk een of twee tegelijk, van de ene kant van het membraan naar de andere kant te vervoeren. Dit genereert een spanning over het membraan (het membraanpotentiaal) en een chemische onbalans tussen de concentraties van ionen aan beide zijden. Hun gecombineerde effect geeft een elektrochemische gradiënt, die energie levert voor andere functies.

Mitochondriën gebruiken elektrochemische gradiënten om energie te transporteren

Mitochondriën zijn kleine structuren, ongeveer de grootte van bacteriën, binnen bijna al onze cellen. Ze ontwikkelden zich toen een aërobe bacterie, die zuurstof gebruikte om zijn voedsel te verteren, werd

overspoeld door een anaërobe organisme, dat dit niet kon doen, maar in andere opzichten efficiënter was. Vanaf dat tijdstip leefden ze symbiotisch samen, maar zijn nog steeds gescheiden doordat de mitochondriën zijn omgeven door twee membranen; de binnenste behorend bij de bacterie de buitenste aan zijn gastheer.

Het binnenste membraan doet het elektrische werk door een proces dat bekend staat als chemiosmose. De binnenkant van het mitochondrion bevat enzymen, die stoffen uit ons voedsel omzetten in vormen die zich kunnen verbinden met zuurstof. Deze combinatie met zuurstof vindt plaats door enzymen daadwerkelijk binnen het membraan te gebruiken en de vrijgekomen energie wordt gebruikt om waterstofionen te verdrijven, om een elektrochemische gradiënt te creëren tussen de binnenkant en de buitenkant van het mitochondrion. Ze mogen dan terug door een ander enzym in het membraan, genoemd de ATP synthase, die de gradiënt gebruikt om ATP aan te maken. Dit is de belangrijkste energie-eenheid van de cel. De cyclus wordt vervolgens herhaald, om een elektrisch circuit te creëren met waterstof ionen, die de elektriciteit brengen stroom brengen van waar hij wordt gemaakt naar waar hij wordt gebruikt, waarbij het membraan fungeert als isolator (Alberts et al. . 2002).

Wat gebeurt er als het mitochondriale membraan is beschadigd?
Schade aan het binnenste mitochondriale membraan kan twee belangrijke effecten hebben. Als het alleen gelekt zou hebben, zou kortsluiting in het systeem ontstaan, de synthese van ATP verlagen en energie aan de cel onttrekken. Indien de schade ook de oxiderende enzymen zou omvatten, dan kunnen ze vrije radicalen vrijmaken, die normaal tussenproducten zijn in het proces. Dit zou zowel de binnenzijde van de mitochondriën (inclusief DNA) alsook de rest van de cel beschadigen. Mitochondriale dysfunctie van deze soort wordt beschouwd als een mogelijke oorzaak van het chronische vermoeidheidssyndroom.

Andere membranen gebruiken ook ionenstromen om energie te transporteren
De meeste andere celmembranen gebruiken ionenstromen als energiebron. Bijvoorbeeld, enzymen in het buitenste membraan van elke cel (het plasmamembraan) gebruiken energie van ATP om positief geladen natriumionen de cel uit te pompen. Dit genereert een eigen membraanpotentiaal, dat typisch de binnenkant van de cel ongeveer 70 tot 100 millivolt negatief maakt ten opzichte van de buitenkant. Dit levert energie voor het actieve transport van andere stoffen door het membraan, tegen een concentratiegradiënt. In dit geval worden de natriumionen, die zijn uitgestoten, weer toegelaten via transport enzymen, maar nemen ze nutriënten van buitenaf mee door een proces genaamd ionen co-transport (Alberts et al. . 2002). Als dit membraan lekt, zal dit het spanningsverschil erover kortsluiten en het opnemen van nutriënten alsook een aantal andere processen die dit spanningsverschil als energiebron gebruiken, verminderen.

Ionenkanalen in celmembranen worden gebruikt voor cel signalering
Ionenkanalen zijn poriën in celmembranen die grote hoeveelheden specifieke ionen heel snel kunnen doorlaten, maar alleen beneden hun eigen elektrochemische gradiënt. Ze openen en sluiten normaal als reactie op specifieke stimuli; bijvoorbeeld bij veranderingen in spanning over het membraan of de aanwezigheid van andere chemicaliën. Ze kunnen worden gezien als versterkers, waarbij een kleine stimulus kan leiden tot een zeer grote stroom, die vrijwel direct gaat vloeien om een snel biologisch effect teweeg te brengen. Een voorbeeld hiervan is het gecoördineerde openen en sluiten van natrium en kalium kanalen, die continu zenuwimpulsen versterken en hen toelaten om van het ene uiteinde van het lichaam naar het andere te reizen, zowel snel als zonder verlies.

De mechanismen van het lekken van celmembranen

We weten al sinds het werk van Suzanne Bawin en haar mede-onderzoekers (Bawin et al.. 1975) dat elektromagnetische straling die veel te zwak is om aanzienlijke verwarming te veroorzaken, toch radioactief gelabelde calciumionen uit celmembranen kan verwijderen. Later toonde Carl Blackman aan dat dit alleen gebeurt bij zwakke stralingen en dan nog alleen binnen een of meer "amplitude vensters"; boven en beneden deze vensters is er weinig of geen effect (Blackman et al.. 1982, Blackman 1990).

De appeloogst: een verklaring voor amplitude vensters

Een eenvoudige manier om de selectieve verwijdering van tweewaardige ionen uit te leggen is om je voor te stellen om rijpe appels te oogsten door aan de boom te schudden. Als je niet hard genoeg schudt, vallen geen appels naar beneden, maar als je te hard schudt, vallen ze allemaal. Echter, als je precies hard genoeg schudt, vallen allen de rijpe appels uit de boom en worden 'selectief geoogst'. We kunnen dezelfde logica toepassen op de positieve ionen die aan celmembranen zijn gebonden. Wisselspanningen proberen deze ionen bij elke spanningscyclus weg- of terug te duwen naar de membranen. Als de spanning te laag is, gebeurt er niets. Als hij te hoog is, vliegen alle ionen weg, maar keren terug als de spanning omkeert. Echter, als hij precies hoog genoeg is, zal hij alleen de sterker geladen deeltjes, zoals tweewaardige calcium met haar dubbele lading verwijderen. Als de frequentie laag is, zullen op zijn minst enkele van deze tweewaardige ionen weg-diffunderen en willekeurig worden vervangen door andere ionen als het veld omkeert. Er zal dan bij elke opeenvolgende cyclus een netto verwijdering plaatsvinden van tweewaardige ionen, totdat er genoeg zijn verwijderd om significant lekken van het membraan te veroorzaken en een biologisch effect te veroorzaken, maar alleen binnen een nauwe bandbreedte van veldsterkte. Hierdoor wordt het amplitude venster gecreëerd. Pulsen zijn hierbij meer effectief dan sinusgolven, omdat hun snelle opkomst en ondergang elke keer de ionen snel wegschiet vanaf het membraan en meer tijd overlaat om te worden vervangen door andere ionen vóórdat de polariteit omkeert.

Frequentie-vensters en resonantie-effecten

Indien een molecule of structuur een natuurlijke resonantiefrequentie heeft, kan die selectief op die frequentie reageren. Bijvoorbeeld, als u een slinger steeds op het juiste moment aan het einde van zijn zwaai een lichte duw geeft, bouwt de energie van elke druk zich op en wordt opgeslagen in de steeds toenemende kracht van zijn beweging. Als u hem plotseling wilt stoppen door uw hand in de weg te houden, wordt de gecombineerde energie van elke duw in één keer vrijgegeven en kan meer schade aan uw hand veroorzaken dan de energie die u gaf bij elke duw zou doen vermoeden.

Op dezelfde manier, als een elektrisch geladen atoom of molecule één of meer natuurlijke resonantiefrequenties heeft en u hem een elektromagnetische puls op die frequentie geeft, kan de gecombineerde energie van elke puls worden opgeslagen als een soort trillings-energie. Deze kan een chemische reactie teweegbrengen die niet mogelijk zou zijn geweest door de energie van elke individuele puls, maar *uitsluitend op zijn resonantiefrequentie*. Sommige frequenties zijn vooral effectief in het veroorzaken van biologische effecten. Een voorbeeld hiervan is 16 Hz, de ion-cyclotron resonantie frequentie van kaliumionen in het magnetisch veld van de aarde.

Ion-cyclotron resonantie treedt op wanneer ionen bewegen in een stabiel magnetisch veld, zoals dat van de Aarde. Ze worden zijdelings afgebogen door het magnetisch veld en gaan bewegen in een baan

rond krachtlijnen op een frequentie die afhangt van de lading tot massa verhouding van de ionen en de sterkte van het stationaire veld (zie Liboff et al.. 1990). Als ze gelijktijdig worden blootgesteld aan een wisselend veld bij deze frequentie, absorberen ze de energie en vergroten ze de diameter van hun banen, waardoor hun bewegingsenergie en chemische activiteit wordt verhoogd. Kalium resonantie is in dit verband bijzonder belangrijk, want kalium is het meest voorkomende positief ion in de cytosollen van levende cellen, waar het ongeveer 10.000 keer zoveel voorkomt als calcium. Het is daarom het meest waarschijnlijke ion dat het calcium vervangt dat verloren is gegaan door elektromagnetische blootstelling. Een verhoging van de chemische activiteit van kalium zal daardoor het vermogen om calcium te vervangen doen toenemen en dus verhoging van calciumverlies uit het membraan en haar stabiliteit verder verlagen.

Verlies van calcium en lekkende membranen liggen ten grondslag aan vele biologische effecten

We hebben gezien hoe het verlies van calcium uit celmembranen wordt versterkt op de 16Hz resonantiefrequentie van kalium. Ook kan ieder metabolisch gevolg van dit verlies aan calcium op dezelfde manier worden verklaard. Alle bio-elektromagnetische reacties die hun piek of dal hebben bij 16Hz tonen aan dat ze voortkomen uit divalente ionen uitputting in membranen. In de praktijk blijken veel biologische reacties hun piek te vertonen bij 16Hz. Deze omvatten stimulaties van de groei van gist (Mehedintu en Berg 1997) en hogere planten (Smith et al.. 1993), wijzigingen in het mate van beweging in diatomeeën (McLeod et al.. 1987), en de bijzonder ernstige neurofysiologische symptomen gemeld door elektrogevoelige mensen die waren blootgesteld aan de straling van TETRA apparatuur (die is gepulst op 17,6 Hz). Dit alles ondersteunt het idee dat een groot aantal van de biologische reacties op zwakke elektromagnetische straling voortkomen uit het verlies van calcium (en eventueel andere divalente ionen) uit celmembranen.

Hoe verwijderen van calcium celmembranen laat lekken

Positieve ionen versterken celmembranen omdat ze een bijdrage leveren aan het samenbinden van de negatief geladen fosfolipide moleculen, die een groot deel van hun structuur vormen. Calciumionen zijn hier vooral goed in, omdat hun dubbele positieve lading hen in staat stelt zich sterker te binden aan de omringende negatieve fosfolipiden door hun wederzijdse aantrekkingskracht en ze samenbindt, zoals mortelcement de bakstenen in een muur bij elkaar houdt. Monovalente ionen zijn minder in staat om dit te doen (Steck et al.. 1970, Lew et al.. 1998, Ha 2001). Daarom zal, als elektromagnetische straling calcium vervangt door monovalente ionen, het membraan zwakker worden en meer kans maken op scheuren en tijdelijke poriën vormen, vooral onder invloeden van stress en spanningen, veroorzaakt door de bewegende cel-inhoud. Normaal gesproken, zijn kleine poriën in fosfolipide membranen zelf-herstellend (Melikov et al.. 2001), maar, terwijl ze open blijven, zal het membraan een grotere neiging tot lekken hebben. Dit kan ernstige metabolische gevolgen hebben omdat ongewenste stoffen ongehinderd in en uit de cellen diffunderen en omdat stoffen in verschillende delen van de cel die gescheiden moeten worden gehouden vermengd raken.

Demodulatie

Zowel extreem lage frequenties als radiogolven die amplitudegemoduleerd zijn door extreem lage frequenties geven biologische effecten, maar niet gemoduleerde radiogolven zijn relatief (maar niet volledig) onschadelijk. Dit houdt in dat levende cellen een met biologisch actieve ELF signalen gemoduleerde draaggolf kunnen demoduleren. Bovendien moeten ze, als ze moeten reageren op mobiele telefoon en WiFi signalen, in staat zijn om dit te doen op microgolf frequenties, maar hoe doen ze dat?

De meest waarschijnlijke verklaring hiervoor ligt in de asymmetrische elektrische eigenschappen van ionenkanalen in celmembranen, veroorzaakt door het membraanpotentiaal tussen de binnen- en de buitenkant van de cel. Zij gedragen zich als puntcontact Schottky diodes met een elektrische voorspanning, die elektriciteit gemakkelijker in de ene richting dan in de andere richting doorlaten. Dit is alles wat nodig is om het signaal gelijk te richten en te demoduleren. Een niet-biologisch voorbeeld van dit effect is een radio apparaat dat werd gemaakt van een koolstof nanobuis (zie http://tinyurl.com/m4u75o). De asymmetrie, geïnduceerd door een gelijkspanning tussen zijn uiteinden aan te leggen, stelde hem in staat de radiosignalen te demoduleren en zelfs te versterken, ook bij microgolffrequenties.

De nanobuis heeft een vergelijkbare diameter met die van een typisch ionenkanaal in een celmembraan. Het lijkt dus waarschijnlijk dat de ionenkanalen in celmembranen een soortgelijke functie, gevoed door het membraanpotentiaal van de cel, kunnen uitvoeren. De laagfrequente component zou dan verschijnen over het membraan, waar hij de meeste schade zou kunnen toebrengen. Voor zover onze “tight junction” barrières een soortgelijk trans-barrière potentiaal hebben (ongeveer 70mV over de huidbarrière, met de binnenkant van het lichaam positief) kunnen de ionenkanalen van de hele barrière samenwerken om het signaal te demoduleren. De schadelijke laagfrequente componenten kunnen dan van invloed zijn op het hele lichaam.

Natuurlijke verdedigingsmechanismen

Het lichaam is in staat om elektromagnetische straling te detecteren en zo gevolgschade te minimaliseren. Dit vermogen is waarschijnlijk geëvolueerd gedurende talloze miljoenen jaren om de effecten te verzachten van ioniserende straling door kosmische stralen en van niet-ioniserende radiofrequenties door bliksem tijdens onweer. Sommige hiervan werken als volgt:

Calcium uitzetting

De concentratie van vrij calcium in de cytosollen van levende cellen wordt gewoonlijk extreem laag gehouden door metabolisch aangedreven ionenpompen in het celmembraan. Onder normale omstandigheden wordt de toegang van vrije calciumionen zorgvuldig gereguleerd en kleine veranderingen in hun concentratie spelen een vitale rol bij het reguleren van vele aspecten rondom metabolisme. Deze processen kunnen worden verstoord indien elektromagnetisch geïnduceerde membraan lekkage extra en ongeplande hoeveelheden calcium in de cel toelaat, hetzij van buitenaf of van in de cel opgeslagen calcium. Om dit te compenseren kan het mechanisme dat normaliter een overschot aan calcium de cel uit pompt, extra hard gaan werken. Echter, het vermogen om dit te doen is beperkt omdat, indien de pompen overactief zouden worden, kleine veranderingen in calciumconcentratie, die normaal het metabolisme regelen, verborgen zouden blijven.

Gap junction sluiting:

Als calcium uitscheiding mislukt en er een grote toename plaatsvindt van intern calcium, is dit het startsein voor de isolatie van de betreffende cel door sluiting van de “gap junctions” (kleine strengen van cytoplasma die normaal aansluiten bij aangrenzende cellen), (Alberts cel et al. . 2002). Dit beperkt ook het vloeien van elektrische stromen door het weefsel en vermindert zo de effecten van straling.

Ornithine decarboxylase (ODC)

De activering van het enzym ornithine decarboxylase wordt getriggerd door het in de cel binnenlekken

van calcium door beschadigde membranen en door stikstofoxide die wordt geproduceerd door beschadigde mitochondriën. Dit enzym leidt tot de productie van chemische stoffen, polyamines genaamd, die helpen bij het beschermen van DNA en andere nucleïnezuren die nodig zijn voor eiwitsynthese. Een van die polyamines is spermine, dat normaal het DNA van sperma beschermt en ook verantwoordelijk is voor de karakteristieke geur van sperma.

“Heat-shock” eiwitten
Deze werden voor het eerst ontdekt nadat cellen waren blootgesteld aan warmte, maar ze worden ook geproduceerd als reactie op een grote verscheidenheid aan andere invloeden, met inbegrip van zwakke elektromagnetische velden. Ze worden doorgaans binnen enkele minuten na het begin van de stress geproduceerd en smelten samen met enzymen van de cel om die te beschermen tegen beschadiging en beëindigen niet-essentiële stofwisseling (het equivalent van het bedrijven van een computer in "veilige modus").

Wanneer de productie van “heat shock eiwitten” elektromagnetisch wordt geactiveerd is 100 miljoen miljoen keer minder energie nodig dan wanneer getriggerd door warmte, dus het effect is echt niet-thermisch (Blank & Goodman 2000). Hun productie als reactie op elektromagnetische velden wordt geactiveerd door specifieke basis volgordes (het nCTCTn motief) in het DNA van hun genen. Bij blootstelling aan elektromagnetische velden initiëren ze transcriptie van het gen om RNA te maken; dit is de eerste stap in de synthese van het eiwit (Lin et al.. 2001). De taak van deze heat-shock-eiwitten is samen te smelten met vitale enzymen, waardoor ze in een soort cocon worden geplaatst die hen beschermt tegen schade. Echter, hiermee stopt hun goede werking en verbruikt het ook energie en middelen van de cel. Dus dit is ook geen ideale oplossing.

Ons verdedigingsmechanisme beschermt ons tegen straling door onweer, maar niet tegen zendmasten, DECT-telefoons en WiFi
Zoals we kunnen zien proberen onze natuurlijke afweermechanismen de elektromagnetisch geïnduceerde schade te beperken, maar ze kunnen niet worden ingezet zonder dat het extra energie kost en zonder de normale functies van de cel te verstoren. Ze hebben zich oorspronkelijk ontwikkeld om ons te beschermen tegen incidenteel optredende zwakke natuurlijke straling, zoals van onweersbuien. Echter, langdurige of herhaalde blootstelling zoals die van zendmasten, WiFi en de meeste DECT-basisstations is schadelijk omdat ze normaal continu optreden en de stofwisseling voor lange periodes verstoren en veel lichamelijke reserves aantasten.

Deze reserves moeten ergens vandaan komen. Sommige kunnen worden onttrokken aan onze fysieke energie, maakt dat we ons moe voelen, sommige komen van ons immuunsysteem, waardoor we minder resistent zijn tegen ziekten en kanker. Er is geen stille reserve. Onze lichamen zijn voortdurend aan het jongleren met reserves om ze zo goed mogelijk te gebruiken. Bijvoorbeeld, overdag zijn ze gericht op fysieke activiteit, maar tijdens de nacht worden ze gebruikt voor de reparatie van opgelopen schade en voor het immuunsysteem. Dag en nacht bestraling door mobiele telefoon masten (die continu stralen) is van invloed op beide, met weinig of geen kans om te herstellen. Op lange termijn zal dit waarschijnlijk leiden tot chronische vermoeidheid, ernstige immuunstoornissen (wat kan leiden tot een verhoogd risico op ziektes en kanker) en veel van de neurologische symptomen die vaak worden gemeld door mensen die dicht bij gsm-basisstations wonen (zie Abdel - Rassoul et al.. 2007).

Ten eerste, het hoeft niet noodzakelijk te zijn om onze elektrische apparaten, huishoudelijke apparaten of mobiele telefoons op te geven. Het is mogelijk om de meeste apparaten veel veiliger te maken. Alles wat nodig is bij de elektrische bedrading binnenshuis is “low-tech” elektromagnetische hygiëne. Voor wat betreft mobiele telefonie; de exploitanten weten al meer dan tien jaar hoe ze het uitgestraalde signaal kunnen wijzigen om het veilig te maken; ze hebben er gewoon voor gekozen dit niet te doen. Ik zal dit stap-voor-stap bespreken.

Bedrading binnenshuis

Het is gemakkelijk om het elektrische veld van de bedrading af te schermen door die te omsluiten met geaarde metalen geleiders of door het gebruik van afgeschermde kabel met een geaard scherm. We kunnen het magnetische veld niet op deze manier afschermen, maar door een zorgvuldig ontwerp van de circuits kunnen we de magnetische velden van de actieve en neutrale draden elkaar laten opheffen. Om dit te doen, is alles wat je nodig hebt om ervoor te zorgen dat de actieve en neutrale draden aan elk apparaat zo dicht mogelijk bij elkaar liggen (bij voorkeur in elkaar gedraaid), waarbij elk apparaat zijn eigen aansluiting heeft op de meterkast. De goedkope Britse praktijk van het gebruik van ringleidingen (waar veel stopcontacten zijn aangesloten in een ring, beginnend en eindigend in de meterkast) moet verboden worden. Dit komt omdat de verschillen in de weerstand van de geleiders er voor zorgen dat elektriciteit die naar een stopcontact stroomt niet langs dezelfde weg terugstroomt, zodat hun magnetische velden elkaar niet opheffen en een onnodig hoog veld rondom de hele ring ontstaat.

Een andere bron van problemen is het gebruik van niet geaarde dubbel geïsoleerde apparaten. Hoewel er zeer weinig kans is op schokken, emitteren die nog steeds sterke magnetische en elektrische velden ter grootte van ongeveer de helft van de voedingsspanning. Daar kunnen sommige mensen echt niet tegen.

Mobiele telefoons

Hoewel we de elektromagnetische velden die samenhangen met de bedrading binnenshuis kunnen blokkeren of neutraliseren, kunnen we dit niet met mobiele telefoons of DECT-telefoons. Die zijn voor hun goede werking afhankelijk van radiofrequente straling. Wij kunnen deze straling echter veel minder biologisch actief maken. Er zijn tenminste twee manieren om dit te doen. De eerste werd bedacht, getest en gepatenteerd door Theodore Litovitz, werkzaam bij de Katholieke Universiteit van Amerika in de jaren 1990. Het enige dat je hoeft te doen is laagfrequente elektromagnetische ruis aan het signaal toevoegen.

De theorie achter de methode van Litovitz

Zijn idee was om een willekeurig ELF (ruis) magnetisch veld toe te voegen aan de regelmatige zich herhalende velden van hoogspanningslijnen of mobiele telefoons. Dit werkt volgens het principe dat de meeste biologische effecten van elektromagnetische velden worden veroorzaakt door het relatief langzame maar progressieve verlies van calcium uit celmembranen, waardoor die gaan lekken. Echter, het effect op elke cel vindt alleen plaats binnen bepaalde amplitude vensters, zoals hiervoor beschreven. We kunnen deze lekkage misschien niet voorkomen door gewoon het vermogen van dit veld te verlagen. Waar dit slechts toe kan leiden is dat andere cellen (misschien dichter bij de bron) in het gevoelige gebied terecht komen en daardoor zouden we niet beter af kunnen zijn

Echter, als we een tweede magnetisch veld met een willekeurig variërende amplitude toevoegen, worden cellen voortdurend in en uit hun amplitude vensters gedreven en blijven ze niet lang genoeg in

dit gevoelige gebied om aanzienlijke hoeveelheden calcium te verliezen voordat ze dit gebied verlaten. Het verloren calcium vloeit dan terug en er is geen biologisch effect. Deze theorie is in verschillende biologische systemen getest en blijkt te werken.

Veel van het werk van Litovitz maakte gebruik van de productie van het enzym ornithine decarboxylase (ODC) door weefselculturen als indicator voor schade door straling aan levende cellen. De activiteit van dit enzym neemt factoren toe bij blootstelling aan elektromagnetische velden (Byus et al.. 1987). ODC maakt onderdeel uit van een verdedigingsmechanisme tegen straling en een toename van de productie wordt gezien als een indicatie voor het optreden van schade. Omgekeerd, als bij het willekeurige signaal die productie niet plaatsvindt is dit een indicatie dat geen schade optreedt.

Het onderzoek in het laboratorium van Litovitz hield zich voornamelijk bezig met het verzachten van de effecten van 60Hz lichtnet frequenties en hij ontdekte dat het toevoegen van een willekeurig (ruis) magnetisch veld van ongeveer dezelfde sterkte hun effecten op de ODC-productie in weefselculturen bij muizen volledig omkeerde (Litovitz et al.. 1994b). Dit bleek ook het geval bij de misvormingen veroorzaakt door 60Hz velden bij kippenembryo's (Litovitz et al.. 1994a).

Ze gingen toen verder met het bestuderen van de effecten van modulatiefrequentie bij 845 MHz microgolfstraling op de ODC productie in weefselculturen bij muizen. Zij stelden vast dat constante frequenties tussen 6 en 600 Hz, zoals gemeten door ODC productie, schadelijk waren. Eenvoudige amplitudegemoduleerde spraak (dat is meer willekeurig) verhoogde de aanmaak van ODC niet, evenmin als frequentie gemoduleerde microgolven en frequentie gemoduleerde analoge telefoon signalen. Continue microgolven hadden slechts een gering effect.

De meeste microgolf pulsfrequenties zijn schadelijk

Penafiel et al.. (1997) medewerker in het laboratorium van Litovitz, concludeerde dat ernstige gezondheidsproblemen alleen optraden bij de microgolven die waren gemoduleerd om pulsen met een standaard hoogte (amplitude) op te wekken, met frequenties tussen de 6 en 600Hz. Er was nagenoeg geen effect boven 600Hz. Dit komt overeen met de observatie van Blackman et al.. (1988), dat calcium uitstoot uit hersenweefsel niet voorkwam boven de 510Hz.

Het lijkt erop dat de mobiele telecommunicatie-industrie haar huiswerk niet goed heeft gedaan voordat ze de klokfrequenties kozen voor hun digitale communicatie. Ze liggen namelijk vrijwel allemaal binnen het biologisch actieve gebied; bijvoorbeeld 2G GSM mobiele telefoons (217Hz), TETRA (17,6 Hz), DECT telefoons (100Hz), WiFi (10Hz) en 3G UMTS signalen time division duplex (100Hz en 200Hz). Die zijn allemaal potentieel schadelijk. Er kunnen andere schadelijke effecten van de straling zijn, die niet leiden tot ODC productie of calcium uitstoot maar in ieder geval hadden deze klokfrequenties niet gebruikt mogen worden als de mobiele telefoon industrie zorgvuldig had gehandeld.

Echter, Litovitz (1997) ontdekte dat zelfs deze veilig gemaakt zouden kunnen worden door het toevoegen van een laagfrequent magnetisch veld aan het signaal. Zij ontdekten dat dit de productie van ornithine decarboxylase (ODC) door de weefsel culturen bij muizen als reactie op digitale mobiele telefoon signalen voorkomt. Bijvoorbeeld, een willekeurig veld tussen 30 en 100 Hz met een RMS sterkte van 5 microtesla blokkeerde de ODC productie, geïnduceerd door een mobiele telefoon signaal met een SAR van ongeveer 2,5 W/kg, volledig. Een spoel, ingebouwd in de mobiele telefoon, zou gemakkelijk een willekeurig magneetveld van deze sterkte kunnen leveren en waarschijnlijk de gebruiker beschermen tegen de schadelijke effecten van de straling.

Ook Lai (2004) toonde aan dat een willekeurig ruis-veld van 5 microtesla zorgde voor een volledige omkering van de schadelijke werking van 2450 MHz continue golven met een SAR van 1,2 W/kg op geheugen van ratten. In geen van de bovenstaande experimenten had de willekeurige ruis zelf enig effect en deze is, op basis van dit criterium, volkomen onschadelijk.

“Gebalanceerde signaal-technologie”
Terwijl de methode van Litovitz de gebruiker zou beschermen tegen de straling, omdat magnetische velden snel verdwijnen als je afstand neemt van de bron, kan hij andere mensen in de omgeving, die buiten het bereik van het beschermende willekeurige (ruis) veld zijn, geen bescherming bieden. Op dezelfde manier, zouden willekeurige laagfrequente magnetische velden afkomstig van een mobiele telefoon basisstation niet in staat zijn om de meeste gebruikers te beschermen. Hiervoor zou zo’n systeem nodig zijn als ik zelf heb bedacht en waaraan ik de naam “Gebalanceerde signaal-technologie” heb gegeven. Ik maak geen aanspraak op octrooirechten en iedereen die dit wil uitproberen en gebruiken kan dit kosteloos doen.

Het principe is heel eenvoudig en het gaat om het uitzenden van twee complementaire spiegelbeeld signalen op verschillende draaggolffrequenties; dat wil zeggen, wanneer het ene signaal een piek vertoont, vertoont het andere een dal. Het basisstation zou hier geen probleem mee hebben, omdat ze er uit zouden zien als twee afzonderlijke telefoongesprekken. Echter, levende cellen zouden waarschijnlijk geen onderscheid te maken tussen de twee draaggolffrequenties en de pieken van de ene zouden de dalen van de andere compenseren, zodat het geheel er uit zou zien als een relatief onschuldige continue golf. Het zou zeer weinig extra bandbreedte kosten, aangezien slechts één van de signalen behoeft te worden gebruikt en het andere effectief wordt weggegooid en ze kunnen beiden op dezelfde frequentie worden gezet. In theorie zou deze technologie kunnen worden toegepast bij zowel mobiele telefoons als bij basisstations, maar e.e.a. is nog niet getest.

De mobiele telefoon bedrijven moeten beide methodes om mobiele telefonie veiliger te maken kennen, maar er zijn geen aanwijzingen dat ze geïnteresseerd zijn, mogelijk omdat de uitvoering geld zou kosten, zonder extra voordeel voor die bedrijven. Het lijkt er sterk op dat ze liever hebben dat veel mensen ziek worden en misschien zelfs sterven, in plaats van toe te geven dat hun veiligheidsregels zijn gebaseerd op foute veronderstellingen en dat hun huidige technologieën nog niet veilig zijn.

Wat kunnen we er zelf aan doen?
Zeer weinig mensen zouden afstand willen doen van hun mobiele telefoons, maar als u er een hebt houd dan, voor uw eigen persoonlijke veiligheid, uw gesprekken kort en bel niet te vaak, zodat uw lichaam een kans krijgt om zich in de tussentijd te herstellen. Gebruik tekst (die in enkele seconden wordt verzonden) in plaats van spraak en vermijd onnodige internet downloads. De keuze is aan u, maar denk ook eens aan de mensen die in de buurt van een basisstation wonen. Sommigen kunnen behoorlijk getroffen worden door hun voortdurende bestraling, maar ze hebben geen keus. Uw mobiele telefoontjes zullen bijdragen aan hun problemen, zodat uw terughoudendheid bij mobiel bellen hen ook kan helpen.

Vergeet ook niet uw eigen persoonlijke bronnen van continue straling zoals WiFi routers en DECT telefoon basisstations, die nog schadelijker kunnen zijn omdat ze dichterbij zijn. Vermijd WiFi helemaal. Ethernet-verbindingen via de kabel zijn niet alleen veiliger, maar ook sneller, betrouwbaarder en bieden meer veiligheid. Diverse "Homeplug" apparaten, die een verbinding tot stand brengen tussen de Ethernet-aansluiting van uw computeren de router via het elektriciteitsnet zijn een “second best”

alternatief. Ze zijn niet perfect aangezien er nog enige straling is van de bedrading, vooral met die hogere snelheden bieden.

DECT-telefoons moeten ook, waar mogelijk, worden vermeden. Maar, als u er een moet hebben, is een redelijk compromis om er een te gebruiken waarvan het basisstation automatisch tussen de gesprekken wordt uitgeschakeld. Op het moment van schrijven van deze publicatie zijn, voor zo ver mij bekend, de enige DECT telefoons die dit doen “Eco-Plus” modellen van Gigaset. Echter, zorg ervoor dat ze zijn geprogrammeerd om te werken in de Eco-Plus-modus, aangezien dit niet de standaardinstelling is.

Afscherming en de beperkingen
Veel elektromagnetisch intolerante mensen zullen zichzelf willen afschermen van de velden, maar we moeten hier iets van begrijpen om de beste resultaten te krijgen.

Het nabije veld
Een wisselend elektromagnetisch veld bestaat uit een elektrisch veld en een magnetisch veld. Het elektrisch veld wordt opgewekt door een spanningsgradiënt en wordt gemeten in volt per meter. Het magnetisch veld wordt opgewekt door een elektrische stroom en wordt gemeten in tesla. Als u dicht bij de bron (meestal binnen een golflengte) bent, bevindt u zich in het nabije veld, waar de elektrische en magnetische velden voornamelijk gescheiden zijn.

Op hoogspanningslijn frequenties lopen de golflengtes in de duizenden mijlen, dus bent u automatisch in het nabije veld van hoogspanningsleidingen. Bijvoorbeeld, staande onder een hoogspanningslijn die werkt op wisselspanning wordt u blootgesteld aan een spanningsgradiënt als gevolg van het spanningsverschil tussen de leiding (die eigendom is van het elektriciteitsbedrijf) en de aarde. U zou ook worden blootgesteld aan een magnetisch veld evenredig met de stroom die daadwerkelijk door de lijn vloeit en die afhankelijk is van de consumentenvraag op dat moment. Zowel de magnetische als de elektrische velden kunnen elektrische stromen in uw lichaam induceren en zijn schadelijk, maar het magnetisch veld is slechter, omdat dit gemakkelijker door levende weefsels heen gaat en door de meeste wanden en aluminiumfolie alsof ze er niet zijn. Het is dus zeer moeilijk om uzelf af te schermen van magnetische velden.

Het verre veld
Echter, als u zich verder van de bron verwijdert vermengen de twee velden zich met elkaar en geven fotonen en radiogolven af. Dit is meestal al het geval binnen een paar golflengten, waarna u zich in het zogenaamde verre veld bevindt, waar alle vermogen de vorm van radiogolven aanneemt. Blootstelling hieraan wordt meestal gemeten in eenheden van vermogen (bv. microwatt per vierkante meter) of de bijbehorende spanningsgradiënt (bv. volt per meter).

Het belang hiervan voor ons is dat radiogolven zich gedragen als lichtgolven en relatief gemakkelijk geabsorbeerd en gereflecteerd kunnen worden. Dit kan worden gedaan met geaarde metaalfolie of andere elektrisch geleidende materialen zoals op koolstof gebaseerde verf en gemetalliseerd textiel. Voor praktische doeleinden betekent dit dat u zichzelf kunt afschermen tegen de straling van een zendmast, WiFi-router, of DECT telefoon basisstation als ze meerdere golflengten verwijderd zijn (enkele tientallen centimeters). Dit gaat echter niet op voor een mobiele telefoon tegen uw hoofd te houden, waarbij u zich in het nabije veld bevindt en de rauwe magnetische component zal diep in uw hersenen doordringen.

Om een idee te geven van de gevaren, magnetische velden lager dan één microtesla (een miljoenste Tesla) kunnen biologische effecten veroorzaken, maar gebruik van een 2G (GSM) mobiele telefoon of een PDA stelt u bloot aan laagfrequente magnetische pulsen die pieken vertonen bij verschillende tientallen microtesla (Jokela et al., 2004; Sage et al., 2007.). Deze komen voornamelijk uit de circuits rondom de accu en liggen duidelijk boven het niveau waarbij schadelijke effecten kunnen optreden. Wanneer ze worden opgeteld bij de schadelijke effecten van hun eigen microgolf velden, zijn deze apparaten potentieel de gevaarlijkste bronnen van elektromagnetische velden en straling die de gemiddelde persoon bezit.

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Bovenstaand kennisbericht heeft uitsluitend als doel mensen die zich willen oriënteren op het gebied van de risico's van Elektromagnetische Straling van relevante informatie te voorzien en verantwoorde omgang met mobiele communicatie te bevorderen.
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Mobile Telecommunications and Health

Review of the current scientific research in view of precautionary health protection

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Contents

1 Introduction

1.1 New Technologies and Precautionary Health Protection

No technology covering virtually entire countries with its emissions has ever been rolled out as quickly as mobile telecommunications. At the same time, there are only few direct studies of the potential health risks of typical mobile telecommunications frequencies and modulations for the exposed population. Also, many of the existing studies worked with high intensities, which will only be found in rare cases in the real environment. High intensities of high frequency electromagnetic fields can heat the absorbing tissue and trigger stress reactions in the body and thus with rising temperatures lead to thermal damage. Effects from high intensity high frequency EMFs, also know as thermal effects, on the central nervous system, the immune system, the cardio-vascular system and the reproductive system including teratogenic effects, have been proven for mammals with a multitude of experiments.

The results of studies of the thermal effects of high frequency EMFs form the basis of the recommendations of the International Commission on Non-Ionizing Radiation Protection (ICNIRP), which, in the past, were the basis for the guidelines set by the government in Germany and many other countries. The base guideline was an upper limit on the Specific Absorption Rate (SAR), i.e. the amount of energy absorbed by the body from the field within a given unit of time.

According to ICNIRP, thermal damage will not occur at SAR values of under 4 W/kg and exposure levels of 0.4 W/kg for professional exposures and 0.08W/kg for the general population are considered safe.

Parallel to the experiments examining thermal effects, there have been a growing number of studies examining the effects on the body of HF EMFs at sub-thermal intensities. We now have a plethora of experimental studies examining a variety of effects on all levels of the organism, ranging from effects on single cells to effects which manifest themselves as reactions of the entire body. In addition to the experimental studies, there have been a number of epidemiological studies in order to establish the possible causal correlations between higher exposures to HF EMFs, for example as found near base stations, and health damage amongst the population groups with higher exposures.

The mobile telecommunications situation reflects, once again, the dilemma already known from chemical toxicology: The study of potential health effects cannot generally compete with the speed of technical development and the roll out of the product. The extremely fast roll out of the mobile telecommunications technology and the accompanying public fear of the potential danger of this technology have stimulated research insofar that now we have more studies examining the effects of frequencies and modulations as used in mobile telecommunications on biological systems. There are also a growing number of experiments using lower intensities, reflecting the real conditions of exposure in the vicinity of base stations and equipment, so that effects found in the studies can be extrapolated into real life conditions. The number of studies which examine the

physiological effects of real mobile exposures is still very low, compared to the degree of penetration achieved by the technology and the number of (potentially) exposed persons. The WHO amongst others, have only recently begun to develop targeted strategies to examine the potential health risk from mobile telecommunications and results can earliest be expected within several years.

In the meantime, it is only possible to assess the potential dangers of mobile telecommunications using the results generated by uncoordinated research, which is still mainly orientated towards topics and criteria of relevant to science only, rather than addressing the requirements of society as a whole.

Faced with a state of incomplete scientific research it is necessary to chose between two fundamentally different assessment theories when planning to assess the potential health risks of new technologies:

The first theory is based on the (without doubt correct) scholarly understanding that is practically impossible to prove the 'non-harmfulness' to human health or the environment of a technology, a material or a product. This understanding is interpreted in such a way that a presupposition of 'not guilty' is adopted and any risks have to be unequivocally proven.

'Unequivocal proof' in this context means the consistent evidence for a biological-physiological or an ecological chain of effects, from the biophysical or biochemical primary effect through to the physiological effects and the resulting illness or, if applicable, the ecological damage.

This theory, which is firmly based in scientific conservatism, has the advantage that it will stand up in court and will not hinder the introduction of new technologies. It is methodologically simple, since it is sufficient to examine studies which are presented as 'proof' with regards to their methodological correctness and their validity and then to put all these reviewed pieces of evidence together like a jigsaw to produce a whole picture. The complete whole picture finally constitutes the scientific proof required by the legislators and courts.

The disadvantage of this theory is obviously the length of time necessary to obtain enough knowledge for a completed chain of proof, during which many facts will be created, which may later prove irreversible or only reversible with very high costs attached, such as investments and irreversible damage to health and the environment.

The second theory solves the dilemma of the time delay. It is based on the assessment of the potential risks of a technology on the basis of existing knowledge. If there are sufficient indications that there may be damaging effects, the precautionary principle for the protection of health and the environment will apply and avoidable exposures will be avoided until such time when there is enough knowledge for a wider introduction of the technology in question. This theory draws its justification not least from the experiences with the introduction of technologies and products (such as asbestos, DDT, CFCs, formaldehyde, wood preservatives, mass X-ray screenings etc.), which were widely used, even many years after the first clear indications of health and ecological damage had appeared. When finally sufficient scientific proof for the health and ecological damage

was provided, it took many more years until the further use was finally reduced and banned through the courts and international negotiations.

The advantage of the precautionary principle is of course primarily medical and ecological, since exposures are initially limited to a level recognised as safe under the precautionary principle. But it can also offer economical advantages, because firstly, it may prevent potentially highly risky investments, but also secondly, because the commitment to and observance of the precautionary principle will create trust within the general population and thus increase acceptance for the placing of emitting equipment.

On the other hand, it will be the industry – as the owner of emitting equipment – who has to bear the disadvantage of this principle, when it becomes clear that, for precautionary reasons, an economically and technically perfectly-suited site can't be approved, or maybe even an entire technology has to be abandoned.

Furthermore, the methodological difficulties of this theory must not be underestimated, since it is not enough to prove the reliability of single scientific studies, which is just as essential under this premise as under the first theory. The ultimate goal however is – to remain with the jigsaw analogy – to put the existing jigsaw pieces together and recognise early on which pictures might appear once the work is completed.

1.2 Terms of Reference and Structure of the Review

The aim of this study was the assessment of the potential risks of electromagnetic fields as they are used for mobile telecommunications with respect to precautionary health protection. To this aim, the scientific literature was reviewed with regards to study results which might be of importance to the assessment of potential health risks from mobile telecommunications.

To create a base for later scientific discussion, a list of studies which are particularly important in this respect should be created. On the basis of these papers, the health risk from exposure to electromagnetic fields from mobile telecommunications should be assessed. Finally, recommendations for future scientific studies should be formulated.

The methodological aspects of this examination are presented in Chapter 2. This is followed by a review of the current scientific knowledge of the effects of high frequency electromagnetic fields. This review is structured according to the different levels of effects:

- biophysical and biochemical primary effects of HF fields on organic matter as a whole or at the level of cells and membranes (Chapter 3)
- primary biological effects on the cellular level, i.e. on the genetic substance and on intracellular processes as well as cell transformation and cell proliferation (Chapter 4)
- patho-physiological effects, i.e. physiological effects with possible but not certain negative health implications (Chapter 5)
- pathological effects, which means manifested illness and other effects such as the damage of cognitive functions, which have been found in epidemiological or experimental studies (Chapter 6).

The conclusions of all findings are drawn in Chapter 7. In Chapter 8, we make recommendations for precautionary health protection with regards to exposures to the electromagnetic fields of mobile telecommunications and for focal points for further research.

2 Collating and Interpreting the Scientific Data (Methodology)

2.1 Criteria for the Selection of Papers

In order to include a maximum of relevant literature, we analysed the literature we have catalogued in our own database, EMFbase, as well as exploring the three following paths:

- research in other relevant scientific databases
- complete sifting of at least the last two full years' issues of all relevant scientific journals available in the Central Library of Medicine in Cologne, the Technical Information Library in Hanover, and the Library of the Medical University of Hanover
- evaluation of all existing monographs, reviews and conference reports related to the subject matter

The basic literature research was finished in February 2000.

Literature databases are a convenient research tool, but their value in assessing the current scientific knowledge in a subject matter is limited by the number of registered publications, inconsistent use of keywords, the changing understanding of certain procedures, effects etc. and last but not least, due to long time delays between the time of publication and availability in the database. Furthermore, databases usually only keep abstracts of papers, and those differ often from the full text with regards to the presentation and interpretation of the results. Our research for this review confirmed this observation, reflecting the results of a study of Pitkin et al. (1999) according to which almost 40% of all papers published in the six largest medical journals contained inaccuracies and mistakes in the abstracts. To be at the cutting edge of scientific knowledge, it is necessary to research current scientific journals and find older papers via monographs and reviews. Reviews are only useful to gain an overview over a subject matter and as a source for literature leads. It is inappropriate to use assessments or interpretations of a review study since some authors of reviews will have based their conclusion on abstracts rather than the full texts of the papers they discuss.

2.2 Assessment Criteria

One sub-goal of the present paper was to identify those scientific papers which are particularly interesting for the assessment of potential health risks caused by the electromagnetic emissions of mobile telecommunications. (Extracts from our database EMFbase with a summary of the results of these papers can be found in Annex E. In the source references, these papers carry an asterisk*). Only peer reviewed papers published in scientific journals were included in our review. We also accorded weight to the 'Impact Factor', which is calculated by the Institute for Scientific Information in Philadelphia. This factor is a rough measure for the amount of importance and reputation attributed to a scientific journal in its subject matter.

The papers able to pass this first filter were subsequently interpreted according to the following criteria:

- carrier frequency or frequency range
- manner of modulation
- modulation frequency or frequency range
- power flux density
- specific Absorption Rate
- electric filed strength
- duration of exposure
- other parameters of exposure (such as other fields [incl. ELF], ambient and if applicable body temperature, particular forms of modulation)
- source of exposure or environment of the exposure (such as antenna emitting freely, anechoic chamber, transmission line)
- object of experiments (human, animal, cell system)
- examined pathological results (manifested illness and other effects on the whole body)
- examined patho-physiological effects (physiological effects with a potential for health damage)
- examined biological effects (mostly on the cellular level)
- examined biophysical and biochemical processes (primary effects on the level of molecules, membranes etc.)
- methodology of the experiments (procedures used)
- results (including a mention if our own interpretations differ from those of the author)
- statistical significance of the results
- appropriateness of the model (with regards to the statements made about effects on humans)
- appropriateness of the methodology (methodical weakness analysis)
- documentation of the conditions of the experiments (completeness, reproducibility)
- context of other experiments (mention of experiments with the same or contradicting results)
- meaning (Main conclusions drawn from the results, importance for the assessment of health risks for humans)

Because of the delay of science with regards to the electromagnetic frequencies emitted by mobile telecommunications, a risk analysis cannot be limited to the frequencies and

modulations actually used by this technology. Therefore, we have included all papers examining carrier frequencies from 100MHz to 10GHz. In the experiments at cellular level, but also in animal experiments, effects have been found that only appear at certain modulations or are a lot stronger at these modulations (chapter 3 and 4). At this point in time it is not possible to determine whether the majority of the found effects are caused by the HF carrier wave or the modulation. This is why we have included all forms of modulation into this review. Because of the nature and the importance of the so-called 'thermal effects' (chapter 3.1) we have not set an exclusion limit for power flux density and Specific Absorption Rate. However, we did not include papers, in which the EMF exposure led to a considerable rise in body temperature (>1ºC) of the animals or human subjects.

When evaluating the papers, we kept making the following observations:

- important single results are 'masked' for example when data are 'pooled'
- certain observations are dismissed by the authors as 'blips' if they don't fit the (expected/otherwise observed) general trend, without sufficient explanation being offered for this dismissal
- single results are not taken into account for statistical reasons, but a common trend is not recognised or not sufficiently acknowledged.

In such cases, whenever this was possible based on the existing data, we proceeded to make our own interpretations. Where our evaluation differed from the main statements of the authors, it will be noted.

3 Primary Reciprocal Effects between High Frequency Electromagnetic Fields and Biological Systems (Biophysical and Biochemical Processes)

3.1 Thermal Effects

3.1.1 Effects of Homogenous Warming

HF electromagnetic fields are absorbed depending on the frequency and polarisation of the fields on the one hand and the dimensions and material characteristics of the biological system on the other hand. They cause electric currents (dominant in the range under 1 MHz), polarisation effects and potential differences on cell membranes (in the range between 1 MHz and 100 MHz) or trigger rotational oscillations of polar molecules (mainly within the GHz range). All these processes can lead to a warming of the biological material if the intensity is sufficient (Ohmic losses in the low frequency range and dielectrical losses in the GHz range). The avoidance of health-damaging warming is the base of the concept of SAR, expressed by limiting the specific absorption rate, measured as the energy absorption per unit, to a rate which will exclude overheating based on the body's own thermo-regulative processes. For humans, a whole body exposure of 0.4 W/kg corresponds approximately to half the metabolic base rate. In absence of heat conduction or other thermal dissipation, a SAR of 0.4 W/kg will lead to a temperature rise of 10^{-4}K/sek (Foster 1996) in soft tissue like muscles or the brain.

3.1.2 Microthermal Effects

The warming through microwaves is fundamentally different from the warming through a water bath for example. In the latter case the energy is transmitted by stochastic collisions. In microwave heating it is in the simplest case the electrical component which puts polar molecules within the medium collectively in vibration (3.2.1). Because of 'friction' with the dense ambient medium, the energy is quickly transmitted to this medium and further dissipated by collisions. When corresponding inner molecular degrees of freedom exist, the microwave energy can also be absorbed as a quantum and, in a large molecule, stored (3.3.). Compared to conventional warming, the absorption of a microwave quantum is a singular process, which can lead to localised warming if the absorbing molecules are suitably distributed. Liu & Cleary (1995) show in a theoretical model that at the cellular level, membrane-bound water can lead to frequency dependent spatial discrepancies in dissipation of the SAR and the induced HF fields.

Microthermal effects can also be caused by the non-uniformity of thermal conductivity of tissue at microscopic level, especially when the warming is short, strong and local. This is of importance mainly for the evaluation of pulsed fields, because in such fields, even at a low average power flux density, the energy absorbed during a pulse can be very high. Radiation in the form of short pulses can lead to a very high rate of temperature rise, which can itself trigger thermoelastic waves, a phenomenon, which is inked to the

acoustic perception of microwaves. A high peak-SAR can also trigger thermally-induced membrane phenomena (Foster 1996).

3.2 Direct Field Effects

3.2.1 Effects from the Electrical Component of the Electromagnetic Field

The electric component of the electromagnetic field exerts a force on electrical charges, permanent dipole moments, induced dipole moments and higher multipole moments. The forces on charges create currents, however these only play a role in the lower HF range, causing changes in membrane potentials (stimulation) or thermal effects (see above).

Permanent charge distributions in biomolecules and cells lead to permanent dipole (or higher multipole) moments. The electrical field exerts a torque on dipoles, which tries to align the dipole moment parallel to the field. In alternating fields with not too high frequencies, the interactions lead to oscillations of the dipoles. In dense media, these oscillations are hindered by interactions with the surrounding particles, which lead to heating (see above). If the particles are too large or the surrounding particle density is too high or if the frequency of the field is too high, the oscillations cannot develop.

The threshold field strengths for the orientation of dipolar cells and other objects of similar size (radius of approx. 1 μm) are at 100 V/m, the cut-off frequencies in water (temperature 300K) are at circa 0.05Hz, hence far outside the HF range. DNA molecules and other bio-polymers can be put into oscillation by fields with frequencies in the kHz range. Spherical protein molecules (radius approx. 5nm) can still follow fields with frequencies up to 400 kHz, however this requires field strengths of 10^6V/m (Foster 1996). Such field strengths are not usually reached in the environment.

The interaction between a field and a particle with an induced dipole moment depends on the field strength to the power of 2, that means, a continuous electrical alternating field influences the particle via a constant torque, however the torque of a modulated field follows the modulation. There is no limitation through a cut-off frequency for the interaction between a field and an induced dipole moment, however for frequencies over 1 MHz, the forces exerted on the cells are very small unless field strengths of several thousand V/m are used. With such field strengths however, strong dielectrophoretic forces appear, which can lead to cell deformations, to the orientation of non-spherical cells and to the so-called coin roll effect, a stringing together of cells. Since the induced dipole moment depends on the polarizability of the particle and the latter on the size of the particle, even higher field strengths are needed for smaller bodies than cells (biopolymers).

Electric fields can induce electrical potentials on cell membranes. The size of these potentials depends on the electric field strength, the dimensions of the cell, the frequency of the field, the electrical conductivity within and outside of the cell as well as the capacitance of the cell membrane.

With frequencies above 1 MHz the membrane is practically short-circuited and the induced membrane potentials become very small. However, theoretical rectification processes and non-linear phenomena at the cell membrane have been discussed, and these could lead to an intensification of the effect and to membrane potentials that have an effect on cell physiology.

3.2.2 Effects from the Magnetic Component of the Electromagnetic Field

With some exceptions, biological tissue is not magnetic and the mutual effects between the magnetic component of an electromagnetic field and tissue are generally small. However, the presence of magnetite crystals, which have a strong capacity to absorb the frequency range of 0.5 to 10 GHz which is relevant for mobile telecommunications, has been found in the human brain as well as in the tissue of many animals (*Kirschvink 1996). Under exposure to amplitude modulated or pulse modulated microwaves, the frequency of the crystal vibrations varies according to the modulation frequency, and thus transmits it, for example in the form of an acoustic wave onto the ambient medium and the cell membrane, which possibly leads to changes of the permeability of the membrane (*Kirschvink 1996). Theoretical calculations show that magnetite transmitted effects can only occur at high densities of superparamagnetic particles (*Dobson & St. Pierre 1998).

3.3 Quantum Effects

The quantum energy from radio and microwaves in the frequency range between 100 MHz to 10 GHz is far too low to break ionic, covalent or hydrogen bonds. Bohr et al. (*1997) have however shown theoretically, that wring resonances can be triggered in chain molecules. The frequencies of these resonances are in the range from 1 to 10 GHz for proteins and 10 MHz to 10 GHz for DNA molecules. The wring modes of molecules manifest themselves as 'torsions' in the molecule chain, which can lead to structural changes.

The influences of microwaves on structural changes in molecules have been found in experiments using the protein ß-Lactoglobuline (*Bohr & Bohr 2000). The triggering of resonant wring modes can even lead to chain breaks, since due to White's Theory, the added energy can be concentrated in a very limited part of the molecule during structural changes (*Bohr et al.). In this part, the chain can break.

3.4 Other Effects

Resonance Phenomena

When the frequency of the electromagnetic wave meets the natural vibrations in the cell structures or in tissue, it can lead to resonances. Rhythmical fluctuations of signal substances, matter-exchange-processes and Ion-conductivity can be found in many neurones, receptors and cell types. These oscillations can influence the membrane potentials and switch certain stimuli on and off. An external field – according to theory – can imprint an external oscillation frequency onto these structures. Neurones which have

been modified in this way can even synchronise the following neurones in the same way. This external synchronisation would even remain after the disappearance of the external stimulus.

Indirect Effects

In addition to the previously described triggering of wring resonances, microwaves can possibly damage the genetic substance via the formation of hydroxyl radicals. The input energy of microwaves is sufficient to raise the ratio of oxidants to anti-oxidants, a self-accelerating chain reaction of free radicals can lead to damage of the DNA (Scott 1992, see also Maes et al. 1995).

3.5 Particular Properties of Pulsed Electromagnetic Fields

In an evaluation of circa 40 studies, in which the biological effects of pulsed high frequency fields were directly compared to those of continuous fields of the same median power density, Postow & Swicord (1996) concluded that in half of the studies, the biological effectiveness of pulsed fields was significantly higher. Only in a few studies were the continuous fields more effective and in the remainder of the studies the effectiveness of both was practically the same. The studies which are mainly discussed in chapter 4 and 5 convey a similar picture.

At first glance, the higher biological effectiveness of pulsed electromagnetic fields in comparison to continuous fields at the same median power flux densities could have an almost trivial cause:

The individual pulses of pulse modulated fields have a higher amplitude than the continuous fields; the possible threshold for the triggering of biological reactions could therefore be passed in these fields during the duration of the pulse.

However, numerous experiments found that the biological response depends in a complicated manner on the duration of the pulse and its frequency. Given that some effects have only been observed at certain pulse frequencies, we presume that in addition to the described effect, there are others which can be originally attributed to the low frequency modulation (see also chapter 4).

4 Biological Primary Effects of High Frequency Electromagnetic Fields Effects on Cellular Level

At the cellular level, it is possible that there may be direct effects of the EM field on the genetic material, which we have collated under the heading Gene Toxicity and which will manifest as mutations if the cell's own repair mechanisms fail. On the other hand, it is also possible that the fields influence cellular processes such as gene-transcription and gene-translation. Furthermore it is possible that the fields can impact on the cell membranes, the intracellular processes of signal transmission and not least the cell cycle. Just like direct damage of the genetic substance, a disruption of these processes can lead to a transformation of the cell, to disruptions of inter-cellular communication and to a changed rate of cell division, which can lead to a slower – or very importantly with respect to a potential carcinogenic effect – faster growth.

4.1 Gene Toxicity

A basic question for the evaluation of the potential dangers of mobile telecommunication is whether the electromagnetic fields used are genotoxic. If the fields had the potential to damage genetic substance directly, they would not only amplify the effects of other carcinogenic teratogenic or mutagenic substances, but they would induce these effects themselves. A direct genotoxic effect of electromagnetic fields with frequencies as they are used for mobile telecommunications has been thought to be not likely in the past (Brusick et al. 1998, Moulder et al. 1999, Repacholi 1997, Repacholi 1998, Saunders et al.1991, Verschaeve 1995, Verschaeve & Maes 1998). The reasons for this assumption were on the one hand that the quantum energy contained in EM field in the radio and microwave range was not sufficient to break molecular bonds. This assumption is no longer tenable after the experiments of Bohr et al. (*1997) and Bohr & Bohr (*2000) (see also chapter 3.3). On the other hand, it was argued that there was a large number of experiments showing no genotoxic effects. Our list of papers in Annex A, Table A.1 shows however, that the much debated findings of the work of Lai & Singh (*1995), in which the direct damage of DNA (single strand and double strand breaks) has been proven, have been confirmed by a whole range of other studies, some by the same laboratory, but also by other groups (*Lai & Singh 1996, 1997, *Phillips 1998, *Sarkar 1994). A study by Varma & Traboulay (1977) on the effect of HF fields on pure DNA had already resulted in hints of direct genotoxic effects, however, this experiment used a relatively high power flux density and therefore significant warming may have occurred, at least locally. Lai and Singh (*1997) found that the dispensation of melatonin and N-Tert-Butylalpha-Phenylnitron (PBN) before the EMF exposure prevented the occurrence of DNA breaks. Melatonin captures free radicals and for PBN it has been proven that it protects cells from cell death induced by free radicals.

In Appendix Table A.1 we also list the experiment of Meltz et al. (*1987) and Stagg et al. (*1997) which examined the influences of EMF fields on the DNA repair mechanisms and the DNA synthesis.

The term chromosome aberration sums up all anomalies of the DNA double strand level with respect to chromatids and chromosomes. Examples for structural chromosome aberrations are: chromatid and chromosome breaks, chromatid gaps, acentric fragments as well as di- and tetracentric chromosomes.

Chromosome aberrations have been observed in a multitude of experimental conditions, *in vivo* as well as *in vitro* (Table A.1). Maes et al.(*1997) found a rise of chromosome aberrations in human lymphocytes in workers who were professionally exposed to radiation from mobile equipment, but also in experiments with human blood under controlled exposure conditions (GSM base station, 15 W/m², exposure time of 2 hours). However, this was the only study so far which used the actual fields of a real base station.

The incidence of micronuclei indicates whether the distribution of chromosomes into the daughter nuclei after a cell division has been normal and complete. A number of studies have proven a higher incidence of micronuclei under the influence of HF EMF fields, which is interpreted as an indication for chromosome damage (Table A.1). With one exception, the frequencies were all over 1 GHz and in most cases the intensities were relatively high.

For the incidence of sister chromatid exchange as a measure for damage at DNA single strand level, only very few studies using typical mobile frequencies and intensities have been done so far (Table A.1). Maes et al.(*1996) found that the radiation of a GSM base station (954 MHz, 217 Hz, duration of exposure: 2 hours) raises the genotoxic effects of Mitomycin C significantly, demonstrated via the sister chromatid exchange.

Genetic damage can lead to cell mutation with possibly damaging effects for the living organism. Mutations which promote faster cell division will be discussed in chapter 4.3. Table A.1 shows in its last block some studies which focussed on the evidence of changes in the genetic materials which manifest themselves as changed properties within the organism.

4.2 Cellular Processes

4.2.1 Gene-Transcription and Gene-Translation

The code of the DNA controls protein synthesis in the ribosomes via the RNA. The creation of RNA, i.e. the imprinting of genetic information happens in the cell nucleus (transcription). The encoded information is transported via messenger-RNA (M-RNA) to the ribosomes and is read there with the help of Transfer RNA (t-RNA). According to the transmitted code, proteins are subsequently synthesized. This process of synthesis is called translation. Since one m-RNA chain can be used by several ribosomes, the rate of synthesis of the corresponding protein can be a lot higher than that of the m-RNA. Mistakes made during the genetic transcription can thus be ‘raised to a higher power’ at the protein level.

In the first block of Appendix Table A.2, we list several recent studies which demonstrated changes of gene transcription and translation under the influence of electromagnetic fields of mobile telecommunications. Fritze et al. (*1997) observed

changed gene transcription in certain areas of the brains of rats which had been exposed to the field of a GSM phone for four hours.

In an *in vitro* experiment, Ivaschuk et al. (*1997) exposed cells to a pulse modulated HF field (836.55 MHz, TDMA 50Hz) and afterwards extracted and analysed the entire cellular RNA.

This showed statistically significant changes with regards to the transcription of the response gene *c-jun* (90W/m², duration of exposure: 20 minutes), however no changes with regards to *c-fos*. The results of the experiments by Goswami et al. (*1999) found a evidence for an influence on the transcription of the response gene *c-fos* by a similar field, whilst for *c-jun* and *c-myc*, no statistically significant effect was observed. The intensities at which effects on gene translation had been observed were well below the values at which thermal effects would occur in mammals.

4.2.2 Membrane Function

There is a large number of experimental evidence that high frequency fields, non-pulsed and pulsed can affect different properties of the ion channels in cell membranes, for example in the form of a lowering of the rate of channel formation or the reduction of frequency of the opening of individual channels (Repacholi 1998). The frequency of openings of ion channels which are activated by acetylcholine was significantly lowered by a microwave field (10.75 GHz) with a power flux density of a few μW/cm². (*D'Inzeo et al.1988). Changes of the membranes as a whole have also been observed under the influence of weak fields. Thus, Phelan et al. (*1992) observed that a 2.45 GHz field, with a pulse modulation of 100 Hz could trigger a phase transition from liquid to solid in melatonin containing cells after an exposure of 1 hour at a SAR of 0.2 W/kg.

4.2.3 Signal Transduction

Ca^{2+}

The divalent Calcium cation Ca^{2+} plays an important role in the cell-signal-transduction: regulating the energy output, the cellular metabolism and the phenotypical expression of cell characteristics.

The signal function of the Ca^{2+} is based on a complicated network of cellular channels and transport mechanisms, which maintains the Ca^{2+} concentration within the cell at a lower level than outside, but which is also linked to dynamic reservoirs. This allows the transduction of extracellular signals (hormones, growth factors) as Ca^{2+} peaks in the cytosol, transmitting information encoded in their intensity and frequency. It is known that this signal process can be disrupted by a variety of toxic chemicals in the environment, which can lead to cell damage and even cell death (Kass & Orrenius 1999).

Studies by Bawin et al. (*1975) and Blackman et al. (*1979) showed very early on *in vitro* experiments that the Ca^{2+} balance of nerve cells and brain tissue can be disrupted by HF fields with low frequency amplitude modulations.

Both studies worked with amplitude modulated 147 MHz fields (with intensities ranging from 5 to 20 W/m^2). The maximum effect occurred at a modulation frequency of 16 Hz. Experiments conducted by Dutta et al. (*1984 *1989) and Lin-Liu & Adey (*1982) also showed significant dependence on the modulation frequencies, in some cases at Specific Absorption Rates of as low as 0.5 W/kg. Equally, Somosy et al. (*1993) found that an effect on the distribution of Ca in intestinal cells is only possible within a field modulated with a low frequency. Wolke et al. (*1996) observed in their experiment on myocytes that exposure to fields with mobile-like carrier frequencies of 900 MHz and 1800 MHz resulted in lower intracellular concentrations of Ca^{2+} for all modulation frequencies (16 Hz, 50 Hz, 217 Hz, 30 KHz) compared to exposures to a continuous 900 MHz field or no exposure at all. A statistically significant effect was only found with the combination of a carrier wave of 900MHz and a modulation frequency of 50 Hz. The Specific Absorption Rate for this experiment was between 0.01 and 0.034 W/kg, far below the range which might be relevant for 'thermal' effects.

Enzymes

Protein kinases are enzymes with the property to phosphorylate other enzymes or proteins. Phosphorylation, a covalent modification by addition of a phosphate group, changes the activity or function of a protein. The protein kinases play an important role in the transmission of information from the membrane receptors for hormones and cytokines into the interior of the cell, and thus in the regulation of many intracellular processes such as glucose and lipid metabolisms, protein synthesis, membrane permeability, enzyme intake and transformation by viruses.

An amplitude modulated 450 MHz field is capable of decreasing the activity of protein kinases which are not activated by cyclical Adenosine monophosphate. Byus et al. (*1984) showed that the degree of inactivity depended on the exposure time as well as the modulation frequency. Maximum effects occurred at exposure times of 15 to 30 minutes with a modulation frequency of 16 Hz.

The enzyme ornithine decarboxylase (ODC) determines the speed of the biosynthesis of polyamines. Polyamines are needed for DNA synthesis and cell growth. ODC is also activated in relation to carcinogenesis. The control of OCD activity from the exterior is facilitated via processes on the cell membrane. Byus et al. (*1988) exposed three different cell types (rat hepatoma cells, egg cells of the Chinese hamster, human melanoma cells) for one hour to a 450 MHz field with a 16 Hz amplitude modulation and a power flux density of 10W/m^2. The exposure raised ODC activity by a little more than 50%. The heightened ODC activity remained for several hours after the exposure. Similar fields with a 60 Hz and a 100 Hz modulation had no effects. Another study (*Penafiel et al. 1997) observed heightened ODC activity after the radiation of L929-cells of mice with a 835 MHz field which had been amplitude modulated at 60Hz or pulse modulated at 50Hz. No effects whatsoever were observed with an analogue mobile phone, a frequency modulation at 60 Hz and a speech amplitude modulation. This last finding confirms other results by the same group, according to which a minimum coherence time of 10 seconds of the field needs to be present for an effect on ODC activity to manifest (*Litovitz et al.1993, 1997, see also Glaser 1998 and Litovitz 1998). The coherence time of speech modulated fields however is shorter than a second.

Further important proof that low frequency modulation has a determining influence on the effects of electromagnetic fields on enzyme activity was found by Dutta et al. (*1994): They compared the effects of a low frequency modulated 147 Hz field (0.05 W/kg) and a combined low frequency electric and magnetic field (ELF EM, 21.2V/97nT). A continuous high frequency field only had a small effect (3.6 per cent) on the activity of enolase in *Escheria Coli*, a 16 Hz modulated field led to an increase in activity of nearly 62 per cent, a 60 Hz modulated field led to a decrease of activity of 28.5 per cent. At ELF-EM a similar response could be observed: increase of enzyme activity by more than 59 per cent at a frequency of 16 Hz and decrease of 24 per cent at 60 Hz. The results of the experiments by Behari et al.(*1998) point in the same direction. They found that a 30 to 35 day long exposure of rats to amplitude modulated fields (6.11 – 9.65 W/kg) led to a significant increase in Na^+-K^+-ATPase activity, which was independent from the carrier frequency, but characteristically dependent on the modulation frequency, because the effect was always stronger at a 16 Hz modulation than at a 76 Hz modulation.

4.2.4 Cell Cycle

An undisrupted signal transduction or efficient cell cycle control mechanisms which are capable of correcting false information or facilitating repairs are the prerequisite for cell cycle progression if the genomic integrity of the cell is to be maintained (Shackelford et al. 1999). Disturbances of the DNA replication can lead to detrimental mutations and as a consequence to cell death or in multicellular organisms to cancer. The causes for irregularities in the course of the cell cycle are almost always to be found in mistakes during signal transduction and/or the failure of control mechanisms.

In Appendix Table A.2. we list studies which examined disruption of the cell cycle. The only *in vivo* experiment is the one by Mankowska et al. (*1979) which also used intensities as they are found in the environment of real emitting equipment. Statistically significant increases of disrupted metaphases with uni-, quadri- and hexavalencies were demonstrated in this study from a power flux density of 5 W/m^2.

Cleary et al. (81996) found in their experiment that 2.45 GHz fields are roughly twice as effective as 27 MHz fields when it comes to the triggering of cell cycle disturbances. Whilst the 27 MHz fields had no influence on the G2/M phase of egg cells of the Chinese hamster, disturbances of all phases were observed in a 2.45 GHz field.

4.3 Cell Transformation and Cell Proliferation

In vitro experiments of the effects of high frequency fields on the rate or division or the rate of proliferation of cells, expressed in the proliferation rate and the (neoplastic) transformation of cells can offer important findings with regards to possible carcinogenic effects of the fields. The adverse influences of the fields which could not be prevented by the cell's own repair mechanisms manifest themselves in disrupted cell proliferation and cell transformation rates.

Table A.3 gives an overview of the studies, in which the effects of high frequency fields on cell transformation and cell proliferation rates were the focus of the examinations.

4.3.1 Cell Transformation

Balzer-Kubiczek & Harrison (*1985, *1989, *1991) found an increase in neoplastic transformations in cells which had been exposed *in vitro* to a high frequency field with a low frequency pulse. The effect depended on intensity, but was only observable, if a tumour promoter (TPA) was added after the exposure.

Czerska et al. (*1992) found that low frequency pulsed microwave radiation (2.45 GHz) increased the rate of transformation of small inactive lymphocytes into large activated lymphoblasts. Continuous radiation could trigger this effect only at power flux densities that also led to measurable warming.

However, the experiments with pulsed radiation which triggered the cell transformation at power flux densities, for which a homogenous warming can be ruled out, showed that homogenous warming cannot be responsible for this effect.

4.3.2 Cell Communication

Disrupted communication between transformed cells and normal cells plays an important role in tumor promotion. Cain et al. (*1997) co-cultivated transformed cells with normal cells. The co-culture was exposed for 28 days to a TDMA (50Hz) modulated 836.55 MHz field as well as to the tumor promoter TPA in various concentrations. At power flux densities of 3 and 30 W/m^2, which corresponded to Specific Absorption Rates of 1.5 and 15 mW/kg, they did not find a statistically significant difference of focus formation between the exposed and the control cultures for any of the TPA concentrations. The data for the lowest intensity (0.3 W/m^2/0.15 mW/kg) show for two of the three TPA concentrations that there was a small but statistically significant difference in the number of foci, and for the lowest TPA concentration also for the surface and density of the foci.

4.3.3 Cell Proliferation

Anderstam et al. (*1983) found in their experiments with bacteria that some strains reacted to the exposure with an amplitude modulated 2.45 GHz field (500Hz, 35 to 100 W/kg) with an increased proliferation. Also for some species, the number of mutations and the frequency of mutations were increased. These results were confirmed by Hamnerius et al. (*1985) amongst others. Grospietsch et al. (1995) found similar results for 150 MHz fields with several amplitude modulations.

Cleary et al. (*1990 a,b) demonstrated on human lymphocytes and on Glioma cells that the rate of cell division was increased after exposure with a continuous 2.45 GHz field. In a newer experiment, the same effect could be observed for exposures with a pulse modulated field of the same carrier frequency (*Cleary et al. 1996).

In the first of the two experiments which were conducted with fields displaying all the characteristics of real pulsed mobile emissions (see also Table A.3), an increased DNA synthesis rate was observed, but no faster proliferation of the examined cells was found. (*Stagg et al. 1997). In the second experiment, at similarly low intensities (0.0021 W/kg) however, transmitted by a GSM modulated 960 MHz wave, an increase of the cell

proliferation rate was found (*Velizarov et al. 1999). The EMF exposure in this experiment was conducted at two different temperatures, which also applied to the relating control cultures. The increase of the proliferation rate only happened in the exposed cell cultures. Similar experiments to prove that microwaves and 'conventional' heat have different effects, were conducted by La Cara et al. (*1999) on a thermophile bacterium, in which the radiation with a 10.4 GHz field led to an irreversible inactivation of the thermostable enzyme ß-galactosidase, whilst heating in a water bath had no effect. This result confirmed the results of Saffer & Profenno (*1992) which had worked with frequencies in the lower GHz range.

5 Patho-Physiological Effects

5.1 Immune System

The immune system plays a central role in the protection against infectious micro-organisms in the environment and, also, against several kinds of cancer cells. Experiments on hamsters, mice and rats found, amongst other things, that there was a reduction in the activity of natural killer cells and an increase in macrophage activity (see e.g. Yang et al. 1983; Ramo Rao et al. 1983; Smialowicz et al. 1983). However, the majority of experiments on living animals were carried out at power flux density levels that produced an increase in body temperature of more than 1°C. On the other hand, it was observed in parallel *in vitro* experiments, that *in vitro* heating of macrophages did indeed lead to increased activity; the effect was, however, weaker than that of the *in vivo* radiation which produced the same temperature (Ramo Rao et al. 1983).

Elekes et al. (*1996) observed that, after exposing mice for a period of 3 hours per day over several days using microwaves (2.45 GHz) with a power flux density of 1W/m² (SAR = 0.14 W/kg), there was an increase in antibody-producing cells in the spleen of about 37% with continuous radiation and around 55% with amplitude-modulated radiation.

In contrast to the *in vivo* experiments, numerous *in vitro* experiments were carried out with intensities at which an effect due to warming can be excluded. Thus, Lyle et al. (*1983) observed an inhibition of cytotoxicity of T-Lymphocytes in the mouse with a 450 MHz field that was amplitude modulated with various frequencies in the range between 3Hz to 100 Hz. The effect that was demonstrated with a relatively low power flux density of 15 W/m² was greatest at the 60 Hz modulation. The inhibition of cytotoxic effectiveness of the irradiated lymphocytes declined continually for both the lower and higher modulation frequencies.

The tables in Appendix A list further experiments with (human) leucocytes in which damaging effects were proven at non-thermal power flux density levels, especially also with low frequency amplitude modulated fields.

The work of Maes et al.(*1995) deserves special consideration. In an *in vitro* experiment with human leucocytes at a GSM base station and also in the examination of the lymphocytes in the blood of workers who were exposed to the fields of the mobile phone base stations during maintenance work, they found that there was an increase in chromosome damage (chromatid breakage, acentric fragments and some chromosome breaks).

5.2 Central Nervous System

5.2.1 Blood Brain Barrier

The brain of mammals is protected from potentially dangerous materials in the blood by the blood brain barrier, a specialized neurovascular complex. The blood brain barrier

functions as a selective hydrophobic filter that can only be easily passed through by small fat-soluble molecules. Other non fat-soluble molecules, e.g. glucose, can pass through the filter with the help of carrier proteins that have a high affinity for specific molecules.

It is known that a large number of disorders of the central nervous system are caused by disturbances of the barrier function of the blood brain barrier (*Salford et al. 1994).

Severe warming of the brain can lead to an increased permeability of the blood-brain barrier for those materials whose passage should actually be prevented. The results of first experiments with high frequency fields of high intensity, which led to a higher permeability of the blood brain barrier, were then interpreted as a consequence of warming by the HF radiation.

However, Appendix Table B.1 lists a whole series of studies in which a greatly increased permeability of the blood brain barrier was produced through pulsed high frequency fields of very low intensity (*Oscar & Hawkins 1977, *Neubauer et al. 1990, *Salford et al.1994, *Fritze et al.1997) amongst others with carrier frequencies and modulation frequencies which corresponded to those of mobile telephony (GSM).

5.2.2 Neurotransmitters

Pulsed and continuous high frequency fields of low intensity may lead to chemical changes in the brain. Inaba et al. (*1992) exposed rats to a continuous 2.45 GHz field with a power flux density of between 50 to 100 W/m2 and found a significant reduction in the Noradrenalin content of the Hypothalamus, whilst the two other neurotransmitters Dihydroxyphenylacetic acid and 5-Hydroxyindolacetic acid were found in the pons and medulla oblongata in significantly increased concentrations. The radiation did not produce significant changes in the dopamine or serotonin concentrations.

Lai et al. (*1987, 1989 a, b, see above Lai et al. 1988) found also in experiments using rats that a 2.45 GHz field modulated with 500 Hz pulse-modulation influences brain activity, especially in the frontal cortex and the hippocampus, via the most important parasympathetic neurotransmitter acetylcholine. It could be demonstrated that the effect was related to the exposure duration. A 45 minute exposure duration led to significant reductions in choline-uptake, the reduction to 20 minutes exposure produced a significant increase. A similar behaviour was found in animals also as a reaction to stress through the reduction of the freedom of movement and through acoustic white noise.

5.2.3 Electroencephalogram (EEG)

In contrast to the neuroendocrine effects, which can barely be measured directly in the brain of humans, EEG studies can be carried out relatively easily. Several valid studies of that kind do now exist.

Most animal experiments have limited validity, since they were carried out with relatively high power flux density values (see e.g. Chizhenkova 1988: 2.397 MHz, cw, 400 W/m^2, Chizhenkova & Safroshkina 1996: 799 MHz, cw, 400 W/m^2, Thuroczy et al. 1994; 2.45 GHz, AM 16 Hz, 100 W/m^2).

One of the few exceptions are the studies by Vorobyov et al. (*1997), who observed an increase on the left-right symmetry in the EEG in rats that were exposed to a 945 MHz field (AM, 4Hz, 1 to 2 W/m^2, within the first 20 seconds after the start of the exposure.

Early experiments by von Klitzing (1995) with EEG recording during the exposure of subjects to pulsed high frequency fields, that were similar to those of mobile telephone fields (150 MHz, 217 Hz, power flux density in the pulse in the brain at a 6 cm depth below 10^{-2} W/m^2), found changes in the awake EEG, these were called into question because of insufficient documentation.

In later experiments however, a clear effect was demonstrated in the awake and sleeping EEGs.

Reiser et al. (*1995) observed, both with exposures to a 150 MHz field (modulated frequency 9.6 Hz, peak power 0.5 mW, 4 cm distance, near-field conditions) and also in the field of a mobile telephone (902 MHz, modulation frequency 217 Hz, peak power 8W, 40 cm distance), a significant increase in the energy in the EEG frequency bands - Alpha, Beta 1 and Beta 2.

Experiments by Röschke & Mann (*1997) resulted in no significant difference in the EEGs for exposed and sham-exposed subjects under short exposure conditions (3.5 minutes, 900 MHz, GSM, 0.5 W/m2). However, the peak of approx. 9Hz in the presented averaged power density spectra of exposed subjects was clearly lower and narrower than for non-exposed subjects. The same authors (*Mann & Röschke 1996) demonstrated again in the field of a GSM mobile telephone (8W, distance 40 cm power flux density 0.5 W/m^2), a reduction of the time taken to fall asleep and a statistically significant reduction of the duration and the proportion of the REM sleep. Furthermore, the spectral analysis revealed an increased power density of the EEG signal during REM sleep above all in the 'Alpha' frequency band. The REM suppressive effect and the reduction of the time taken to fall asleep were also confirmed by the same research team (*Mann et al.1997, *Wagner et al. 1998). The study carried out in 1997 also found a significant increase in the cortisol concentration in the blood of humans exposed to a 900 MHz/217 Hz field with a power flux density value of 0.2 W/m^2. Systematic deviations were also observed for the Growth Hormone and Melatonin levels, but these did not reach significance level.

Whilst in the previously cited studies, changes in the sleep EEG could be demonstrated only as a consequence of the influence of mobile telecommunications fields for several hours, Borbély et al. (1999) were able to demonstrate that changes in sleep were already occurring after 15 to 30 minutes exposure. This research team used also a 900 MHz field, which could be selectively pulse-modulated with either 2, 8, 217 or 1736 Hz. As in the other experiments, a statistically significant reduction in the proportion of REM sleep was found at a Specific Absorption Rate of less than 1W/kg. In addition, the waking-up phase was noticeably reduced.

Freude et al. (*1998, see also Henschel et al. 1999) examined the effect of the radiation from mobile telephones on slow brain potentials.

Slow brain potentials are event-correlated brain potentials that arise during the preparation for motor action and/or information processing. Changes in the slow brain

potentials give an indication about the influences on specific aspects of human information processing. Freude et al. found that the fields of a mobile telephone (916.2 MHz, 217 Hz, SAR 0.882-1.42 W/kg, exposure time 3 to 5 minutes) led to a statistically significant decrease of the slow readiness potentials for specific tasks, in specific brain areas.

5.2.4 Cognitive Functions

Impairments of the brain, e.g. by modification of the choline-uptake, can be expected to cause learning deficits. These were demonstrated in many learning experiments, in which rats were previously exposed to pulsed microwave fields (*Lai et al. 1989, 1994; *Wong & Lai 2000, see above D'Andrea 1999 for older studies). In the study by Lai et al. (*1994), rats were exposed for 45 minutes to a 500 Hz pulsed 2.45 GHz field with a power flux density of 10 W/m^2. This intensity resulted in a mean whole body SAR of 0.6 W/kg. Following the exposure, the starved rats were placed in a labyrinth with several arms in which food was placed. The researchers measured how effectively the 'exposed rats' and the 'sham-exposed rats' searched the labyrinth for food. For the 'exposed' group, significantly more failed attempts were observed, i.e. searching already emptied labyrinth arms. The authors attributed the low performance of the 'exposed' rats to deficits in spatial memory. The 'handicap' of the EMF exposure could be levelled out in a follow-up experiment, in which the rats were given either the acetylcholine agonist Physostigmin or the opiate antagonist Naltrexone before their exposure. According to the authors, these findings are confirmation of their results from previous studies (see above), in which they had found that high frequency electromagnetic fields influence cholinergic and endogenous opioid neurotransmitter systems in the brain and that this effect can lead to memory deficits. In the meantime, the effect has been confirmed by other experiments (Mickley & Cobb 1998).

In a further experiment (*Wang & Lai 2000), rats were trained over several sessions to find a platform situated just under the water surface inside a round water basin. Subsequently, they were exposed to pulsed microwave radiation for an hour (2.45 GHz, 500 pulses per second, mean power flux density 2W/m^2, mean whole-body SAR 1.2 W/kg). Testing was then carried out to determine how long the 'exposed rats' needed to find the platform from different starting positions, compared to the 'non-exposed rats' or 'sham-exposed rats'. The 'exposed rats' clearly required longer for this, as they spent significantly less time in the correct quadrant of the water basin. Finally, the recorded traces of the swimming lanes used by the 'exposed animals' differed from those of the control groups, this suggests that different strategies were used when searching for the platform. This result confirms the findings from other studies that pulsed high frequency fields can influence specific aspects of memory performance.

The effects of a 600 MHz field on the memory of rats were also demonstrated by Mickley et al. (*1994). In this experiment, the capacity of the animals to recognize familiar objects was measured in relation to the radiation they received. Whilst the 'non-exposed control animals and also the animals who were exposed to a SAR of 0.1 W/kg occupied themselves for longer with a novel object compared to a familiar object, the higher exposed animals spent just as much time examining an actually familiar object as with a

novel object. The limit for this exposure dependent change in behaviour was between 0.1 and 1.0 W/kg

The lowest SAR so far which has been shown to have an effect on cognitive functioning in rats was 0.072 W/kg. However, in this experiment, pulses with a peak of more than 700 MW (megawatts) were used (Raslear et al. 1993). The low SAR in this case resulted only from averaging over time with a very low pulse repetition rate of 0.125 pulses per second and a pulse width of only 80 nsec.

It has been shown in experiments by Preece et al. (*1999) that fields like those used in mobile telephony can influence cognitive functions of the brain. In this study, 36 subjects were subjected to a 915 MHz field of a simulated mobile telephone. The field was overlaid either with a 217 Hz sinusoidal modulation or a 217 Hz pulse modulation. In the analogue simulation the net forward power was about one Watt, and in the digital simulation it was 0.125 Watt. Under the conditions 'Exposure to analogue field', 'Exposure to digital field' or 'Sham exposure without any field', each of the test persons had to carry out several tests to measure ability to react and various tests of memory performance. In both exposed groups there was a slight but statistically significant decrease in reaction time, which was more marked for 'Analogue exposure' than for 'Digital exposure'.

5.3 Hormone Systems

5.3.1 Stress Hormones

Environmental pollution can act as a stressor on the body, like physical and mental stressors, and cause 'alarm reactions'. Such reactions are associated with hormonal changes. The presence of a stress-situation can be proved by the presence of hormones like adrenocorticotropin [the adrenocorticotrophic hormone] (ACTH), cortisol and corticosterone in the blood, and also to a lesser extent by changes in the concentration of prolactin and growth hormone.

Electromagnetic fields can clearly cause stress reactions in animals used for experiments. Thus, the experiment by Imaida et al. (*1998a) on rats that were exposed for a duration of 90 minutes daily over a period of 6 weeks to a field with a carrier frequency of 929.9MHz and a 50 Hz pulse modulation, showed a statistically significant increase in the ACTH and corticosterone levels. The whole-body SAR value in this experiment was between 0.58 and 0.8 W/kg. The exposure in the 1.439 GHz field, equally with a 50 Hz pulse modulation and a SAR value between 0.453 and 0.680 W/kg had the same effect (*Imaida et al. 1998b).

Chou et al.(*1992) exposed rats in a long-term experiment (25 months) to 800 MHz pulse-modulated 2.45 GHz field that led to a Specific Absorption Rate of 0.15 to 0.4 W/kg. Alongside other physiological parameters the corticosterone profile was regularly measured for the first half year of the experiment. Whilst the hormone profile of the exposed animals and the non-exposed animals were practically identical in the later stages of the experiment, with the exception of a slight increase in the sham-exposed group of animals in the third phase of the experiment, the first examination after 6 week's exposure showed a statistically significant increase in the corticosterone profile in the blood of the exposed animals.

The authors report that their attempt to replicate this effect produced no statistically significant results, however, only 20 animals were tested in this second experiment whilst the actual series of experiments contained 200 animals.

A similarly extensive experiment on rats like that of Chou et al. However, with an unmodulated 435 MHz field showed no difference in the concentration of the hormones ACTH, corticosterone and prolactin between the exposed animals and the non-exposed animals (Toler et al. 1988).

The few experiments previously carried out on humans do not yet produce a clear picture. Mann et al. (*1998) exposed 24 volunteer subjects whilst asleep to the field of a mobile telephone that was transmitted from a separate antenna (900 MHz, 217 Hz, 0.2 W/ m^2). Blood samples were withdrawn via a catheter whilst the subjects were asleep and they were analysed for, amongst other things, cortisol and growth hormone concentrations. There were systematic differences between the 'exposed subjects' and the 'sham-exposed subjects' during the course of the night for both hormones, which only reached statistical significance levels for cortisol.

De Seze et al. (*1998) examined the effect of a GSM mobile telephone (900MHz, 217 Hz) on subjects who were exposed to the field for 2 hours per day, 5 days per week for over a month. Based on nine blood sample withdrawals per week; amongst other things, the change in the concentrations of ACTH, growth hormone and prolactin were determined over time.

The authors' evaluation of their studies was that at one month, intermittent exposure in the radio-frequent field from the mobile telephone had no lasting or accumulative effects on the hormone secretions from the anterior lobe of the pituitary gland. In their data, it is however noticeable that that ACTH and prolactin follow a quite similar profile over time: the concentrations started at high initial values at the start of the exposure and then decreased in the following 3 weeks, and they then rose slightly again. The growth hormone concentrations are very high for the first measurements during the exposure period, they then fall to the pre-exposure concentration levels and maintain these levels until the end of the experiment. Possibly, these measurements show a temporary stress reaction, which reduced in the following weeks.

5.3.2 Melatonin

The hormone melatonin, which is produced in the pineal gland, functions as a regulating hormonal signal that synchronizes the endocrine rhythms of all the hormone glands. It regulates, amongst other things, the daily cycles of ACTH and the cortisol-release and thereby regulates the daily rhythms of many metabolic processes.

Melatonin also exerts influences (inhibitory) on sex hormones and it has a stimulatory effect on the immune system. Melatonin also influences specific cancer illnesses via the regulation of the release of the sex hormones. In addition, melatonin is a free radical scavenger, inactivating radicals such as OH, which amongst other things can be dangerous for the genetic material. Furthermore, during *in vivo* experiments, it was demonstrated that melatonin hinders changes in DNA produced by chemical carcinogens

and it protects lymphocytes from chromosome damage in high frequency electromagnetic fields (*Lai & Singh 1997).

In the previously described experiments carried out by Imaida et al.(*1998 a, b), it was found that the experimental animals that were exposed to a pulse-modulated high frequency field had a reduced melatonin concentrations in the blood. This finding could not be confirmed by Heikkinen et al. (1999), who exposed mice for 17 months to a 900 MHz field with a 217 Hz GSM pulse modulation (SAR: 0.35 to 1.5 W/kg). Studies by Vollrath et al. (1997) using rats and hamsters with a 900 MHz field (217 Hz GSM, SAR: 0.04 to 0.36 W/kg) could not contribute much to the clarification of the problem, since in several sub-sets of the experiment statistically significant differences between 'exposed animals' and 'non-exposed animals' had been found, but according to the authors these resulted from mistakes in the experimental order.

In experiments by Mann et al. (*1997 see above), the stress hormones were measured as well as the serum melatonin profile. This showed, in the case of the exposed humans, that for a period of between 3 to 4 hours in the middle of the night there was an increase compared to the control values, but these were not statistically significant according to the evaluation of the authors.

6 Pathological Effects

6.1 Results of Experimental Studies

6.1.1 Cancer

Carcinogenesis

Carcinogenesis is a multi-layered process, at the beginning of which is a certain impact on the level of the genetic material. This can be a direct impact (for example ionising radiation) or an indirect action via the product of a reaction (for example OH radicals). A direct or indirect interaction with DNA can lead to damage of the DNA or the chromatin structures (see also Chapter 3). If those damages are not repaired by endogenous processes, the damage will be permanent. Thus, the initiated cell can, if the immunological control fails, under the influence of hormones and promoters develop into a pre-neoplastic focus, which can then lead to a malignant tumor. The different steps of carcinogenesis are summarised in three phases:

- Initiation: Triggering of damage on the DNA and mutations on critical genes
- Promotion: Increased rate of DNA synthesis and proliferation of transformed cells
- Progression: Transition of a pre-neoplastic focus to a malignant tumor

A physical or chemical pollutant can in principle be effective in all three phases of carcinogenesis.

- Initiation: Triggering of direct DNA damage or of a substance which causes DNA damage, disruption of repair processes of the DNA
- Promotion: Promotion of the proliferation of transformed cells
- Progression: Suppression of immune-reactions and promotion of tumor growth

Results from Animal Experiments

In vivo experiments using animals with an inbred genetic predisposition for certain tumor illnesses or in which animals were injected with cancer cells, yielded very different results (see Appendix C, Table C.1). In the majority of the studies, no cancer promoting effect of high frequency electromagnetic fields could be found, or effects were only observed under certain conditions of exposure (marked in the Table with 'partly'), and even in those cases they were often not statistically significant. However, it needs to be noted that many studies with negative results had very short exposure times and durations of the study itself (for example Chagnaud et al. 1999: 2 weeks, Salford et al. 1993: 2 to 3 weeks) and hence they do not have much relevance to answer the question whether high frequency electromagnetic fields have carcinogenic potential.

Some long-term studies have yielded results which indicate a carcinogenic or co-carcinogenic effect of electromagnetic fields with mobile telecommunications frequencies

if the animals are exposed over a long period of time. (*Repacholi et al. 1997, *Szmigielski et al. 1982 and *Szudinski et al. 1983). Important in this context is also the study of Chou et al. (*1992). This study did not find a statistically significant rise in tumors in a particular organ. However, the exposed group developed not only a higher number of tumors in total, but also the number of primary malignant and metastatic malignant neoplasms was significantly higher in the exposed animals. In their discussion of the results, the authors point to the fact that the number of the primary malignant neoplasms in the exposed group compared to the control group is four times higher and that this finding is statistically significant, but then go on to undermine their finding by quoting literature, according to which the tumor incidence of the exposed group should still be within the normal range.

The experiment of Toler et al. (*1997) using animals with a predisposition for chest tumors did not result in a higher incidence of these, but the number of ovarian tumors was significantly higher in the exposed group compared to the controls.

The intensities at which an increase in tumors was found in animals were one to two powers of ten below the values at which one would expect a triggering of 'thermal' effects. According to the presenting results, low frequency modulation does not seem to be responsible for the carcinogenic effect.

6.1.2 Infertility and Teratogenic Effects

Teratogenesis

Teratogenic effects of a pollutant can – as with the carcinogenic effect – either be caused by the triggering of a genetic defect or a harmful impact on the foetal development. The formation of a genetic malformation during its initiation phase is analogous to carcinogenesis, i.e. teratogenic effects are also caused by direct or indirect impact on the DNA and disruptions of the endogenous repair mechanisms. Later damages of the foetus can either be caused by direct effects of the pollutant on the foetus or by reactions to the pollutant within the mother's organism, which would then be passed on to the foetus.

Results from Animal Experiments

A multitude of studies have demonstrated that high body temperatures in mammals lead to a spermatotoxic and teratogenic effect. Since many studies examining such effects from high frequency electromagnetic fields worked with intensities that were capable of significantly raising body temperature, it cannot be excluded that the observed spermatotoxic and teratogenic effects were caused by a thermal effect, (see for example Berman et al. 1982, 1983, Berman & Carter 1984, Jensh et al. 1983a,b, Kowalczuk et al. 1983, Lary et al. 1983, Nawrat et al. 1985, Saunders et al. 1981, 1983, for the results of older studies, see O'Connor 1980). The results of these studies do not always appear consistent, however, this can possibly be explained by a different thermal susceptibility of the different animal species used. In rats for example, a loss of thermally damaged embryos is often observed, whilst the birth of malformed animals is rare. Other mammals show a wider bandwidth between teratogenic and lethal exposures. (Verschaeve & Maes 1998).

However, there are some indications in the literature for teratogenic effects at intensities that cause no (or, if at all very small) rises in temperature. Magras & Xenos (1997) exposed mice during six months to a real transmitter. The mice had offspring five times during this period and a continuous decrease in offspring was found down to irreversible infertility. The exposure consisted of several radio and TV transmitters in the VHF and UHF bands and measured between 0.00168 and 0.01053 W/m^2. A repetition of this study would be desirable in order to exclude that the effect was due to problems with the maintenance of the animals or the screening of the control group.

Khillare and Behari (*1998) found that male rats that had been exposed to a 200 MHz field (power flux density:14.7W/m^2, SAR:1.65 to 2.0W/kg) during a period of 35 days for six days per week and two hours per exposure day and which were afterwards mated with unexposed females, produced significantly less offspring that the males in the unexposed control group.

In an experiment by Akdag et al. (1999) male rats were exposed one hour every day to a 9.45 GHz field (power flux density:2.5W/m^2, SAR:1.8 W/kg) during different periods of 13, 26, 39 or 52 days corresponding to one, two, three and four cycles of the seminal epithelium.

At the end of each exposure period the following data were measured and compared to an unexposed control group: number of sperm in the epididymides, morphology of the sperm and weight of the testicles, epididymides, seminal vesicles and prostate.

They found amongst other effects a decrease in the number of sperm (statistically significant in the group exposed for 53 days) and an increase of abnormal sperm (statistically significant in the groups exposed for 26, 39 and 52 days).

A co-teratogenic effect under non-thermal exposures with power flux densities of 10 to 100 W/m^2 in combination with cytosine arabinoside (CA) was found in a study by Marcickiewicz et al. (*1986). In the experiment, mice were exposed in utero for two hours a day to 2.45 GHz from the first to the 18th day of the pregnancy. The field, which alone was not teratogenic, significantly increased the teratogenic effect of CA. A direct teratogenic effect of microwave radiation with a frequency of 2.45 GHz on the brains of newborn rats was found by Inalösz et al. (*1997). However the authors declared that the SAR of 2.3W/kg led to a rise of rectal temperature of 1.0ºC.

6.2 Results of Epidemiological Studies

Methodological Requirements

In principle, epidemiological studies are an effective instrument to prove potential health risks of a pollutant under real environmental and exposure conditions. Usually, they are carried out by comparing statistical data about the incidence of an illness in an exposed population as opposed to the incidence of this illness in an unexposed population. The exact classification of exposure would require the metrological recording of the pollutant for all participants (exposed and unexposed) during the entire latency period of the illness. This is often not practicable and for long latency periods, which can usually only be addressed via retrospective studies, inherently impossible. Under such circumstances it

has to suffice that surrogates are used, for example having a profession which is linked to a certain exposure or the proximity of the home to an emitting installation. In some cases, if the emitting installations have been used for a long time in the same mode, it is possible to extrapolate past exposures from current measurements.

The quality of the exposure classification determines the validity of an epidemiological study. Possible weaknesses, which can lead to wrong results, are:

- People are classified as 'exposed' or 'strongly exposed' although in fact there is no or only little exposure. An example with regards to high frequency fields is the often-used exposure classification on the basis of professional categories, such as radar operators or telecommunications engineers, for whom it cannot be excluded that the main occupation is a desk job without exposure.

- It is assumed that the control group is completely unexposed, although the pollutant is actually ubiquitous, which will lead to smaller but still potentially significant exposures in the control group. One known example are mains frequency magnetic fields, which affect the immediate neighbours of power supply equipment, but still exist at non-negligible strengths in houses which are further away from such equipment.

Both effects lead to a levelling out between the exposed and unexposed group and hence to an underestimation of the real health risk posed by the pollutant in question.

Another weakness of epidemiological studies can be the presence of unrecognized confounders, i.e. other influences, which also affect the groups studied and influence the development of the illness. This can be environmental factors, such as exposures to other pollutants, but also socio-economic and behavioural factors. If not all potentially relevant confounders are factored in, the results can be distorted, either towards an overestimation or an underestimation of the real risk.

The fast development of mobile technology has lead to a double dilemma with regards to the study of potential risks through epidemiological studies:

- For illnesses like cancer with latency periods of many years it is still too early to expect valid results. If mobile telecommunications are indeed linked to a higher incidence of cancer, the illness will only have manifested in a few people so far. This should at least be valid for the part of the population whose exposures are from base stations only. Potentially it could be different for direct mobile phone users, since these are generally exposed to significantly higher intensities. But also for this group, at this moment in time, we would expect results from epidemiological studies to underestimate the real risk.

- In some years epidemiological studies will hit a different obstacle: once base stations cover the entire country and a large proportion of the population use a mobile phone, it will become difficult to find the necessary unexposed control groups.

Given this dilemma, epidemiological studies carried out in the past have a certain validity, even if the exposures are not exactly the same as they would be today and the studies do not always correspond to today's quality standards.

The Selection of Studies

At the time of finishing this present report there were only two epidemiological studies of health risks in relation to actual existing mobile telecommunications exposures (*Rothman at al. 1996, *Hardell et al. 1999). However there are a much larger number of studies available, in which the health effects of high frequency electromagnetic fields in humans were examined (see also Appendix D, Table D.1). Just under a quarter of all results relate to exposures with low frequency pulse or amplitude modulated high frequency fields, such as they are used for mobile telecommunications, even if the carrier and modulation frequencies are in most cases not identical with those of mobile telecommunications.

In Appendix Table D.1, the examined illnesses are listed with their evaluated end point (incidence or mortality), data describing the exposure situation is given and the quality of the exposure classification is assessed. Finally, the result of the study is evaluated as 'Relative Risk' (RR) which includes the relevant risk factors in the form of standardised mortality rates, standardised morbidity rates and odds ratios, and the statistical significance is assessed. For each study we list the value for the highest exposure class or if there was a further differentiation of the examined groups, for example according to occupational groups, the highest found value.

Values are considered statistically significant (s.s.) if the value RR=1 outside of the 95% confidence interval or if $p<0.05$.

A statistical evaluation of the results presented in Table D.1 can be found in Table 6.1. Here, we list for every illness how many studies or separate results are available, how many of these show a relative risk RR >1 and how many are statistically significant.

Almost all the studies, in which the total cancer risk without any differentiation according to tumor form were examined, showed a risk factor of RR>1. Half of the studies resulted in statistically significant risk factors with a maximum value of 2.1, which corresponds to a doubling of the statistical risk to develop cancer from exposure to high frequency electromagnetic fields.

A similar picture was found in relation to tumors of the nervous system, especially brain tumors. Here, the maximum value for relative risk found was 3.4. Eleven of the total of 15 studies yielded a positive result, more than half of which were statistically significant.

The incidence of breast cancer in relation to high frequency fields must be examined separately for men and women. All three studies relating to the breast cancer incidence in women yielded risk factors greater than 1, the statistically significant values were 1.15 and 1.5. For men, risk factors of up to 2.9 were found; however, not all were statistically significant.

Of the total of 16 results for leukaemia without further differentiation of the illness, 13 were positive (RR>1), more than half of these results were statistically significant. The highest statistically significant value for the relative risk was 2.85. Amongst the results of the differentiated studies, the following are notable: lymphatic leukaemia (7 results, 5 positive, 4 statistically significant, RR maximum value: 2.74) and acute myeloic leukaemia (4 different studies, 3 positive results, 2 statistically significant, maximum RR value: 2.89).

With regards to the correlation of high frequency electromagnetic fields from radar and other sources and testicular cancer, three studies have been conducted. All lead to statistically significant risk factors with a maximum value of 6.9.

The studies regarding cardio-vascular diseases did not result in a clear picture, not least because of the multitude of the symptoms examined.

All four studies of fertility problems in relation to the exposure of men to microwaves indicate increased risk. In two studies statistically significant risk factors of up to 2.7 were found.

With regards to irregular courses of pregnancies and malformations in children of mothers which had been exposed to high frequency fields, there are a large number of studies with positive results, of which only two fit into the frequency range relevant to our report. Both of these studies found statistically significant positive results with risk factors of up to 2.36.

Of the studies of cancer risk of children whose fathers had been exposed to electro-magnetic fields, only two correspond to the quality criteria required for inclusion into this report. Both indicate an increased risk, but only one result is statistically significant at a value of RR=2.3. (With regards to the cancer risk of children in correlation to the exposure of their parents, see also Colt & Blair 1998).

Regarding the disruption of motor functions as well as psychological functions and well-being, there is only one valid study for the frequency bands relevant to this report, which yielded a slightly increased risk factor. However since other studies of transmitters with frequencies below 100 MHz resulted in serious indications of increased risk, indicating that this problem should be given more attention in the future, we also included the study of Zhao et al. (1994), although it didn't meet our quality standards with regards to the statistical evaluation.

Unfortunately, the majority of the studies do not state the actual strength of the exposures. Measurements are only available for the radio and television transmitter used for the studies of Hocking et al. (1996) and McKenzie et al. (1998). The mean power flux densities for all 16 municipalities affected by this transmitter were $3.3\ 10^{-3} W/m^2$ within the range from $2.6\ 10^{-4}$ to $1.46\ 10^{-2} W/m^2$ (McKenzie et al. 1998). The ICNIRP guidelines for the general population recommend a maximum value of 2 to 2.51 W/m^2 for the range of frequencies emitted by this transmitter (64.25 to 527.25MHz). This means that the exposures in these studies were below the German guidelines by a factor of 10^{-4}.

Table 6.1
Overview over the results of epidemiological studies with regards to the health risks of high frequency electromagnetic exposures (see also Appendix D, Table D.1)

Illness	Number of studies (results)	Studies (results) with RR>1	Statistically significant results
All illnesses	2	0	0
Cancer, unspecified	6 (7)	5 (6)	3
Brain tumours unspecified and tumours of the nervous system unspecified	14 (21)	10 (15)	6 (7)
Cancer (eyes)	1	1	1
Cancer of the respiratory organs, lung cancer	5	2	1
Chest cancer, men	2	2	0
Breast Cancer, women	3	3	2
Cancer of the lymphatic and blood forming system unspecified	4	4	1
Leukaemia unspecified	12 (16)	9 (13)	5 (7)
Acute leukaemia unspecified	4	4	0
Lymphatic leukaemia unspecified	4 (7)	2 (5)	1 (4)
Acute lymphatic leukaemia	2	2	0
Chronic lymphatic leukaemia	4	4	1
Leukaemia, non lymph. non-myelo	1 (4)	1 (4)	1 (2)
Lymphoma, Hodgkin-Syndrome	5 (7)	3 (4)	1
Testicular cancer	3 (5)	3 (5)	3 (4)
Uterine cancer	1	1	1
Skin cancer	4	3	1
Cardio-vascular diseases	4 (5)	3 (4)	1
Infertility, reduced fertility, men	4 (7)	4 (7)	2 (4)
Infertility, reduced fertility, women	1	1	0
Miscarriages, stillbirths, malformations and other birth defects	2 (3)	2 (3)	2
Cancer, offspring (parental exposure)	2	2	1
Neurodegenerative diseases, Alzheimer's	1	1	0
Disruptions of motor and psychological functions and well-being	2 (9)	2 (9)	1 (7)

7 Health Risks to Humans Resulting from Exposure to the Electromagnetic Fields of Mobile Telecommunications

The triggering of an illness caused by an (environmental) pollutant and the development of this illness are a multi-phased process, which begins with a biological, biochemical or biophysical primary interaction of the pollutant with the biological system and ends with the manifestation of the illness. During the different phases of the process, the body's own repair mechanisms can intervene and impede the further development of the illness. An assessment of the potential health risks of electromagnetic fields as they are used for mobile telecommunications should therefore be mainly based on studies conducted directly on humans, because extrapolations from animal studies or even *in vitro* studies on cell cultures only have limited validity for effects in humans, due to the difference in susceptibilities and the lack of organic interactions in cell cultures. However, due to the ethical limits to the research on humans, it is unavoidable to use results from experiments with animals, single organs or cells in order to discover the biological and physiological mechanisms.

Cancer

Given the results of the present epidemiological studies, it can be concluded that electromagnetic fields with frequencies in the mobile telecommunications range do play a role in the development of cancer. This is particularly notable for tumours of the central nervous system, for which there is only the one epidemiological study so far, examining the actual use of mobile phones. The most striking result of this study was an obvious correlation between the side at which the phone was used and the side at which the tumour occurred. The brain tumour incidence however was only slightly increased. A (hypothetical) explanation of such a finding could for example be that mobile fields have a promoting effect on previously initiated (multiple) tumours, triggering a defence mechanism in the body which is capable of suppressing unpromoted tumours.

Higher risks were also demonstrated for several forms of leukaemia.

Although the studies in relation to testicular cancer were examining particular exposure conditions (emitting equipment worn partly on the body at hip level), given the high risk factor found, a possible risk cannot be excluded, especially not for mobile users wearing the devices in standby mode on their belts. The epidemiological findings for testicular cancer also need to be interpreted in conjunction with the results of the studies of fertility problems occurring in relation to high frequency electromagnetic fields.

The risk factors for cancers other than testicular cancer are only moderately increased, but not negligible, considering this technology will potentially reach full coverage of the entire population.

Reliable conclusions about a possible dose-response-relationship cannot be made on the basis of the present results of epidemiological studies, but an increase of cancer risk cannot be excluded even at power flux densities as low as 0.1 W/m².

In long-term animal experiments, the carcinogenic effect of pulse modulated high frequency fields was demonstrated for power flux densities of circa 3W/m² (mouse, exposure duration 18 months, 30 minutes per day, SAR (mouse) circa 0.01 W/kg).

On the cellular level, a multitude of studies found the type of damage from high frequency electromagnetic fields which is important for cancer initiation and cancer promotion:

Direct damage on DNA as well as influences on DNA synthesis and DNA repair mechanisms were demonstrated in *in vivo* and *in vitro* experiments for continuous and pulsed fields at power flux densities from 10W/m² and 9W/m² respectively.

Chromosome aberrations and micronuclei occurred at power flux densities from 5 W/m².

Neoplastic cell transformation and an enhanced cell proliferation were demonstrated for Specific Absorption Rates of below 0.5W/kg, and individual studies demonstrated that the obvious disturbance of the communication between cells, which is a prerequisite for the uninhibited proliferation of cells that is characteristic for cancer development, occurs at just a few W/m².

Conclusion:

The results of the studies for all stages of cancer development from the damage of the genetic material via the uninhibited proliferation of cells and debilitation of the immune system (see below) up to the manifestation of the illness prove effects at power flux densities of less than 1 W/m². For some stages of cancer development, intensities of 0.1 W/m² or even less may suffice to trigger effects.

Debilitation of the Immune System

Damaging effects on the immune system which can aid the development of illnesses were demonstrated in animal experiments at power flux densities of 1 W/m² (mouse, exposure duration 6 days, 3 hours per day, SAR (mouse) 0.14W/kg). In *in vitro* experiments on lymphocytes, defects of the genetic material were demonstrated at power flux densities of circa 10 W/m². The presence of stress hormones, which when permanent can debilitate the immune system, was found to be increased in human experiments from power flux densities of 0.2W/m². In animal experiments (rat) a similar effect was observed at a Specific Absorption Rate of circa 0.2 W/kg.

Conclusion:

Experiments on animals prove harmful effects on the immune system from circa 1 W/m²; at power flux densities of 0.2 W/m² higher secretions of stress hormones in humans have been demonstrated.

Influences on the Central Nervous System and Cognitive Function

The effects of pulsed and continuous high frequency fields on the blood-brain-barrier and the activity of neurotransmitters were demonstrated in animal experiments for power flux densities of 3 and 10 W/m^2 respectively.

In humans, influences on the slow brain potentials were found at SAR values of 0.882 to 1.42W/kg, i.e. well below the current guidelines for partial body exposure of 2 W/kg.

Changes in the sleep EEG of humans, which showed a shortening of the REM sleep phase occurred at intensities as low as 0.5 W/m^2.

In animal experiments, changes in the EEG were demonstrated at power flux densities of 1 to 2W/m^2.

Impairment of cognitive functions was found in animal experiments at power flux densities of 2W/m^2. In humans, there are indications that brain functions are influenced by fields such as they occur when using a mobile telephone.

An epidemiological study of children who had been exposed to pulsed high frequency fields, found a decrease in the capability to concentrate and an increase in reaction times.

Conclusion:

Effects of high frequency electromagnetic fields on the central nervous system are proven for intensities well below the current guidelines. Measurable physiological changes have been demonstrated for intensities from 0.5 W/m^2. Impairments of cognitive functions are proven for animals from 2W/m^2.

Electrosensitivity or Electromagnetic Hypersensitivity

The terms 'electrosensitivity' or 'electromagnetic hypersensitivity' describe disturbances of well-being and impairments of health, such as they are suffered by certain sensitive people when working with or being in the presence of devices and equipment emitting electrical, magnetic or electromagnetic fields. The sensitivity manifests in a variety of symptoms including:

- nervous symptoms such as sleep disturbances, headaches, exhaustion, lack of concentration, irritability, anxiety, stress
- cardio-vascular complaints
- disruptions of hormones and metabolism
- skin complaints

The composition and strength of the complaints varies enormously in different individuals. The correlation of the complaints with electromagnetic exposures and other environmental influences seems to vary strongly not only between affected persons but also in time, a fact that has so far impeded the conclusive scientific proof of a cause-effect-relationship in provocation studies. The present results of scientific studies are often not conclusive and partly contradictory. On the other hand, however, there is a wealth of data

collected by the self-help organisations of affected people, which has not yet been explored.

Conclusion:

On the basis of current knowledge it is impossible to estimate the risk of electrosensitive reactions or to make recommendations for guidelines designed to avoid such a risk for the general population, which is composed of sensitive and non-sensitive persons.

8 Recommendations

8.1 Precautionary Health Protection in Relation to Exposures to Electromagnetic Fields of Mobile Telecommunications

With mobile telecommunications we have to differentiate to exposure situations:

- exposure of residents near base stations
- exposure of mobile users when using the devices

To limit exposure to an acceptable degree, if this is possible at all, there need to be different strategies for the two different exposure groups.

Exposures from Base Stations

In humans, harmful organic effects of high frequency electromagnetic fields as used by mobile telecommunications have been demonstrated for power flux densities from 0.2W/m² (see Chapter 7). Already at values of 0.1 W/m² such effects cannot be excluded. If a security factor of 10 is applied to this value, as it is applied by ICNIRP and appears appropriate given the current knowledge, the precautionary limit should be 0.01W/m². This should be rigorously adhered to by all base stations near sensitive places such as residential areas, schools, nurseries, playgrounds, hospitals and all other places at which humans are present for longer than 4 hours.

We recommend the precautionary limit of 0.01 W/m² independent of the carrier frequency. The rough dependency on frequency with higher limits outside of the resonance range, as it is applied in the concept of SAR, is not justifiable given the results of the scientific studies which conclusively prove non-thermal effects of high frequency fields. Also, the current allowed higher exposures for parts of the body, as long as they refer to the head or thorax are not justifiable.

Exposures of Mobile Phone Users

Given the state of technology now and in the foreseeable future, it is currently technically impossible to apply the recommended maximum value for mobile base stations also to the use of mobile phones. However, a lowering of the guidelines to a maximum of 0.5 W/m² should urgently be considered.

A particular problem in this exposure group is posed by children and adolescents, not only because their organism is still developing and therefore particularly susceptible, but also because many adolescents have come to be the most regular users of mobile phones.

Advertising towards this population group should be banned. Furthermore, particular efforts should be made to lower the exposures during calls. It would be recommendable to conduct (covert) advertising campaigns propagating the use of headsets. It would also be important to develop communications and advertising aiming at minimising the exposures created by carrying mobile phones in standby mode on the body.

8.2 Scientific Studies Regarding the Health Risk of Mobile Telecommunications

The precautionary limits recommended in Chapter 8.1 are based on the current scientific knowledge. This is, however, still incomplete and in the case of this technology, which is exposing the entire population to its emissions, further research efforts are needed to create a base for the setting of truly reliable guidelines. Based on the scientific knowledge presented in this report, the further research requirements are mainly for studies on living organisms (humans or animals):

Epidemiological studies

- studies that metrologically record the exposure on existing radio transmitters (USW), TV transmitters and longer-established radio communications and paging networks. (The emissions of this type of equipment with regards to the modulation frequencies may not be directly comparable to those of mobile telecommunications, but such studies could nevertheless offer important indications for the assessment of the exposure risks of high frequency electromagnetic fields; the studies should focus on cancer and illnesses of the central nervous system including neurodegenerative diseases as well as cardio-vascular diseases and any diseases caused by a disruption of the immune system; such studies should also address potential clusters of unspecified symptoms and impairments of well-being (electrosensitivity)).
- a meta-study with retrospective dosimetry for the studies which examined the residents near emitting base stations (see Appendix D) with the help of measured data from comparable sites
- a cohort study examining the health (see above) of mobile users and residents near mobile base stations
- epidemiological animal studies on pets

Experimental long-term studies

Studies of the chronic effects of the fields emitted by mobile telecommunications

- on the central nervous system (preferably on humans)
- on the immune and endocrine system (preferably on humans, but further animal experiments at low intensities would also be helpful for example with regards to EMF-induced stress)
- on the cardio-vascular system (variability of heartbeat rates, blood pressure, etc., on humans and on animals)

Experimental short-term studies

Studies of the acute effects of the fields emitted by mobile telecommunications

- on the brain in various rest and stress situations (preferably making use of EEG and similar methods)

Beyond these suggestions, it would be important to develop a strategy for the research of the 'electrosensitivity' phenomenon and its incidence, which would acknowledge the failure of traditional scientific methods to address the problem and allow the inclusion of the data available from the self-help groups and associations of the affected.

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Appendix A

Studies of the effects of high frequency electromagnetic fields on the cellular level

Abbreviations

neg.	negative finding
n.s.	not statistically significant
pos.	positive finding
s.s.	statistically significant
partly	some findings
#	disagreement with the conclusions of the authors
?	unknown; not provided; unreliable

Table A.1 Genotoxic effects of high frequency electromagnetic fields

Frequency	Modulation	Power Flux Density / SAR	Exposure duration	Studies subject / Method	Result	Ref.
Direct DNA damage						
2,45 GHz	cw	10 – 20 W/m^2 0,6 – 1,2 W/kg	2 h	Rat, in vivo	pos., s.s.	Lai & Singh 1995
2,45 GHz	PM, 500 Hz	10 – 20 W/m^2 0,6 – 1,2 W/kg	2 h	Rat, in vivo	pos., s.s.	Lai & Singh 1995
2,45 GHz	PM, cw	20 W/m^2 1,2 W/kg	2 h	Rat, in vivo	pos., s.s.	Lai & Singh 1996
2,45 GHz	PM, 500 Hz	20 W/m^2 1,2 W/kg	2 h	Rat, in vivo	pos., s.s.	Lai & Singh 1996
2,45 GHz	PM, 500 Hz	20 W/m^2 1,2 W/kg	2 h	Rat, in vivo	pos., s.s.	Lai & Singh 1997
2,45 GHz	cw	0,7 – 1,9 W/kg	2 h – 24 h	Glioblastoma Cells (Human), in vitro	neg.?	Malyapa et al. 1997a
2,45 GHz	cw	0,7 – 1,9 W/kg	2 h – 24 h	Fibroblasts (Mouse), in vitro	neg.?	Malyapa et al. 1997a
836 – 848 MHz	cw, FM, PM	0,6 W/kg	2 h – 24 h	Glioblastoma Cells (Human), in vitro	neg.?	Malyapa et al. 1997b
836 – 848 MHz		0,6 W/kg	2 h – 24 h	Fibroblasts (Mouse), in vitro	neg.?	Malyapa et al. 1997b
2,45 GHz	cw	1,2 W/kg	2 h	Rat (Brain), in vivo	?	Malyapa et al. 1998
814 – 837 MHz	PM, TDMA, 50 Hz	8 – 90 W/m^2 2,4 – 26 W/kg	1 h – 10,67 h	T-Lymphoblasten	pos., s.s.	Phillips et al. 1998
2,45 GHz	cw	10 W/m^2 1,18 W/kg	120 d, 2 h/d – 200 d, 2 h/d	Mouse (Brain, Testicles), in vivo	pos., s.s.	Sarkar et al. 1994
1,7 GHz	cw	500 W/m^2	30 min	Mouse (Testicles), in vivo	pos.	Varma & Traboulay 1977

Frequency	Modulation	Power Flux Density / SAR	Exposure duration	Studies subject / Method	Result	Ref.
Influences on DNA synthesis and repair						
350 MHz	cw	10 – 100 W/m^2 0,039 – 4,5 W/kg	1 h – 3 h	Fibroblasts (Human), in vitro	unclear, partly pos.	Meltz et al. 1987
350 MHz	PM, 5,0 Hz	10 – 100 W/m^2 0,039 – 4,5 W/kg	1 h – 3 h	Fibroblasts (Human), in vitro	unclear, partly pos.	Meltz et al. 1987
850 MHz	cw	10 – 100 W/m^2	1 h – 3 h	Fibroblasts (Human), in vitro	unclear, partly pos.	Meltz et al. 1987
850 MHz	PM, 5,0 Hz	10 – 100 W/m^2	1 h – 3 h	Fibroblasts (Human), in vitro	unclear, partly pos.	Meltz et al. 1987
1,2 GHz	cw	10 – 100 W/m^2	1 h – 3 h	Fibroblasts (Human), in vitro	unclear, partly pos.	Meltz et al. 1987
1,2 GHz	PM, 80 kHz	10 – 100 W/m^2	1 h – 3 h	Fibroblasts (Human), in vitro	unclear, partly pos.	Meltz et al. 1987
836,55 MHz	PM, TDMA, 50 Hz	0,9 – 90 W/m^2 0,00015 - 0,059 W/kg	4 h – 14 d	Glioma-Cells (Rat), in vitro	pos., s.s.	Stagg et al. 1997
Chromosome aberrations						
2,45 GHz	cw	?	?	Mouse (bone marrow), in vivo	pos.	Banerjee et al. 1983
2,45 GHz	cw	400 W/m^2	6 d, 30 min/d	Rat, in vivo	pos.	Beechey et al. 1986
7,7 GHz	cw	300 W/m^2	15 - 60 min	Fibroblasts (Chin. Hamster), in vitro	pos., s.s.	Garaj-Vrohac et al. 1990
7,7 GHz	cw	5 W/m^2	15 - 60 min	Fibroblasts (Chin. Hamster), in vitro	pos., s.s.	Garaj-Vrohac et al. 1991
7,7 GHz	cw	5 – 300 W/m^2	10 min	Lymphocytes (Human), in vitro	pos., s.s.	Garaj-Vrohac et al. 1992
0,4 MHz – 20 GHz	cw, AM, PM			Human, in vivo	pos.#, n.s.	Garson et al. 1991
2,45 GHz	PM, 25 kHz	490 W/m^2 33,8 W/kg	2 h	Egg Cells (Chinese Hamster)	pos., partly s.s.	Kerbacher et al. 1990

Frequency	Modulation	Power Flux Density / SAR	Exposure duration	Studies subject / Method	Result	Ref.
2,45 GHz	cw	104 – 193 W/kg	20 min	Lymphocytes (Human), in vitro	neg.	Lloyd et al. 1984
2,45 GHz	cw	4 – 200 W/kg	20 min	Lymphocytes (Human)	neg.	Lloyd et al. 1986
2,45 GHz	cw	75 W/kg	30 – 120 min	Lymphocytes (Human), in vitro	pos.	Maes et al. 1993
954 MH	PM, 217 Hz, GSM	Occupational exposure		Lymphocytes, Human, in vivo	pos., s.s.	Maes et al. 1995
954 MHz	217 Hz, GSM	15 W/m^2 1,5 W/kg	2 h	Lymphocytes (Human), in vitro	pos., s.s.	Maes et al. 1995
935,2 MHz	PM/GSM, 217 Hz	0,3 – 0,4 W/kg	2 h	Lymphocytes (Human), in vitro	pos., n.s.	Maes et al. 1997
9,4 GHz	PM, 1000 Hz	1 – 100 W/m^2	2 w, 3 d/w, 1 h/d	Mouse, in vivo	pos., s.s.	Manikowska et al. 1979
2,45 GHz	cw	0,05 – 20 W/kg	2 w, 6 d/w, 30 min/d	Mouse, in vivo	pos., s.s.	Manikowska-Czerska et al. 1985
2,55 GHz	cw	2W/kg	20 min	DNA (E.coli), in vitro	pos.	Sagripanti & Swicord 1986
2,0 – 8,75 GHz	cw	10 W/kg	5 min – 25 min	DNA, in vitro	pos., s.s.	Sagripanti et al. 1987
2,45 GHz	cw	100 W/m^2	120 d 6 h/d	Spermatogonia (Mouse), in vivo	neg.	Saunders et al. 1988
2,45 GHz	cw	50 W/m^2 12,46 W/kg	90 min	Lymphocytes (Human), in vitro	pos., n.s.	Vijayalaxmi et al. 1997
2,45 GHz	cw	750 W/m^2	5 – 30 min	Chinese Hamster (Corneal Epithelium), in vivo	pos, s.s.	Yao 1978
2,45 GHz	cw	15,2 W/kg		RH5- and RH16-Cells (Kangaroo-Rat), in vitro	pos., s.s.	Yao 1982

Frequency	Modulation	Power Flux Density / SAR	Exposure duration	Studies subject / Method	Result	Ref.
Micronuclei						
154 – 162 MHz	PM, 24,4 Hz	Changing exposures on the pastures		Cow (Erythrocytes) in vivo	pos., s.s.	Balode 1996
2,45 GHz	CW	530 W/m^2 90 W/kg	10 min	Lymphocytes (Human), in vitro	pos., partly s.s.	d'Ambrosio et al. 1995
2,45	AM, 50 Hz, sin	530 W/m^2 90 W/kg	10 min	Lymphocytes (Human), in vitro	pos., partly s.s.	d'Ambrosio et al. 1995
1,25 – 1,35 GHz	?PM	0,1 – 200 W/m^2	Occupational exposure	Lymphocytes (Human), in vivo	pos.	Fucic et al. 1992
7,7 GHz	cw	5 W/m^2	15 - 60 min	Fibroblasts (Chin. Hamster), in vitro	pos., s.s.	Garaj-Vrohac et al. 1991
7,7 GHz	cw	5 – 300 W/m^2	10 min	Lymphocytes (Human), in vitro	pos., s.s.	Garaj-Vrohac et al. 1992
2,45 GHz	cw	75 W/kg	30 – 120 min	Lymphocytes (Human), in vitro	pos.	Maes et al. 1993
9,0 GHz	cw	70 W/kg	10 min	Lymphocytes (bovine), in vitro	pos., s.s.	Scarfi et al. 1996
2,45	cw	50 W/m^2 12,46 W/kg	90 min	Lymphocytes (Human), in vitro	pos.#, n.s.	Vijayalaxmi et al. 1997 b
2,45	cw	1,0 W/kg	18 mon	Erythroczyten (Mouse blood / bone marrow)	pos, s.s.	Vijayalaxmi et al. 1997 a
Sister chromatid exchange						
380 MHz	PM, 17,65 Hz	80 W/kg	?	Lymphocytes (Human), in vitro	neg.	Antonopoulos et al. 1997
900 MHz	PM/DCS, 217 Hz	208 W/kg	?	Lymphocytes (Human), in vitro	neg.	Antonopoulos et al. 1997
1,8 GHz	PM/GSM, 217 Hz	1700 W/kg	?	Lymphocytes (Human), in vitro	neg.	Antonopoulos et al. 1997
2,45 GHz	cw	?	?	Mouse (bone marrow), in vivo	neg.	Banerjee et al. 1983

Frequency	Modulation	Power Flux Density / SAR	Exposure duration	Studies subject / Method	Result	Ref.
2,45 GHz	PM, 25 kHz	490 W/m^2 33,8 W/kg	2 h	Egg Cells (Chinese Hamster), in vitro	neg.	Ciaravino et al. 1987
2,45 GHz	PM, 25 kHz	490 W/m^2 33,8 W/kg	2 h	Egg Cells (Chinese Hamster), in vitro	neg.	Ciaravino et al. 1991
2,45 GHz	cw	104 – 193 W/kg	20 min	Lymphocytes (Human), in vitro, Add. caffeine	pos., s.s.#	Lloyd et al. 1984
2,45 GHz	cw	75 W/kg	30 – 120 min	Lymphocytes (Human), in vitro	neg.	Maes et al. 1993
954 MHz	PM/GSM, 217 Hz	1,5 W/kg	2 h	Lymphocytes (Human), in vitro	pos., s.s.	Maes et al. 1996
935,2 MHz	PM/GSM, 217 Hz	0,3 – 0,4 W/kg	2 h	Lymphocytes (Human), in vitro	pos., partly s.s.	Maes et al. 1997
2,45 GHz	cw	100 W/m^2	120 d 6 h/d	Spermatogonia (Mouse), in vivo	neg.	Saunders et al. 1988
Mutations						
2,45 GHz	AM, 100 Hz	40 – 80 W/kg	2 h –6 h	Escherichia coli, in vitro	partly pos., s.s.	Anderstam et al. 1983
2,45 GHz	AM, 100 Hz	40 – 80 W/kg	4 h – 7 h	Salmonella typhimurium, in vitro	neg.	Anderstam et al. 1983
3,07 GHz	PM, 500 Hz	95 W/kg	1 h	Escherichia coli, in vitro	neg.	Anderstam et al. 1983
3,07 GHz	PM, 500 Hz	75 - 100 W/kg	2 h – 2,5 h	Salmonella typhimurium, in vitro	neg.	Anderstam et al. 1983
9,4 GHz	cw	600 W/m^2 23 W/kg	30 – 120 min	Escherichia coli, in vitro	neg.	Dardalhon et al. 1981
9,4 GHz	cw	600 W/m^2 23 W/kg	30 – 120 min	Saccharomyces cerevisiae, in vitro	partly pos., s.s.	Dardalhon et al. 1981
9,4 GHz	cw	10 – 600 W/m^2	330 min	Saccharomyces cerevisiae, in vitro	pos.	Dardalhon et al. 1985

Frequency	Modulation	Power Flux Density / SAR	Exposure duration	Studies subject / Method	Result	Ref.
2,45 GHz	AM, 100 Hz	130 W/kg	5,7 h	Salmonella typhimurium, in vitro	partly pos, s.s.	Hamnerius et al. 1985
3,10 GHz	PM, 500 Hz	90 W/kg	6 h	Salmonella typhimurium, in vitro	partly pos., n.s.	Hamnerius et al. 1985
2,45 GHz	AM, 100 Hz	110 W/kg	6 h	Drosophila melanogaster, in vivo	neg.	Hamnerius et al. 1985
3,10 GHz	PM, 500 Hz	60 W/kg	6 h	Drosophila melanogaster, in vivo	neg.	Hamnerius et al. 1985
2,375 MHz	cw	150.000 – 250.000 W/m^2	25 – 300 min	Drosophila melanogaster, in vivo	partly pos., s.s.	Marec et al. 1985
2,45	PM, 25 kHz	480 W/m^2 30 W/kg	bis 63 h	Leukaemia-Cells (Mouse), in vitro	pos./neg., partly s.s.	Meltz et al. 1989
2,45 GHz	PM, 25 kHz	650 – 870 W/m^2 40 – 40,8 W/kg	4 h	Leukaemia-Cells (Mouse), in vitro	neg.	Meltz et al. 1990

Table A.2 Effects of high frequency electromagnetic fields on cellular processes

Frequency	Modulation	Power Flux Density SAR	Exposure Duration	Examines Subject Method	Result	Ref.
Gene transcription and gene translation						
890 – 915 GHz	PM/GSM, 217 Hz	0,3 – 7,5 W/kg	4 h	Brain (Rat), in vivo	pos., partly s.s.	Fritze et al. 1997 a
835,62 MHz	FM/cw	0,6 W/kg	4 d	Fibroblasts (Mouse), in vitro	partly pos., s.s.	Goswami et al. 1999
847,74 MHz	PM/CDMA, 50 Hz	0,6 W/kg	4 d	Fibroblasts (Mouse), in vitro	partly pos., s.s.	Goswami et al. 1999
836,55 MHz	PM/TDMA, 50 Hz	0,9 – 90 W/m^2 0,00026 – 0,026 W/kg	20 – 100 min	Pheochromocytoma Cells (Rat), in vitro	pos., s.s.	Ivaschuk et al. 1997
Cell-Cycle						
380 MHz	PM, 17,65 Hz	80 W/kg	?	Lymphocytes (Human), in vitro	neg.	Antonopoulos et al. 1997
900 MHz	PM/DCS, 217 Hz	208 W/kg	?	Lymphocytes (Human), in vitro	neg.	Antonopoulos et al. 1997
1,8 GHz	PM/GSM, 217 Hz	1700 W/kg	?	Lymphocytes (Human), in vitro	neg.	Antonopoulos et al. 1997
2,45 GHz	PM, 25 kHz	490 W/m^2 33,8 W/kg	2 h	Egg Cells (Chinese Hamster), in vitro	neg.	Ciaravino et al. 1991
2,45 GHz	cw	5 – 25 W/kg	2 h	Egg Cells (Chinese Hamster), in vitro	pos., s.s.	Cleary et al. 1996
9,4 GHz	PM, 1,0 kHz	1 – 100 W/m^2	2 w 5 d/w 1 h/d	Mouse, in vivo	pos., s.s.	Manikowska et al. 1979
2,45 GHz	cw	100 W/m^2	6x1 h	Lymphocytes (Human), in vitro	neg.	Pazmany et al. 1990
2,45 GHz	cw	100 W/m^2	3x1 h	Lymphocytes (Human), in vitro	neg.	Pazmany et al. 1990
2,45 GHz	cw	100 W/m^2	5 h	Lymphocytes (Human), in vitro	pos., s.s.	Pazmany et al. 1990

Table A.3 Effects of high frequency electromagnetic fields on cell transformation and cell proliferation

Frequency	Modulation	Power Flux Density SAR	Exposure Duration	Studied Subject Method	Result	Ref.
Cell Transformations (including neoplastic)						
2,45 GHz	PM, 120 Hz	4,4 W/kg	24 h	Fibroblasts (Mouse), in vitro	partly pos., s.s.	Balcer-Kubiczek & Harrison 1985
2,45 GHz	PM, 120 Hz	4,4 W/kg	24 h	Fibroblasts (Mouse), in vitro	partly pos., s.s.	Balcer-Kubiczek & Harrison 1989
2,45 GHz	PM, 120 Hz	0,1 – 4,4 W/kg	24 h	Fibroblasts (Mouse), in vitro	partly pos., s.s.	Balcer-Kubiczek & Harrison 1991
2,45 GHz	cw	0,8 – 12,3 W/kg	5 d	Lymphocytes (Human), in vitro	neg.	Czerska et al. 1992
2,45 GHz	PM, 1000 Hz	0,8 – 12,3 W/kg	5 d	Lymphocytes (Human), in vitro	pos., s.s.	Czerska et al. 1992
2,45 GHz	cw	50 W/m^2		Lymphocytes (Mouse)	pos.	Smialowicz et al. 1979
Cell Communication						
836,55 MHz	PM, TDMA, 50 Hz	0,3 – 30 W/m^2 0,00015 - 0,015 W/kg	28 d	Fibroblasts (Mouse), in vitro	partly pos., s.s.	Cain et al. 1997
Cell Proliferation						
2,45 GHz	AM, 100 Hz	40 – 80 W/kg	2 h –6 h	Escherichia coli, in vitro	partly pos., s.s.	Anderstam et al. 1983
2,45 GHz	AM, 100 Hz	40 – 80 W/kg	4 h – 7 h	Salmonella typhimurium, in vitro	partly pos., s.s.	Anderstam et al. 1983
3,07 GHz	PM, 500 Hz	95 W/kg	1 h	Escherichia coli, in vitro	partly pos., s.s.	Anderstam et al. 1983
3,07 GHz	PM, 500 Hz	75 - 100 W/kg	2 h – 2,5 h	Salmonella typhimurium, in vitro	partly pos., s.s.	Anderstam et al. 1983
900 MHz	PM/GSM, 217 Hz	0,55 – 2,0 W/m^2 0,075 – 0,270 W/kg	10 d 2 h/d	Lymphocytes (Rat, (Sprague-Dawley), in vivo	neg.	Chagnaud & Veyret 1999
2,45	cw	5 – 50 W/kg	2 h	Blut (Human), Lymphocytes, in vitro	pos., s.s.	Cleary et al. 1990 a
2,45	cw	5 – 75 W/kg	2 h	Glioma-Cells, in vitro	pos. s.s.	Cleary et al. 1990 b

Frequency	Modulation	Power Flux Density SAR	Exposure Duration	Studied Subject Method	Result	Ref.
2,45 GHz	cw	5 – 50 W/kg	2 h	T-Lymphocytes (Mouse, CTLL-2), in vitro	pos., s.s.	Cleary et al. 1996
2,45 GHz	PM/PCS, 50 Hz	5 W/kg	2 h	T-Lymphocytes (Mouse, CTLL-2), in vitro	pos., s.s.	Cleary et al. 1996
2,45 GHz	?	?	15 s – 5 h	Myeloma- and Hybridoma-Cells (Mouse), in vitro	?, Methode fragwürdig	Dorp et al. 1998
150 MHz	AM, 72 Hz, 217 Hz, 1100 Hz	1,6 kV/m 5,4 µT		Escherichia coli, in vitro	pos., partly s.s.	Grospietsch et al. 1995
2,45 GHz	AM, 100 Hz	130 W/kg	5,7 h	Salmonella typhimurium,	pos, s.s.	Hamnerius et al. 1985
3,10 GHz	PM, 500 Hz	90 W/kg	6 h	Salmonella typhimurium,	pos., s.s.	Hamnerius et al. 1985
836,55 MHz	PM, TDMA, 50 Hz	0,9 – 90 W/m^2 0,00015 - 0,059 W/kg	4 h – 14 d	Glioma-Cells (Rat), in vitro	neg.	Stagg et al. 1997
960 MHz	PM, GSM, 217 Hz	0,0021 W/kg	30 min	transform. Epithel-Amnion-Cells (Human), in vitro	pos., (s.s)	Velizarov et al. 1999

Appendix B

Studies of the effects of high frequency electromagnetic fields on the central nervous system (Blood-Brain-Barrier)

Abbreviations

neg.	negative finding
n.s.	not statistically significant
pos.	positive finding
s.s.	statistically significant
partly	some findings
#	disagreement with the conclusions of the authors
?	unknown; not provided; unreliable

Table B.1 Effects of high frequency electromagnetic fields on the central nervous system

Frequency	Modulation	Power Flux Density / SAR	Exposure duration	Studies subject / Method	Result	Ref.
2,8 GHz	cw	100 W/m^2	2 h	Rat (Wistar)	pos.	Albert 1979
2,45 GHz	cw	100 W/m^2 2,5 W/kg	2 h	Hamster (Chin.)	pos., s.s.	Albert & Kerns 1981
900 MHz	PM/GSM, 217 Hz	0,3 – 7,5 W/kg	4 h	Rat (Wistar)	pos., partly s.s.	Fritze et al. 1997 b
2,8 GHz	cw	100 – 400 W/m^2	4 h	Rat (Tac:N(SD)sBR)	partly pos, n.s.	Gruenau et al. 1982
2,8 GHz	PM, 500 Hz	10 – 150 W/m^2	4 h	Rat (Tac:N(SD)sBR)	partly pos, n.s.	Gruenau et al. 1982
2,45 GHz	PM, 100 Hz	100 W/m^2 2 W/kg	30 min – 2 h	Rat (Sprague Dawley)	pos., s.s.	Neubauer et al. 1990
1,3 GHz	cw	3 – 30 W/m^2	20 min	Rat (Wistar)	pos., s.s.	Oscar & Hawkins 1977
1,3 GHz	PM, 5 Hz	0,3 – 0,5 W/m^2	20 min	Rat (Wistar)	pos., s.s.	Oscar & Hawkins 1977
1,3 GHz	PM, 1000 Hz	1 – 10 W/m^2	20 min	Rat (Wistar)	pos., s.s.	Oscar & Hawkins 1977
2,45 GHz	cw	1,0 – 300 W/m^2	30 min	Rat (Sprague-Dawley)	partly pos., s.s.	Preston et al. 1979
915 MHz	cw	0,3 – 5,0 W/kg	2 h	Rat (Fischer 344)	pos., s.s.	Salford et al. 1994
915 MHz	PM, 8 Hz	0,016 – 0,16 W/kg	2 h	Rat (Fischer 344)	pos., s.s.	Salford et al. 1994
915 MHz	PM, 16 Hz	0,03 – 2,1 W/kg	2 h	Rat (Fischer 344)	pos., s.s.	Salford et al. 1994
915 MHz	PM, 50 Hz	0,3 – 5,0 W/kg	2 h	Rat (Fischer 344)	pos., s.s.	Salford et al. 1994
915 MHz	PM, 200 Hz	0,4 – 2,9 W/kg	2 h	Rat (Fischer 344)	pos., s.s.	Salford et al. 1994

Appendix C

Studies of the Carcenogenic Effects of High Frequency Electromagnetic Fields in Animal Experiments

Abbreviations

neg.	negative finding
n.s.	not statistically significant
pos.	positive finding
s.s.	statistically significant
partly	some findings
#	disagreement with the conclusions of the authors
?	unknown; not provided; unreliable

Table C.1 Animal experiments regarding the carcenogenic effects of high frequency electromagnetic fields

Frequency	Modulation	Power Flux Density / SAR	Exposure duration	Studies subject / Method	Result	Ref.
836,55 MHz	PM/TDMA, 50 Hz	0,74 – 1,6 W/kg	24 mon 4 d/w 2 h/d	Rat (Fischer 344)	neg.	Adey et al. 1999
900 MHz	PM/GSM, 217 Hz	0,55 – 2,0 W/m^2	2 w, 2 h/d	Rat, Cancer, total	neg.	Chagnaud et al. 1999
2,45 GHz	PM, 800 Hz	0,15 – 0,4	25 mon	Rat, Cancer, total	pos., s.s.	Chou et al. 1992
2,45 GHz	cw	0,3 W/kg	18 mon, 7 d/w, 20 h/d	Mouse (C3H/HeJ), Cancer, total	neg.	Frei et al. 1998 a
2,45 GHz	cw	1,0 W/kg	78 w, 7 d/w, 20 h/d	Mouse (C3H/HeJ), Cancer, total	partly pos., n.s.	Frei et al. 1998 b
835,62 MHz	FM, cw	0,75 W/kg	150 d, 5 d/w, 4 h/d	Rat (Fischer 344), B16 Melanoma	partly pos., n.s.	Higashikubo et al. 1999
835,62 MHz	PM/CDMA, 50 Hz	0,75 W/kg	150 d, 5 d/w, 4 h/d	Rat (Fischer 344), B16 Melanoma	neg.	Higashikubo et al. 1999
929,2 MHz	PM/TDMA, 50 Hz	0,58 – 0,8	6 w, 5 d/w, 90 min/d	Rat (Fischer 344), Liver cancer	neg.	Imaida et al 1998 a
1,439 GHz	PM/TDMA, 50 Hz	0,453 - 0,680 W/kg	6 w, 5 d/w, 90 min/d	Rat (Fischer 344), Liver cancer	neg.	Imaida et al. 1998 b
900 MHz	PM/GSM, 217 Hz	2,6 – 13 W/m^2 0,008 – 4,2 W/kg	18 mon 30 min/d	Mouse (transgenic Eμ-Pim1), Lyphomas	pos., s.s.	Repacholi et al. 1997
915 MHz	PM, 4 – 217 Hz	0,0077 – 1,0 W/kg	2-3 w 5d/w 7h/d	Rat (Fischer 344), Brain Tumor	partly pos., n.s.	Salford et al. 1993
2,45 GHz	cw	10 W/m^2 1,2 W/kg	max. 46 w, 6 d/w, 2,5 h/d	Mouse (C57BL/6J), B16 Melanoma	partly pos., n.s.	Santini et al. 1988
2,45 GHz	PM, 25 Hz	10 W/m^2 1,2 W/kg	max. 46 w, 6 d/w, 2,5 h/d	Mouse (C57BL/6J), B16 Melanoma	partly pos., n.s.	Santini et al. 1988
2,45 GHz	cw	50 – 150 W/m^2 2 – 8 W/kg	12 mon 6d/w, 2h/d	Mouse (C3H/HeA), Cancer, total	pos., s.s.	Szmigielski et al. 1982
2,45 GHz	cw	50 – 150 W/m^2 2 – 8 W/kg	5 mon 6d/w, 2h/d	Mouse (Balb/c), Skin Cancer	pos., s.s.	Szmigielski et al. 1982

2,45 GHz	cw	50 – 150 W/m^2	6 mon, 2 h/d	Mouse (Balb/c), Hautcancer	pos., s.s.	Szudinski et al. 1982
435 MHz	PM, 1,0 kHz	10 W/m^2 0,32 W/kg	21 mon	Mouse (C3H/HeJ), Chest tumors, Ovarian tumors	partly pos., s.s.	Toler et al. 1997
2,45 GHz	cw	100 W/m^2 11 W/kg	5 mon, 6 d/w, 3 h/d	Mouse (Balb/c), Intestinal cancer	partly pos., n.s.	Wu et al. 1994

Appendix D

Epidemiological Studies of the health Risks of HF EMFs

Table D.1 Overview of the results of epidemiological studies regarding exposures in the high frequency spectrum and health risks

Column 1: studied illness

Column 2: Exposure situation

Column 3: Reliability of the exposure classification:

- 3: Source of exposure and quantity clearly identified,
- 2: Method of exposure clearly identified
- 1: HF-exposure probable

Column 4: Relative Risk (R.R.), Explanations see text

Column 5: Statistical significance of the findings:

- s.s.: statistically significant(R.R.=1 outside of 95 %-trust interval, or. $p<0,05$
- n.s.: statistically not significant

Column 6: Literatur reference

Column 7: Comments:

- R: Values in the Column R.R. obtained by conversion (reciprocal value, proportion) of other numerical values or via the interpretation of diagrams
- *: Paper listed in the literature references of Appendix E

Illness	Exposure	Exp. class.	R.R.	stat. Sign.	References	C
All Illnesses						
All illnesses, morbidity	MW, Radar, Military	2	1,18	n.s.	Robinette et al. 1980	R*
All Illnesses, morbidity	MW, mobile telecommunications	3	0,93	n.s.	Rothman et al. 1996	
Cancer, total						
Cancer, total, morbidity	MW, Radar, Military	2	1,50	n.s.	Robinette et al 1980	R*
Cancer, total, Incidence	RF, Radio, women	2	1,2	s.s.	Tynes et al. 1996	*
Cancer, total, Incidence	RF/MW, Military	2	2,07	s.s.	Szmigielski 1996	*
Cancer, total, Incidence	HF, Radio and TV transmitters, local residents	3	1,09	s.s.	Dolk et al. 1997 a	*
Cancer, total, Incidence	HF, place of work	1	2,0	n.s.	Lagorio et al. 1997	
Cancer, total, Incidence	RF/MW, Radar and Radio, Police	2	0,96	n.s.	Finkelstein 1998	*
Multiple Myelome	HF, Radio and TV transmitter, local residents	3	1,23	n.s.	Dolk et al. 1997 a	*
Brain tumors, total and tumors of the nervous system, total						
Brain-Tumors, total, Morbidity	HF, Place of work	1	1,54	n.s.	Lin et al. 1985	
Brain-Tumors, Glioblastomas and Astrocytoma, Morbidity	HF, Place of work	1	2,15	s.s.	Lin et al. 1985	
Brain-Tumors, total, Morbidity	HF, Place of work, Men	1	0,38	n.s.	Milham 1985	
Brain-Tumors, total, Morbidity	RF/MW, Place of work, Men	2	2,3	s.s.	Thomas et al. 1987	*
Brain-Tumors, total, Morbidity	RF, Amateur Radio Users	2	1,39	n.s.	Milham 1988	
Brain-Tumors, total, Incidence	HF, Place of work	1	2,9	s.s.	Törnqvist et al. 1991	
Brain-Tumors, Glioblastomas, Incidence	HF, Place of work	1	3,4	s.s.	Törnqvist et al. 1991	
Brain-Tumors, total, Incidence	RF, Place of work, Men	2	0,61	n.s.	Tynes et al. 1992	
Brain-Tumors, total, Incidence	RF, Radio, Women	2	1,0		Tynes et al. 1996	*
Brain-Tumors, total, Incidence	HF, Place of work, Men	1	2,4	s.s.	Beall et al. 1996	
Brain-Tumors, total, Incidence	RF/MW, Military	2	1,39	s.s.	Grayson 1996	*

Illness	Exposure	Exp. class.	R.R.	stat. Sign.	References	C
Brain-Tumors, total, Morbidity	HF/MW, TV transmitters and others residents (adults)	3	0,89	n.s.	Hocking et al. 1996	*
Brain-Tumors, total, Incidence	HF/MW, TV and other transmitters, Local residents/ Adults	3	0,82	n.s.	Hocking et al. 1996	*
Brain-Tumors, total, Morbidity	HF/MW, TV and other transmitters, Local residents/child.	3	1,0		Hocking et al. 1996	*
Brain-Tumors, total, Incidence	HF/MW, TV and other transmitters, Local residents/child.	3	1,3	n.s.	Hocking et al. 1996	*
Tumors des Nervensystems einschl. Hirntumors, Incidence	RF/MW, Military	2	1,91	s.s.	Szmigielski 1996	*
Brain-Tumors, total, Incidence	HF, Sender Radio and Fernsehen, Local residents	3	1,29	n.s.	Dolk et al. 1997 a	*
Brain-Tumors, maligne, Incidence	HF, Sender Radio and Fernsehen, Local residents	3	1,31	n.s.	Dolk et al. 1997 a	*
Brain-Tumors, total, Incidence	RF/MW, Radar and Radio, Police	2	0,84	n.s.	Finkelstein 1998	*
Brain-Tumors, total, Incidence	MW, Mobil telecommunications, Mobile phones	3	1,20	n.s.	Hardell et al. 1999	*
Brain-Tumors, Expos.seite, Incidence	MW, Mobilradio, Handy	3	R 2,45 L 2,40	n.s. n.s.	Hardell et al. 1999	*
Cancer, Eyes						
Melanome, Augen, Incidence	MW, Radar, Military	1	2,1	s.s.	Holly et al. 1995	
Cancer of the respiratory system, lung cancer						
Cancer der Atmungsorgane, Morbidity	MW, Radar, Military	2	2,59	s.s.	Robinette et al. 1980	R*
Lungencancer, Morbidity	HF, Place of work, Men	1	0,80	n.s.	Milham 1985	
Lungencancer, Incidence	RF, Radio, Women	2	1,2	n.s.	Tynes et al. 1996	*
Lungencancer, Incidence	HF, Sender Radio and Fernsehen, Local residents	3	1,01	n.s.	Dolk et al. 1997 a	*
Lungencancer, Incidence	RF/MW, Radar and Radio, Police	2	0,66	s.s.	Finkelstein 1998	*
Chest cancer, Men						
Brustcancer, Mönner, Incidence	HF, Place of work	1	2,9	n.s.	Demers et al. 1991	

Illness	Exposure	Exp. class.	R.R.	stat. Sign.	References	C
Brustcancer, Men, Incidence	HF, Sender Radio and Fernsehen, Local residents	3	1,64	n.s.	Dolk et al. 1997 a	*
Breast cancer, Women						
Brustcancer, Women, Morbidity	HF, Place of work	2	1,15	s.s.	Cantor et al. 1995	*
Brustcancer, Women, Incidence	RF, Radio, Women	2	1,5	s.s.	Tynes et al. 1996	*
Brustcancer, Women, Incidence	HF, Sender Radio and Fernsehen, Local residents	3	1,08	n.s.	Dolk et al. 1997 a	*
Cancer of the lymphatic and blood forming systems, total						
Cancer des lymphat. and des blutbild. Systems, Morbidity	MW, Radar, Military	2	1,98	n.s.	Robinette et al. 1980	R*
Cancer des lymphat. and des blutbild. Systems, Morbidity	HF, Place of work, Men	1	1,37	n.s.	Milham 1985	
Cancer des lymphat. and des blutbild. Systems, Incidence	HF, Sender Radio and Fernsehen, Local residents	3	1,21	n.s.	Dolk et al. 1997 a	*
Cancer des lymphat. and des blutbild. Systems, Incidence	RF/MW, Military	2	6,31	s.s.	Szmigielski 1996	*
Leukaemia, total						
Leukaemia, total, Morbidity	HF, Place of work	1	1,11	n.s.	Milham 1982	
Leukaemia, total, Morbidity	RF, Amateur radio user	2	1,91	s.s.	Milham 1985 a	
Leukaemia, total, Morbidity	HF, Place of work, Men	1	1,02	n.s.	Milham 1985 b	
Leukaemia, total, Morbidity	RF Amateur radio user	2	1,24	n.s.	Milham 1988	
Leukaemia, total, Incidence	HF, Military	1	2,4	s.s.	Garland et al. 1990	
Leukaemia, total, Incidence	HF, Place of work	1	0,8	n.s.	Törnqvist et al. 1991	
Leukaemia, total, Incidence	RF, Place of work, Men	2	2,85	s.s.	Tynes et al. 1992	
Leukaemia, total, Incidence	RF, Radio, Women	2	1,1	n.s.	Tynes et al. 1996	*
Leukaemia, total, Morbidity	RF/MW, TV and other transmitters, Local residents/ Adults	3	1,17	n.s.	Hocking et al. 1996	*
Leukaemia, total, Morbidity	RF/MW, TV and other transmitters, Local residents/ children.	3	2,32	s.s.	Hocking et al. 1996	*
Leukaemia, total, Incidence	RF/MW, TV and other transmitters , Local residents/	3	1,24	s.s.	Hocking et al. 1996	*

Illness	Exposure	Exp. class.	R.R.	stat. Sign.	References	C
	Adults					
Leukaemia, total, Incidence	RF/MW, TV and other transmitters, Local residents/ Children.	3	1,58	s.s.	Hocking et al. 1996	*
Leukaemia, total, Incidence	HF, Sender Radio and Fernsehen, Local residents	3	1,83	s.s.	Dolk et al. 1997 a	*
Leukaemia and Non-Hodgkin-Lymphoma, total, Incidence	HF, Sender Radio and Fernsehen, Local residents	3	1,25	n.s.	Dolk et al. 1997 a	*
Leukaemia, total, Incidence	RF/MW, Radar and Radio, Police	2	0,6	n.s.	Finkelstein 1998	*
Leukaemia, total, Incidence	RF/MW, TV and other transmitters, Local residents/ children.	3	1,47	n.s.	McKenzie et al. 1998	*
Acute Leukaemia, total						
Acute Leukaemia, total, Morbidity	HF, Place of work	1	2,39	n.s.	Milham 1982	
Acute Leukaemia, total, Morbidity	HF, Place of work, Men	1	2,12	n.s.	Milham 1985	
Acute Unspez. Leukaemia, Morbidity	RF, Amateur radio users	2	1,76	n.s.	Milham 1988	
Acute Leukaemia, total, Incidence	HF, TV and Radio transmitters, Local residents	3	1,86	n.s.	Dolk et al. 1997 a	*
Lymphat. Leukaemia, total						
Lymphat. Leukaemia, total, Morbidity	RF, Amateur radio users	2	0,77	n.s.	Milham 1985	
Lymphat. Leukaemia, total, Morbidity	RF, Amateur radio users	2	1,03	n.s.	Milham 1988	
Lymphat. Leukaemia, total, Morbidity	RF/MW, TV and other transmitters, Local residents/ Adults	3	1,39	s.s.	Hocking et al. 1996	*
Lymphat. Leukaemia, total, Morbidity	RF/MW, TV and other transmitters, Local residents/ children.	3	2,74	s.s.	Hocking et al. 1996	*
Lymphat. Leukaemia, total, Incidence	RF/MW, TV and other transmitters, Local residents/ Adults	3	1,32	s.s.	Hocking et al. 1996	*
Lymphat. Leukaemia, total, Incidence	RF/MW, TV and other transmitters, Local residents/ children	3	1,55	s.s.	Hocking et al. 1996	*

Illness	Exposure	Exp. class.	R.R.	stat. Sign.	References	C
Lymphat. Leukaemia, total, Incidence	RF/MW, TV and other transmitters, Local residents /children.	3	1,53	n.s.	McKenzie et al. 1998	*
Acute Lymphat. Leukaemia						
Acute Lymphat. Leukaemia, Morbidity	RF, Amateur radio users	2	1,20	n.s.	Milham 1988	
Acute Lymphat. Leukaemia, Incidence	HF, Sender Radio and Fernsehen, Local residents	3	3,57	n.s.	Dolk et al. 1997 a	*
Chron. Lymphat. Leukaemia						
Chron. Lymphat. Leukaemia, Morbidity	RF, Amateur radio users	2	1,43	n.s.	Milham 1985	
Chron. Lymphat. Leukaemia, Morbidity	RF, Amateur radio users	2	1,09	n.s.	Milham 1988	
Chron. Lymphat. Leukaemia, Incidence	HF, Place of work	1	1,3	n.s.	Törnqvist et al. 1991	
Chron. Lymphat. Leukaemia, Incidence	HF, Sender Radio and Fernsehen, Local residents	3	2,56	s.s.	Dolk et al. 1997 a	*
Myelo. Leukaemia, total						
Myelo. Leukaemia, total, Morbidity	RF, Amateur radio users	2	2,81	s.s.	Milham 1985	
Myelo. Leukaemia, total, Morbidity	RF, Amateur radio users	2	1,40	n.s.	Milham 1988	
Myelo. Leukaemia, total, Morbidity	RF/MW, TV and other transmitters, Local residents/ Adults	3	1,01	n.s.	Hocking et al. 1996	*
Myelo. Leukaemia, total, Morbidity	RF/MW, TV and other transmitters, Local residents/child.	3	1,77	n.s.	Hocking et al. 1996	*
Myelo. Leukaemia, total, Incidence	RF/MW, TV and other transmitters, Local residents/ Adults	3	1,09	n.s.	Hocking et al. 1996	*
Myelo. Leukaemia, total, Incidence	RF/MW, TV and other transmitters, Local residents/child.	3	1,73	n.s.	Hocking et al. 1996	*
Acute Myelo. Leukaemia						
Acute Myelo. Leukaemia, Morbidity	RF, Amateur radio users	2	2,89	s.s.	Milham 1985	
Acute Myelo. Leukaemia, Morbidity	RF, Amateur radio users	2	1,76	s.s.	Milham 1988	
Acute Myelo. Leukaemia, Incidence	HF, Place of work	1	2,1	n.s.	Törnqvist et al. 1991	
Acute Myelo. Leukaemia, Incidence	HF, Radio, TV, Local residents	3	1,02	n.s.	Dolk et al. 1997	*

Illness	Exposure	Exp. class.	R.R.	stat. Sign.	References	C
Chron. Myelo. Leukaemia						
Chron. Myelo. Leukaemia, Morbidity	RF, Amateur radio users	2	2,67	s.s.	Milham 1985	
Chron. Myelo. Leukaemia, Morbidity	RF, Amateur radio users	2	0,86		Milham 1988	
Chron. Myelo. Leukaemia, Incidence	HF, Radio and TV transmitters, Local residents	3	1,23	n.s.	Dolk et al. 1997	*
Leukaemia, non-lymph. and non-myelo.						
Leukaemia, non-lymph. and non-myelo., Morbidity	RF/MW, TV and other transmitters, Local residents/ Adults	3	1,57	s.s.	Hocking et al. 1996	*
Leukaemia, non-lymph. and non-myelo., Morbidity	RF/MW, TV and other transmitters, Local residents/child.	3	1,45	n.s.	Hocking et al. 1996	*
Leukaemia, non-lymph. and non-myelo., Incidence	RF/MW, TV and other transmitters, Local residents/ Adults	3	1,67	s.s.	Hocking et al. 1996	*
Leukaemia, non-lymph. and non-myelo., Incidence	RF/MW, TV and other transmitters, Local residents/child.	3	1,65	n.s.	Hocking et al. 1996	*
Lymphomas, Hodgkin-Syndrome						
Lymphosarkome, Morbidity	HF, Place of work, Men	1	0,73	n.s.	Milham 1985	
Lymphome, excl. Lymphosarkoma, Morbidity	HF, Place of work, Men	1	3,42	n.s.	Milham 1985	
Hodgkin-Syndrome, Morbidity	RF, Amateur radio users	2	1,23	n.s.	Milham 1988	
Other malignant illness of the lymphat. tissues, Morbidity	RF, Amateur radio users	2	1,62	s.s.	Milham 1988	
Lymphomas, total, Incidence	RF, Radio, Women	2	1,3	n.s.	Tynes et al. 1996	*
Hodgkin-Syndrome, Incidence	RF/MW, Radar and Radio, Police	2	0,84	n.s.	Finkelstein 1998	*
Non-Hodgkin-Lymphoma, Incidence	HF, Radio and TV transmitters, Local residents	3	0,66	n.s.	Dolk et al. 1997 a	*
Testicular cancer						
Testicular cancer, Incidence	RF/MW, Place of work	2	3,1	s.s.	Hayes et al. 1990	
Germ cell-Carcinoma, Seminoma	RF/MW, Place of work	2	2,8	n.s.	Hayes et al. 1990	
Germ cell-Carzinome, others	RF/MW, Place of work	2	3,2	s.s.	Hayes et al. 1990	

Illness	Exposure	Exp. class.	R.R.	stat. Sign.	References	C
Testicular cancer, Incidence	MW, Radar, Police	2	6,9	s.s.	Davis & Mostofi 1993	*
Testicular cancer, Incidence	RF/MW, Radar and Radio, Police	2	1,33	s.s.	Finkelstein 1998	*
Cancer of the uterus						
Cancer of the uterus, Incidence	RF, Radio, Women	2	1,9	s.s.	Tynes et al. 1996	*
Skin cancer						
Skin Cancer, Malignant Melanoma, Incidence	RF, Radio, Women	2	0,9	n.s.	Tynes et al. 1996	*
Skin Cancer, total, Incidence	RF/MW, Military	2	1,67	n.s.	Szmigielski 1996	*
Skin cancer, Malignant Melanoma, Incidence	HF, Radio and TV transmitters, Local residents	3	1,43	n.s.	Dolk et al. 1997 a	*
Skin cancer, Malignant Melanoma, Incidence	RF/MW, Radar and Radio, Police	2	1,37	s.s.	Finkelstein 1998	*
Heart and cardio vascular diseases						
Cardio vascular diseases, Morbidity	MW, Radar, Military	2	1,09	n.s.	Robinette et al. 1980	R*
Cardio vascular diseases, Morbidity	RF, Amateur radio users	2	0,70	s.s.	Milham 1988	
Abnorm. Hearbeat rate variability	RF/AM, Radio transmitters, Place of work	2	1,6	s.s.	Bortkiewicz et al. 1996	*
Abnormal ECG	MW	2	2,9	?	Zhao et al. 1994	R
Cardio vascular complaints	MW	2	3,2	?	Zhao et al. 1994	R
Infertility, reduced fertility, Men						
reduced Fertility, reduced Sperm count	MW, Place of work	2	1,20	s.s.	Lancranjan et al. 1975	R
reduced Fertility, immob. Spermatozoa	MW, Place of work	2	1,39	s.s.	Lancranjan et al. 1975	R
reduced Fertility, normal Spermatozoa	MW, Place of work	2	1,18	s.s.	Lancranjan et al. 1975	R
reduced. Fertility, reduced Sperm count	MW, Military	2	2,70	s.s.	Weyandt et al. 1996	R
reduced Fertility, reduced sperm count	MW, Radar	2	1,54	n.s.	Hjollund et al. 1997	R
reduced Fertility, immob. Spermatozoa	MW, Radar	2	1,58	n.s.	Hjollund et al. 1997	R
reduced Fertility, reduced Sperm count	MW, Radar	2	1,10	n.s.	Schrader et al 1998	R

Illness	Exposure	Exp. class.	R.R.	stat. Sign.	References	C
Infertility, reduced. fertility, Women						
reduced. fertilityt	KW, Place of work, Physiotherapie, Mothers	2	1,7	n.s.	Larsen et al. 1991 a	*
Miscarriages, Stillbirths, Malformations and other abnormalities of newborns						
Malformations and perinatal death	KW, Place of work, Mother	2	2,36	s.s.	Källén et al 1982	
Miscarriage	MW, Place of work, Mother	2	1,28	s.s.	Ouellet-Hellstrom & Stewart 1993	*
Miscarriage	KW, Place of work, Mother	2	1,07	n.s.	Ouellet-Hellstrom & Stewart 1993	*
Cancer, Offspring (parental exposure)						
Tumors of the nervous system	HF, Place of work, fathers	1	2,01	n.s.	Cole Johnson & Spitz 1989	
Cancer, total, Incidence	Radar, Place of work, fathers	2	2,3	s.s.	Smulevich et al. 1999	*
Neurodegenerative Diseases						
Alzheimer's, Morbidity	HF, Place of work	1	1,5	n.s.	Savitz et al. 1998	*
Parkinson's Disease	HF, Place of work	1	-		Savitz et al. 1998	*
Amyotrophic Lateral Sklerosis	HF, Place of work	1	-		Savitz et al. 1998	*
Disturbances of motoric and psychological reactions, Unwellness						
Reduced stamina, Boys	MW, Radar	2	1,38	s.s.	Kolodynski & Kolodynska 1996	R*
Reduced stamina, Girls	MW, Radar	2	1,38	s.s.	Kolodynski & Kolodynska 1996	R*
reduced memory, Boys	MW, Radar	2	1,09	s.s	Kolodynski & Kolodynska 1996	R*
Reduced memory, Girls	MW, Radar	2	1,12	s.s	Kolodynski & Kolodynska 1996	R*
Reduced concentration, Boys	MW, Radar	2	1,23	s.s.	Kolodynski & Kolodynska 1996	R*

Illness	Exposure	Exp. class.	R.R.	stat. Sign.	References	C
Reduced Concentration, Girls	MW, Radar	2	1,20	s.s.	Kolodynski & Kolodynska 1996	R*
Extended reaction time, Boys	MW, Radar	2	1,07	n.s.	Kolodynski & Kolodynska 1996	R*
Extended reaction time, Girls	MW, Radar	2	1,12	s.s.	Kolodynski & Kolodynska 1996	R*
Unwellness. ('Neurosis')	MW	2	3,2	?	Zhao et al. 1994	R

Appendix E (only available in German)

Extracts of our database (EMFbase)

Important research papers relevant to the assessment of health risks resulting from exposure to the electromagnetic fields of mobile telecommunications under the aspect of precautionary health protection

Contents lists available at SciVerse ScienceDirect

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journal homepage: www.elsevier.com/locate/scitotenv

Review

Elektromagnetische Hypersensitiviteit: Feit of fictie ? ☆

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Samenvatting

Terwijl de verspreiding van draadloze technologie wereldwijd steeds verder escaleert, worden professionals in de gezondheidszorg geconfronteerd met de uitdaging van patiënten die symptomen vertonen waarvan zij zeggen dat ze worden veroorzaakt door de blootstelling aan elektromagnetische straling (EMV). Sommige wetenschappers en artsen bevestigen het fenomeen van overgevoeligheid voor EMV welke voorkomt uit de blootstelling aan verschillende bronnen zoals draadloze systemen en elektrische apparaten thuis of op kantoor; anderen suggereren dat de Elektro Hyper Sensitiviteit (EHS) psychosomatisch is, of een verzinsel. Verschillende organisaties waaronder de Wereld Gezondheid Organisatie (WHO) net als de regeringen van verschillende landen zijn zorgvuldig dit klinisch fenomeen aan het onderzoeken, om zo een beter antwoord te geven op het voorkomen van stijgende verspreiding van vage, uiteenlopende, vaak hinderende symptomen, die in verband worden gebracht met de blootstelling aan niet-ioniserende EMV. Naast een verscheidenheid aan verschillende mentale klachten, melden patiënten die gediagnosticeerd zijn als EHS tevens enorme sociale en persoonlijke hindernissen, die hun vermogen om normaal te kunnen functioneren in de samenleving belemmeren. Dit artikel geeft een opsomming van de schaarse literatuur over deze verbazingwekkende conditie en een discussie over de controverse met betrekking tot de erkenning dat iemand EHS zou kunnen hebben. Er worden aanbevelingen gedaan om clinici te helpen in hun behandeling en ondersteuning van mensen die zeggen last te hebben van EHS.

Inhoud

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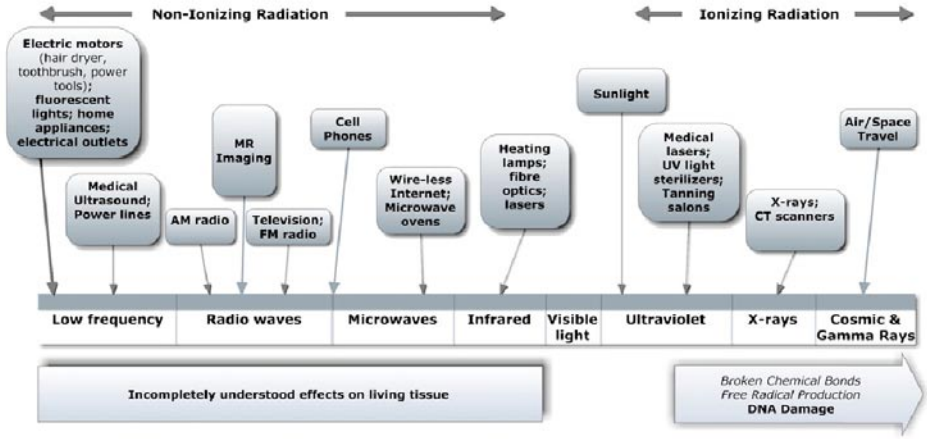

Fig.1. *Het elektromagnetische spectrum*

Not everything that is faced can be changed. But nothing can be changed until it is faced.
James Baldwin

1. Inleiding

In de beginjaren van de 21e eeuw zijn er wereldwijd steeds meer verslagen van individuen en groepen van mensen die klagen over uiteenlopende klinische symptomen die veroorzaakt worden door een blootstelling aan lage hoeveelheden elektromagnetische straling (EMV). Sommige individuen ervaren problemen als ze in de buurt zijn van draadloze systemen, als ze gebruik maken van draadloze huistelefoons of mobiele telefoons, als ze worden blootgesteld aan kunstmatig licht, of als reactie op verschillende alledaagse bronnen van elektromagnetische straling. Eenmaal blootgesteld, ontwikkelen deze kwetsbare individuen vaak een reeks aan symptomen die in verband staan met de verschillende orgaansystemen.

Hoewel oorspronkelijk werd gedacht dat deze symptomen psychologisch van aard waren, worden deze symptomen waargenomen bij een steeds groter wordende groep van voorheen gezonde individuen (Hallberg en Oberfeld, 2006) Dit fenomeen zorgt ervoor dat we meer te weten komen over de oorsprong van de klachten die individuen rapporteren die overgevoelig zijn voor elektromagnetische straling (EHS).

In dit artikel wordt een samenvatting gegeven van de verschenen literatuur welke gaat over de verbijsterende EHS aandoening, samen met een chronologisch overzicht van hoe EHS zich als aandoening heeft ontwikkeld.

Daarbij worden de fysieke, mentale en sociale aspecten van deze aandoening belicht. Maar ook wordt een onderzoek gedaan naar de tweestrijd in het debat dat er om EHS heerst. Er worden aanbevelingen gedaan aan therapeuten en artsen hoe zij patiënten met EHS kunnen helpen om hun gezondheid en welbevinden te verbeteren.

2. Achtergrond

De stortvloed aan draadloze telecommunicatie over onze aarde, roept bij velen de vraag op of verschillende elektromagnetische frequenties mogelijk een schadelijk effect op onze gezondheid kunnen hebben. Het is algemeen erkend dat vanwege de hoge energiehoeveelheden, ioniserende hoogfrequente straling van röntgenstraling of van radioactief materiaal, schadelijk is voor onze gezondheid. (Ramirez et al., 2005; Brenner et al, 2003). De schadelijke invloed van niet-ioniserende straling op mensen, is echter niet algemeen geaccepteerd.

Een breed scala aan bronnen zenden kunstmatige EMV uit zoals hoogspanningsleidingen, mobiele telefoons, draadloos internet, haardrogers, CT-scanners en radioactief materiaal (Fig. 1). Terwijl de golflengtes en frequenties uitgezonden door deze bronnen variëren, hebben ze allemaal de eigenschap om energie in de vorm van elektromagnetische straling te zenden. De vraag die door vele wetenschappers en patiëntenverenigingen wordt gesteld is tweeledig:

1. Kunnen bepaalde frequenties van niet-ioniserende straling de potentie hebben om biologische schade te veroorzaken?

2. Kunnen sommige mensen hypersensitief worden door niet-waarneembare alledaagse blootstellingsniveau's van elektromagnetische frequenties (EMV)?

Deze vragen waren voor de World Health Organization (WHO) aanleiding om in 1996 een internationaal samenwerkingsverband te formeren om de invloed van EMV op onze gezondheid te onderzoeken (World Health Organization, 2011a). Dit samenwerkingsverband is nog steeds operationeel en coördineert het onderzoek dat wereldwijd wordt uitgevoerd. Terwijl er een debat gaande is over mogelijk schadelijke effecten van niet-ioniserende straling, is er tegelijkertijd ook sprake van een intrigerende tweestrijd. Tot dusverre werd het meeste onderzoek gedaan door onafhankelijke onderzoekers, niet gebonden aan industrie of overheid, die opperden dat er sprake is van potentieel ernstige effecten bij blootstelling aan veel straling van niet-ioniserende EMV. (Sage, 2007). Onderzoek gesponsord door industrie

en enkele overheden, twijfelen echter aan mogelijke gevaren (Genuis, 2008). Echter, dankzij voortschrijdend onderzoek worden meer en meer schadelijke effecten door blootstelling aan EMV ontdekt en groeit het inzicht (Genuis, 2008; Dode et al., 2011; Marino et al., 1977; Kabuto et al., 2006). Onlangs nog ontdekte men dat er door het gebruik van mobiele telefoon wijzigingen optreden in het metabolisme dat het glucose gehalte in de hersenen regelt (Volkow et al., 2011). Dit onderzoek is gepubliceerd in: the Journal of the American Medical Association (JAMA).

Of EHS wel of niet bestaat wordt fel betwist door beide kampen. De blootstelling aan EMV, met bijbehorende meldingen van overgevoeligheid, is een verschijnsel dat niet eerder is opgetreden in de historie van de mensheid. Het is interessant om enkele mijlpalen in de ontwikkelingsgeschiedenis van EHS nader te bekijken.

2.1 Historische mijlpalen i.v.m. elektromagnetische overgevoeligheid

In de jaren 50 werden in verschillende Oost-Europese centra, duizenden werknemers beschreven en behandeld voor opvallende gezondheidsklachten waarbij sprake was van meervoudig ontregelde lichaamsprocessen. Deze personen waren veelal werkzaam in 1. productie, inspectie, bediening of reparatie van zendapparatuur voor microgolven, en/of 2. bediening van radiozendapparatuur. Voor deze gezondheidsklachten werd de naam 'Radio Wave Sickness' bedacht en getroffen personen vertoonden symptomen als hoofdpijn, algehele zwakte, vermoeidheid, slaapstoornis, emotionele instabiliteit, duizeligheid, geheugenproblemen vermoeidheid en hartritmestoornissen (Sadchikova, 1960). Dit opkomend type gezondheidsklachten duurde voort in de jaren 60 en 70. De rapporten die destijds verschenen uit verschillende delen van de wereld, brachten details van onderzoeksresultaten naar buiten over gezondheidseffecten als gevolg van blootstelling aan straling van elektromagnetische frequenties. (Klimková-Deutschová, 1973; Glaser, 1971; Zaret, 1973; Frey en Seifert, 1968; Frey, 1970). De belangstelling bij het grote publiek nam toe door boeken als 'The Zapping of America' in 1977 (Brodeur, 2000) en 'Terminal Shock' in 1985 (DeMatteo, 1985). Hierdoor nam de maatschappelijke bezorgdheid over de nadelige gevolgen van blootstelling aan EMV toe. Onder wetenschappers was er echter weinig discussie over dit onderwerp. Dr. Olle Johansson, een neuroloogwetenschapper uit Zweden begon met het documenteren van symptomen, zoals CNS (centraal zenuw stelsel) klachten, hartklachten en huidveranderingen bij personen die blootgesteld waren aan diverse bronnen van niet-ioniserende straling. Dit had tot gevolg dat er een vereniging voor electrogevoeligen werd opgericht (Swedisch Association for the Electrosensitive, 1994) met als mandaat mensen te steunen die lijden aan 'Electrical Hypersensitivity'. Om meer erkenning en steun te verwerven, verspreidden zij in 1994 een persbericht. Daarin werd aan mensen over de hele wereld een oproep gedaan om de krachten te bundelen om dit toenemende gezondheidsprobleem aan te pakken. Deze toestand werd sindsdien elektrohypersensitiviteit, electromagnetische hypersensitiviteit, magnetische hypersensitiviteit of simpelweg elektrosensitiviteit genoemd.

In de jaren 90 begon het onderzoek naar de fysiologische oorzaak van deze conditie. Rea et al. rapporteerde in 1991 bij een aantal EHS patiënten abnormale reacties bij bepaalde EMV frequenties (in vergelijking tot sham exposities)(Rea et al., 1991). Met een dubbelblindonderzoek werd bevestigd dat bij een aantal EHS patiënten veranderingen optraden in enkele medische parameters van de longen. Vervolgonderzoek van Johansson en zijn collega's, bevestigden dat er fysiologische veranderingen van de huid optreden bij overgevoelige personen door blootstelling aan bepaalde EMV (Johansson et al., 2001; Johansson and Liu, 1995). Aan de hand van deze waarnemingen werd een hypothese opgesteld over het fysiopathologische mechanisme van EHS. Deze zijn gebaseerd op een theoretische degranulatie van mestcellen (mastocyten) in verschillende weefsels, - met het vrijkomen van een spectrum aan signaalstoffen, zoals histamine - in reactie op EMV blootstelling. (Gangi and Johansson, 2000).

Begin 2000 namen de schattingen van het aantal gevallen van EHS toe tot ongeveer 1.5% van de Zweedse bevolking (Hillert et al., 2002), in Californië op 3.2% (Levallois et al., 2002) en in Duitsland op 8% (infas Institut fur Angewandte Sozialwissenschaft GmbH, 2003). Door toename van het verschijnsel EHS en een toenemende belangstelling vanuit de wetenschap, organiseerde de WHO in 2004 een internationale discussiebijeenkomst in Praag over deze aandoening. Hoewel er geen fysiologische oorzaak voor EHS werd erkend, werd EHS gedefinieerd als "*…een fenomeen waarbij individuen nadelige gezondheidseffecten ervaren door gebruik van of in de buurt zijn van apparaten met elektrische, magnetische of elektromagnetische velden (EMV's)…Wat de oorzaak ook is , EHS bestaat echt en is soms een probleem dat de betroffen persoon invalide kan maken*" (Mild et al., 2004). Het debat over het bestaan van EHS is losgebarsten, maar diverse onderzoekers vinden dat er te weinig bewijs is voor het aantonen van deze stoornis. In dit artikel wordt een poging gedaan om een overzicht te geven van de literatuur over EHS, om vervolgens de klaarblijkelijke tegenstellingen te onderzoeken in de bewijsvoering naar etiologie(leer der ziekteoorzaken) en legitimiteit van de diagnose EHS.

2.2 Overzicht van EHS

Men spreekt van EHS in díe gevallen waarbij gevoelige/kwetsbare personen last krijgen van ziektesymptomen als ze in de nabijheid verblijven van apparaten/toestellen die een of andere frequentie uitzenden (Leitgeb en Schrottner, 2003). Terwijl het merendeel van de bevolking geen en-

kele verandering in de gezondheid waarneemt als gevolg van blootstelling aan EMV, is er een groeiend aantal personen dat een verscheidenheid aan onaangename symptomen rapporteert (Tabel 1) die ze toeschrijven aan blootstelling aan EMV. Deze elektromagnetische velden lijken als een trigger te werken voor waargenomen fysiologische verstoringen in het lichaam. De reeks van frequenties die zijn geassocieerd met EHS vallen gewoonlijk binnen het niet-ioniserende bereik van het elektromagnetische spectrum (Fig. 1).

Tabel 1
Algemeen gerapporteerde symptomen die in verband worden gebracht met EHS

Een aantal algemene tekenen en symptomen van EHS (Havas 2006; Johansson 2006)

Hoofdpijn
Problemen bij denkprocessen
Geheugen problematiek
Hartkloppingen
Slaapstoornissen
Algemene malaise
Wazig zien
Zwakte
Duizeligheid
Pijn op de borst
Spierpijnen
Tinnitus
Vermoeidheid
Misselijkheid
Nachtelijk zweten
Restless legs (tintelende benen)
Paresthesie (tintelingen in de ledematen)

Het menselijk organisme -als een bio elektrisch geheel- wordt in de 21e eeuw in toenemende mate blootgesteld aan drie algemene soorten van (door de mens gemaakte) niet-ioniserende EMV:

a) Extreem laag-frequente EMV van hoogspanningskabels, elektrische apparaten en elektronische toestellen.

b) Elektrische vervuiling: sommige elektronische apparaten, zoals plasma TV's, sommige energiezuinige apparaten, motoren met variabele snelheid, enz. hebben het vermogen om signaalfrequenties te maken die over het algemeen liggen tussen de 3 en 150 kHz dat binnen het elektromagnetische spectrum beschouwd wordt als heel laag tot laag). In de getroffen huizen en gebouwen stromen deze frequenties dan door de bedrading (*dirty power*) of stralen er vanaf (*dirty air*).
Men spreekt dan van elektrische vervuiling of vuile elektriciteit (dirty electricity) (Havas, 2006).

c) Microgolf- en radiofrequente straling van draadloze telecommunicatie apparaten zoals draadloze telefoons, zendmasten, antennes, als ook radio- en televisie masten (Sage, 2007).

Bepaalde personen met EHS ervaren klachten als ze worden blootgesteld aan EMV die binnen het extreem lage frequentie bereik liggen. Anderen lijken meer gevoelig te zijn voor frequenties zoals die worden uitgezonden binnen het bereik van de radiofrequenties en microgolven (zie fig. 1). Daarnaast blijkt dat sommige personen verschillende symptomen ervaren als reactie op diverse frequenties zoals stemmingswisselingen bij blootstelling aan het ene frequentiebereik en klachten van spieren en botten bij een andere. Een aantal heeft gevoeligheidsreacties in het gehele niet-ioniserende frequentie spectrum en een subgroep krijgt klachten aan het centrale zenuwstelsel en problemen met het gezichtsvermogen als reactie op natuurlijke (dus niet door de mens gemaakte) frequenties van dát gedeelte van het spectrum waarbinnen het zichtbare licht zich bevindt (Coyle, 1995).

Er is ook wetenschappelijk onderzoek gedaan naar de relatie tussen bepaalde gehoorstoornissen zoals Tinnitus en gevoeligheid voor bepaalde EMV frequenties (Landgrebe et al., 2009).
Hoe dan ook, er kunnen dus vervelende symptomen optreden als de kwetsbare persoon worden blootgesteld aan EMV van gewone gebruiksvoorwerpen als mobiele telefoons, draadloze headsets, TL licht en spaarlampen, bepaalde computers, draadloze telefoons, apparaten en telecommunicatie signalen (Havas, 2006). Daarnaast zijn er andere EMV bronnen die vaak niet als zodanig worden beschouwd, zoals motoren in bijv. hete lucht kacheltjes, verschillende soorten van elektronische beveiligingssystemen (bijv. metaal detectoren op vliegvelden), evenals industriele machines zoals medische diathermische instrumenten (laser tools).(Floderus et al., 2002).
Door gebrek aan objectief bewijs heeft de diagnose van EHS, niet veel bijval gekregen binnen de medische wereld. Echter, in een poging om de legiti-

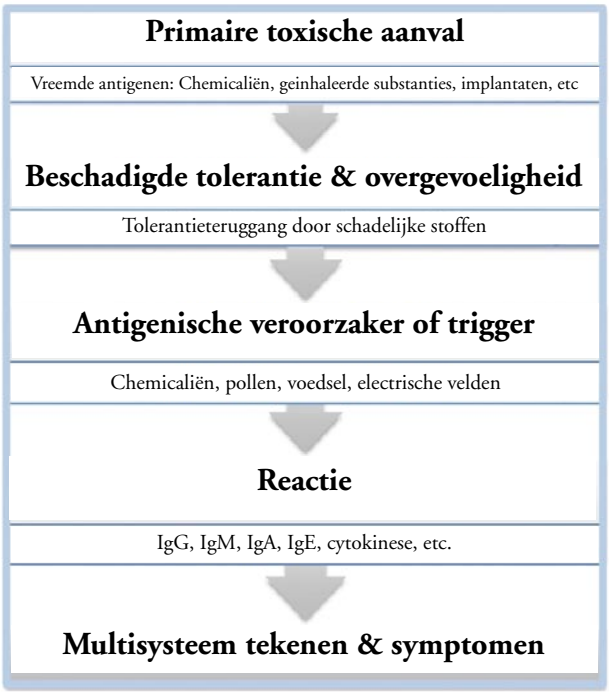

Fig.2. *Pathogeen mechanisme voor ontstaan van gevoeligsafhankelijke ziekte*

miteit van EHS als een neurologische aandoening te bepalen, heeft recent een groep wetenschappers en artsen een dubbelblind onderzoek uitgevoerd naar de gevolgen van EMV provocatie (bestraling), welke is gepubliceerd in 'The International Journal of Neuroscience' (McCarty et al., 2011). De onderzoekers zijn in staat gebleken om objectief, door middel van bestraling met de gewone dagelijkse niveau's van de huidige straling, bepaalde somatische reacties bij een patiënt die lijdt aan EHS, aan te tonen. Zij concluderen dat "de gevoeligheid voor EMV beschouwd kan worden als een *bona fide* neurologisch syndroom dat wordt opgewekt door omgevingsfactoren" (McCarty et al., 2011). Daarnaast toont een recente studie van Havas et al. (2010) in bepaalde personen fysiologische reacties aan als gevolg van blootstelling aan lage doses EMV. Bij proefpersonen die werden blootgesteld aan niveaus die slechts 0,5% van de toegestane Canadese en Amerikaanse richtlijnen betroffen (Havas et al., 2010), werden onmiddellijke en dramatische veranderingen in zowel hartslag als hartslag-variabliliteit gemeten. Deze studie suggereert dat bepaalde personen hartproblemen en ontregeling van het autonome zenuwstel kunnen ervaren als een pathofysiologische reactie op elektromagnetische prikkels.

2.3 Pathogenese van elektromagnetische overgevoeligheid

Net zoals bij andere meervoudig-systeem ziektes, zoals meervoudige chemische overgevoeligheid (MCS), fibromyalgie en chronische oververmoeidheid (ME), is er geen volledig begrip van de pathogenese van EHS.
Er komen steeds meer aanwijzingen dat het afwijkende biologische proces voor het ontwikkelen van EHS, ontstaat door een fascinerend pathofysiologische mechanisme (Fig. 2), dat aangeduid wordt als overgevoeligheid gerelateerde ziekte (sensitivity-related illness=SRI) (Genuis, 2010; De Luca et al., 2010). Bovendien is er nieuw bewijs van mogelijke verstoring van de vorming van catecholamine als reactie op EMV. Dit kan het menselijk organisme op vele manieren beïnvloeden.

a) Overgevoeligheid gerelateerde ziekte (sensitivity-related illness=SRI)
Bij SRI betreft het een pathofysiologische reactie op een biologische opstapeling van lichaamsvreemde stoffen afkomstig van diverse bronnen, zoals giftige chemicaliën, chirurgische implantaten, infecties, tandtechnisch materiaal en radioactieve stoffen. Het mechanisme waardoor het lichaam over-reactief of overgevoelig wordt voor elektromagnetische energie, zou kunnen ontstaan door blootstelling aan een of meerdere totaal andere giftige lichaamsvreemde stoffen.
Dit proces leidend naar ziekte wordt ook wel aangeduid als TILT (Toxicant Induced Loss of Tolerance) (Miller, 2001; Miller, 1997). Nadat een bepaalde grens van lichaamsvreemde stoffen bereikt is, verliest het individuele immuunsysteem de normale, door immuuntolerantie gekenmerkte reacties en wordt overgevoelig voor schijnbaar onbeduidende en ongerelateerde prikkels uit de omgeving. Uit een studie in Zweden bleek bijvoorbeeld dat er bij elektrogevoeligen een aanzienlijk hogere concentratie was van meervoudig gebromineerde difenyl ethers (PBDEs), die zich ophopen in vetweefsel (Hardell et al., 2008). Die PBDEs worden veelvuldig toegepast als brandvertrager. Ze beïnvloeden het hormoonsysteem en zijn hardnekkige milieuvervuilers. Tot voor kort werden deze stoffen veelvuldig gebruikt in matrassen, bijvoorbeeld om aan brandvoorschriften te voldoen, met als gevolg dat door het uitgassen die stoffen door het lichaam van de slapende persoon worden opgenomen. Bij patiënten met TILT verschijnselen roept de daarop volgende activering van het overgevoelige immuunsysteem door chemische of elektromagnetische triggers een klinische ziekmakende reactie op, die voortkomt uit een ontregeld biochemische reactie door diverse onderdelen van het immuunsysteem (Genuis, 2010a; Duramad et al., 2007; Tracey, 2007). Het is onduidelijk, waarom sommige mensen na het ontwikkelen van TILT, een overgevoeligheid ontwikkelen voor chemische of elektromagnetische triggers, of voor beide. De aard van de reactie wordt bepaald door de unieke samenstelling van de ophoping van gifstoffen en de biochemische vingerafdruk van het individu (Genuis, 2010a). De daarop volgende activering van antilichamen, cytokinese, interleukine en chemokine door triggers uit de omgeving kunnen diverse orgaan systemen en fysiologische functies, zoals het hormoonsysteem, het centrale zenuwstelsel, genetische aanleg, etc., beïnvloeden. Dit leidt tot afwijkende meervoudig-systeem signalen en symptomen (Genuis 2010a; Ashford and Miller, 1998). Dit activerings fenomeen wordt aangeduid met MATES: Minute Assorted Triggers Evoke Symptoms. Dit betekent dat minuut-gereguleerde triggers, symptomen oproepen. (Genuis 2010a). Alhoewel het precieze pathofysiologische mechanisme van de overgevoeligheidsreactie op EMV nog niet nauwkeurig is beschreven, bevestigen nieuwe onderzoeksresultaten dat bepaalde EMV frequenties kunnen leiden tot een ontregeling van het immuunsysteem door een toename van de productie van in vitro geselecteerde cytokinese – een vaak voorkomend kenmerk van SRI (Stankiewicz et al., 2010; Dabrowski et al., 2003). Verder schijnt het dat genomische factoren een rol spelen bij de ontwikkeling van een ontregeld immuunsysteem door SRI en EHS na ophoping van gifstoffen. De Luca et al. (2010) ontdekten dat mensen die lijden aan EHS mogelijk diverse gendefecten hebben aan genen die betrokken zijn bij het verwijderen van gifstoffen uit hun lichaam. Deze genen zijn verantwoordelijk voor de productie van antioxidant- en ontgiftings-enzymen, zoals gluthation-S-transferasen, superoxide dismutase, catalase, N-acetyl transferasen, cytochrome 450 enzymen en andere (Wormhoudt et al., 1999). Als gevolg daarvan hebben deze mensen mogelijk een afwijkend ontgiftingsmechanisme waardoor ze aanleg hebben voor ophoping van gifstoffen.

b) Ontregeling fysiologie catecholamine
Een ander belangrijk mechanisme dat de oorzaak

zou kunnen zijn voor het optreden van EHS, heeft te maken met een verstoring of tekort m.b.t. de fysiologie van catecholamine als reactie op schadelijke EMV (Buchner and Eger, 2011). Hoewel in 1977 voor het eerst werd gerapporteerd dat EMV-frequenties processen van het hormoonsysteem beïnvloeden, zoals de bijnierschors functie, wordt in nieuwe onderzoeksresultaten de dosis-response relatie benadrukt die optreedt bij blootstellingen aanmerkelijk lager dan de geldende grenswaarden voor EMV van mobiele telefonie. (Buchner and Eger, 2011). Daarnaast kan bij langdurige blootstelling, bijvoorbeeld zoals het wonen dichtbij een zendmast, deze pathofysiologische reactie een biologische verandering van noradrenaline, adrenaline, dopamine en fenylethylamine optreden met nu nog onbekende gevolgen voor de gezondheid (Buchner and Eger, 2011). Van deze endogene verbindingen kent men het werkingsmechanisme bij diverse fundamentele biologische processen goed, zoals bij het autonome zenuwstelsel, neurotransmissie, mate van alertheid en respons op stress. Het is onzeker of verstoring door blootstelling aan belastende EMV, een rol speelt bij EHS en/of het kwetsbare personen vatbaar maakt voor tal van gezondheidsproblemen, die geassocieerd zijn met een ontregeling van catecholamine en neurotransmitters. Er zijn andere hypothesen voor het pathofysiologisch mechanisme van het EHS fenomeen opgesteld. Costa et al. (2010) stelden dat een vergiftiging door zware metalen EHS kan veroorzaken, doordat metaal in het lichaam onder invloed van EMV opnieuw kan worden gemobiliseerd met als mogelijk gevolg symptomen in orgaansystemen. Er wordt ook beweerd dat in het complexe klinische milieu van de 21e eeuw, bij EHS –althans voor een deel- een veelzijdig samenspel tussen bepaalde neuro-cognitieve factoren in de psyche van de patiënt een rol zou kunnen spelen (Landgrebe et al., 2008). Alles overziend is een precies pathofysiologische werkingsmechanisme van EHS niet helemaal opgehelderd. Er zijn twee opmerkingen die veronderstellen dat het TILT werkingsmechanisme een belangrijke factor zou kunnen zijn in de ontstaansgeschiedenis van dit complexe klinische fenomeen:
1) EHS-patiënten waren voordien meestal gezonde personen, die een toxische belasting hebben opgelopen; en
2) EHS verdwijnt vaak als de toxische belasting is verwijderd. De precieze rol van langdurige ontregeling van catecholamine bij de manifestatie van EHS, moet nog worden uitgezocht.

2.4 Biologische kenmerken bij elektromagnetische overgevoeligheid

Het zou een klinisch voordeel zijn als er een pathogenetische kenmerk was dat wijst op een bepaald mechanisme bij de ontwikkeling van EHS. Dit is niet het geval. Lopend onderzoek identificeert voortdurend veranderingen in het immuunsysteem die betrokken kunnen zijn bij immuunverstoringen welke in verband worden gebracht met EHS. Zo is bij ionische straling gewoonlijk veel thermische energie nodig om een breuk in een DNA-keten te bewerkstelligen. Mashevich et al. (2003) vond daarnaast dat zeer laagfrequente EMV en microgolven veranderingen kunnen veroorzaken van genotype in het menselijke lymfocyt DNA door niet-thermische proteïne-stress. Recent bewijs laat zien dat onder invloed van EMV DNA replicatie en mitose verstoord kan worden en er gewijzigde proteïnen ontstaan (Lin et al., 1997; Lin et al., 1998; Tsurita et al., 1999; de Pomerai et al., 2000). Afwijkingen in het werkingsmechanisme van cellen, kunnen leiden tot afwijkende reacties van het immuunsysteem. Echter, tot nu toe is er geen enkele biochemische marker typisch voor EHS gevonden dat wijst op zulke onderliggende veranderingen.

Verder kan het immuunsysteem hyper-reactief worden als onmiddellijke reactie op regulerende invloeden van andere orgaansystemen zoals het centraal zenuwstelsel. Een onderzoek van D'Andrea et al. (2003) toont aan dat elektromagnetische frequenties in staat zijn de fysiologie van het centraal zenuwstelsel te beïnvloeden.
Door talrijke laboratoriumonderzoeken over mensen en dieren te beoordelen, werd aangetoond dat microgolven de doorlaatbaarheid van de hersen-bloedbarrière voor geneesmiddelen beïnvloeden en effect heeft op hormonen, cortisolspiegel van het bloed, geheugenprestaties, meetuitkomsten EEG en neurochemische markers (D'Andrea et al.,2003; Salford et al., 2008). Tot nu toe echter is er geen sluitende laboratoriumuitslag die een objectieve diagnose van EHS mogelijk maakt.

3. EHS beheersbaar maken

Het is voor patiënten met EHS met de juiste zorg mogelijk om aanzienlijk te herstellen en zelfs weer normaal te kunnen gaan functioneren. Door te begrijpen op welke manier een SRI zich ontwikkelt, kan de situatie van patiënten aanzienlijk worden verbeterd. Deze verbetert door het ontlopen van de triggers, het voorkomen van de verdere blootstelling aan toxische stoffen en het ondergaan van de juiste therapeutische maatregelen wanneer deze vereist zijn. Een complete aanpak om ziekten aan te pakken die worden veroorzaakt door blootstellings gerelateerde ziektes, zoals EHS, wordt voorgesteld in Figuur 3 (Genius, 2010a).
Een gedetailleerde uitleg over deze aanpak is te vinden in andere artikelen (Genius 2010a; Genius 2011) maar de algemene aanpak is samengevat in

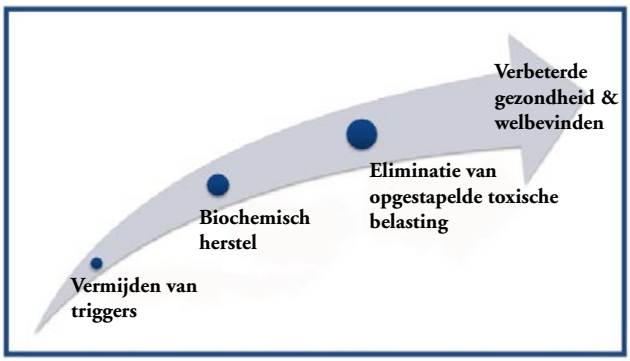

Fig.3. *Aanbevolen aanpak om ziekten die te maken hebben met overgevoeligheid te lijf te gaan.*

deze drie hoofdlijnen.

a. **Ontlopen van triggers veroorzaakt door de omgeving**

Om te zorgen dat de symptomen verdwijnen, is het noodzakelijk voor SRI patiënten om de triggers te ontlopen die voor hun klachten zorgen. Patiënten met EHS moeten waakzaam zijn dat ze die EMV frequenties ontlopen die hun symptomen triggeren. Tabel 2 geeft een voorbeeld weer van hoe de blootstelling aan alledaagse bronnen van EMV kan worden gereduceerd bij mensen die lijden aan EHS. Veel personen ervaren, als gevolg van een opeenstapeling van toxische stoffen in hun lichaam, ook symptomen die worden opgewekt door de blootstelling aan chemische triggers. Ook deze zal men dienen aan te pakken wil men succes boeken. Verschillende autoriteiten zijn begonnen om plekken in te richten waar mensen die lijden aan EHS veilig kunnen verblijven en herstellen.

b. **De voedingsbalans en biochemische processen herstellen**

Als eenmaal de juiste maatregelen zijn genomen om de overbelasting te voorkomen, dan is de volgende stap om de juiste voedingsstoffen aan te gaan vullen. Tijdens periodes van chronische stress en ontstekingen, verliest het lichaam bijzonder snel zijn voorraad aan voedingsstoffen die nodig is om de cellulaire processen en het normale functioneren van het fysieke lichaam in stand te houden. Het is mogelijk om via biochemische testen de huidige status van de chemische processen in het lichaam die met voeding te maken hebben, te kunnen aanduiden. Op die manier kan er bij afwijkingen met maatregelen worden ingegrepen die specifiek op dat probleem inspelen. Biochemische ontgifting in het lichaam moet optimaal zijn om verder te kunnen naar de volgende stap, - namelijk het kwijtraken van de totale opstapeling van toxische belasting die de gezondheidsproblemen in de eerste plaats heeft veroorzaakt.

c. **De giftige belasting verminderen**

De totale belasting van toxische stoffen op het immuunsysteem, dient te worden afgebouwd om de hyperactieve reactie van het immuunsysteem te verminderen en optimale gezondheid te bereiken. Recent onderzoek is begonnen met een link te leggen tussen specifieke toxische stoffen zoals zware metalen en EHS, (Costa et al.2010) maar het is noodzakelijk de totale belasting in kaart te brengen die de range van stoffen omvat, inclusief verschillende schadelijke chemische stoffen, implantaten, sommige tandheelkundige materialen, schimmels en andere toxines. (Genuis, 2012). Voor sommige gifstoffen geldt, dat het vermijden van verdere blootstelling het lichaam spontaan zou kunnen ontgiften door deze stoffen uit te scheiden; maar voor sommige hardnekkige stoffen, zoals cadmium, lood, gefluorideerde verbindingen en andere, zal een actieve tussenkomst nodig zijn om deze verhoogde toxische last te verminderen. (Genius, 2011; Genius, 2010b). Wanneer men effectief gaat ontgiften en verdere blootstelling vermijdt, is het mogelijk voor patiënten om te herstellen van hun overgevoeligheidsproblemen.

Tabel 2 *Voorbeelden van hoe elektromagnetische straling te verminderen*

Bronnen van EMV	Hoe EMV blootstelling te reduceren
Mobieltjes en draadloze huistelefoons	• Minimaliseer het gebruik van deze telefoons en gebruik telefoons met een draad wanneer het enigszins mogelijk is. • Houdt deze telefoons weg van het lichaam, in plaats van ze in een zakje of vastgemaakt aan de heup bij je te dragen.
Draadloos Internet	• Leg een bekabeld netwerk aan. • Zet de router uit als hij niet in gebruik is (bijvoorbeeld 's nachts). • *Gebruik zogenaamde homeplugs die via het bestaande electriciteitsnetwerk in een huis werken en voor een verlichting van de draadloze vervuiling zorgen.*
Computers die veel EMS afgeven	• Beperk de hoeveelheid tijd die je gebruikt om met een computer te werken. • Zet een laptop niet op je schoot. • Vergroot je afstand tot de laadadapter. • Blijf op een redelijke afstand van de computer.
Draagbare elektronica (elektrische tandenborstel, haardroger, SmartPhone, Tablets, etc.)	• Beperk het gebruik van electronica en schakel over naar apparatuur die geen stroom gebruiken. Wanneer niet in gebruik, schakel apparatuur uit.
Fluoriserende lichten (TL-verlichting)	• Overweeg om deze verlichting te vervangen door alternatieve verlichting, zoals gloeilampen (over de veiligheid van LED-lampen bestaat onzekerheid). Gebruik zonlicht om te lezen.
Elektriciteit in huis	• Meet de hoeveelheid EMV en pas dit aan zover dit mogelijk is. • Vermijdt het slapen op plaatsen waar veel EMV is. • Er kunnen filters kunnen worden ingezet om "vuile stroom" te neutraliseren.
Hoogspanningskabels en transformatorhuisjes	• Overweeg om te verhuizen naar een plaats die niet in de buurt ligt van hoogspanningskabels.
Zendtorens en masten (mobiele telefoon, radar, etc.)	• Blijf op een verstandige afstand van deze zenders. • Overweeg afscherming (afschermende verf, metalen weefsels die geaard zijn)
Utility neutral-to-ground bonded to water pipes	*Increase size of neutral-wire to subsation and install dieleletric coupling in water pipe.*

3.1 Onderzoek geassocieerde gezondheidsproblemen

De behandeling van EHS patiënten zou moeten bestaan uit een grondige gezondheidsbeoordeling evenals onderzoek en interventie om alle ziekmakende factoren te bepalen en te duiden. Bijvoorbeeld, zowel Dahmen en Hillert ontdekten dat bij mensen met EHS een verhoogde kans is op het niet goed functioneren van de schildklier en op leverziekte (Hillert et al., 2002; Dahmen et al., 2009). De psychische klachten die soms gepaard gaan met, of het gevolg zijn van EHS, kunnen behandeld worden met cognitieve gedragstherapie, dat kan leiden tot mogelijke verbeteringen bij depressies, angsten, fobieën en andere gerelateerde symptomen (Hillert et al., 1998; Rubin and Das, 2006).

Een van de grootste gezondheidsproblemen bij EHS is de kwaliteit van het slapen. Ongemerkt is er vaak sprake van belastende EMV in de slaapkamer (bijvoorbeeld van elektronische apparatuur, draadloze netwerken, en mogelijk door metalen onderdelen van het bed) die een rustgevende slaap verstoort (Hallberg and Johansson, 2010). Een verstoorde slaap en dag/nacht ritme leidt vaak tot vertraagd wakker worden, slaperigheid overdag, verminderde concentratie en andere kwalen. Elk behandelplan voor EHS dient factoren te onderzoeken en duiden die mogelijk tot een verstoorde slaap kunnen leiden (Hobbs, 2011).

3.2 Opnieuw programmeren van de hersenen

Er is een voortdurende discussie in de wetenschappelijke literatuur over de buigbaarheid van neuronen en de natuurlijke eigenschap van de hersenen om opnieuw te worden geprogrammeerd met als resultaat een blijvende verandering van ingesleten reactiepatronen van de hersenen (Berlucchi, 2011; Cioni et al., 2011). Als gevolg hiervan verschijnen er steeds meer trainingen die erop zijn gericht om de reacties van overgevoeligheid bij patiënten met verschillende, aan gevoeligheid gerelateerde aandoeningen zoals EHS, te beïnvloeden (Hooper, 2011). Er is tot op de dag van vandaag maar weinig wetenschappelijk onderzoek beschikbaar over de effectiviteit van zulke trainingen. Maar volgens de verhalen weten we dat het reduceren van de opgestapelde giftige belasting gecombineerd met de intensieve hertraining van het aangetaste brein, de gewenste resultaten worden bereikt.

3.3 Afscherming van EMV

EHS-patiënten die herkennen dat de blootstelling aan EMV de trigger is voor hun aandoening, proberen de uitlokkende frequenties in hun huis of op hun werkplek af te schermen door het gebruik van afschermingsmaterialen (Less EMV Inc., 2011). Hoewel sommige frequenties van EMV eenvoudig te blokkeren zijn door het gebruik van verschillende materialen, zijn andere bronnen van EMV, zoals laagfrequente magnetische velden, veel moeilijker te blokkeren. Er is momenteel geen enkele wetenschappelijke studie beschikbaar waarin het effect van zulke afschermingstechnieken op EHS-patiënten is onderzocht, maar volgens de verhalen zijn er individuen die er successen mee boeken. Afschermen kan een zeer lastige zaak zijn. Het probleem is dat blootstelling ook kan worden veroorzaakt door de weerkaatsing van EMV in het naar verluidt afgeschermde domein.

3.4 Aardingstechnieken

Er bestaat een simpele techniek, waarvan het niet zeker is hoe effectief het is, die - door de EHS-patiënt te aarden - opgelopen elektrische lading in de aarde kan ontladen. (Chevalier et al., in press). Deze bescheiden oefening bestaat uit het plaatsen van de blote voeten op de aarde of op een ander geleidend oppervlak (zoals een metalen plaat), welke in direct contact staat met de aarde. Hoewel er meer wetenschappelijk onderzoek moet worden gedaan om de validiteit van deze aanpak te bewijzen, rapporteren sommige patiënten met zware EHS symptomen klinische voordelen en voorlopige verlichting van de symptomen door het gebruik van deze techniek. Een waarschuwing is echter van toepassing, omdat het aarden in een omgeving met verborgen elektriciteitskabels of in de nabijheid van stroom door elektrische bronnen, voor een omgekeerd effect kan zorgen doordat de spanning door deze bronnen aan de aarde wordt afgegeven. Dit kan de symptomen zelfs doen verergeren.

Er volgt nu een achtergrondverhaal over de historie van deze aandoening om de uitdagingen en de mogelijk succesvolle afloop te beschrijven die kunnen voortkomen uit het klinisch beheren van deze aandoening.

4. Voorbeeld van elektromagnetische overgevoeligheid

Dit geval betreft een 35-jarige, voordien gezonde vrouw, hoogopgeleid, getrouwd en moeder van twee kinderen. Drie weken nadat zij verhuisde naar een pas gerenoveerd huis bemerkte ze een abrupte verslechtering van haar gezondheid. Ze ontwikkelde een toenemende vermoeidheid, spierpijn, een achteruitgang in cognitieve vermogens, angst en niet eerder ervaren geheugenstoornissen. Dit werd zo erg dat ze meermaals vergat haar kinderen op te halen van de lagere school. Ondanks bezoeken aan meerdere artsen en het ondergaan van uitgebreide medische onderzoeken (inclusief MRI en CT-scans), verergerden haar symptomen. Ze zweette doorlopend 's nachts, kreeg last van misselijkheid, ernstige hoofdpijn, spierzwakte, spierpijn, en verloor ze bijna 10 kilo. Er werd geen medische verklaring gevonden en ze ontving diverse uiteenlopende medische diagnoses zoals allergische aandoeningen, een psychosomatische ziekte, multiple sclerose in een vroeg stadium en chronisch vermoeidheidssyndroom.

Wat echter opviel was dat als ze op reis ging, weg van haar onlangs gerenoveerde huis, haar symptomen opvallend verbeterden, om vervolgens in volle hevigheid terug te keren als ze weer thuis kwam. Ze

vermoedde dat haar woonomgeving mogelijk de oorzaak kon zijn. Deze reinigde ze grondig. Ze installeerde lucht- en waterzuiveringssystemen, en spande zich in om een perfect gebalanceerd dieet te eten. Ondanks haar inspanningen bleven de symptomen echter verergeren. In wanhoop zocht ze de hulp van andere (alternative) gezondheidsprofessionals en er werd haar uiteindelijk gesuggereerd dat ze mogelijk overgevoelig geworden was voor de elektromagnetische straling in haar huis.

Door scherpe observatie kon zij een duidelijk verband vaststellen tussen haar symptomen en de blootstelling aan de talloze elektrische apparaten in haar omgeving. Haar symptomen werden erger in de buurt van Tl-verlichting, magnetrons, en actieve keukenapparatuur. Ondanks dat ze haar blootstelling aan deze toestellen sterk wist te beperken, bleven 's nachts haar symptomen van misselijkheid, koorts, koude rillingen, trillen, en overgeven terugkomen. Als ze een nacht doorbracht in een motel, verminderden deze symptomen dan weer.

Naast haar eigen gezondheidsproblemen, bemerkte ze dat haar andere familieleden steeds vaker ziek waren. Haar kinderen ontwikkelden hardnekkige kwalen aan de luchtwegen en verscheidene oor- en keelontstekingen waarvoor herhaalde medische behandelingen nodig waren. Haar man ontwikkelde ook problemen met de luchtwegen waaronder longontsteking. Bij het zoeken naar de oorzaken van deze gezondheidsproblemen, vond zij een aantal problemen met het uitgassen van chemische stoffen vanwege de recente renovatie, en in het bijzonder, ontdekte ze een vlek op de vloer die verkeerd was afgewerkt en zwaar aan het uitgassen was. Bezorgd over de mogelijke gevolgen van het voortdurend uitgassen, de 200A elektrische voeding van hun huis, en de nabijheid van een elektrisch tussenstation, besloten ze om te verhuizen naar een omgeving met minder elektromagnetische velden (EMV) en minder blootstelling aan chemicaliën.

Na de verhuizing naar een wat ouder huis in de buurt van een natuurreservaat, begonnen haar symptomen te verbeteren, maar verdwenen niet helemaal totdat ze maatregelen nam om de hoeveelheid EMV in haar nieuwe omgeving te reduceren - maatregelen zoals het bekabelen van de internetverbinding en het 's nachts uitschakelen van de elektrische stroom van niet-essentiële apparaten. Haar gezondheid verbeterde vervolgens aanzienlijk en ze was in staat om weer deel te nemen aan de normale activiteiten, zoals fietsen met haar familie, skaten, en het maken van lange wandelingen. Nu dertien jaar later is haar gezondheid stabiel en is ze in staat om een actief normaal leven te leiden, maar ze neemt nog steeds maatregelen om blootstelling aan chemische stoffen en EMV zoveel mogelijk te vermijden.

De veronderstelling is dat deze voorheen gezonde persoon een te hoge belasting heeft gehad met giftige stoffen en daaruit voortvloeiende TILT nadat ze is verhuisd naar een gerenoveerd huis met diverse chemische blootstellingen. Een overgevoeligheidsreactie voor EMV volgde, resulterend in talloze klachten – die verdwenen als ze haar EMV blootstelling verminderde. Na haar verhuizing en het vermijden van verdere blootstelling, had ze minder last omdat haar lichaam in staat was om spontaan de toxische stoffen te elimineren door endogene mechanismen. Als gevolg van de verminderde totale toxische belasting, nam haar SRI langzaam af terwijl haar TILT afnam, en haar overgevoeligheid voor elektromagnetische triggers werd minder.

5. Overwegingen gevolgen kwaliteit van leven

Mensen die lijden aan EHS, worden steeds geconfronteerd met een aantal zaken. Een grote uitdaging i.v.m. EHS is, dat andere gezonde mensen EMV niet opmerken. De afwezigheid van waarneembare prikkels zorgt ervoor dat artsen, gezinsleden, vrienden, collega's en verzekeringsmaatschappijen de neiging hebben om de symptomen van EHS te bestempelen als psychisch of psychiatrisch (Rubin e.a., 2010; Kanaan e.a., 2007; Das-Munshi e.a., 2006; Rubin e.a., 2011). Met als gevolg dat patiënten met EHS vaak ervaren dat het belachelijk gemaakt wordt, of ontkend, of dat ze geïsoleerd raken van hun sociale omgeving. Dit heeft een vergaande invloed op vele aspecten van het leven zoals werk, huisvesting, gezondheidszorg, financiën en zorgt tevens voor een zware belasting op het sociale, emotionele en psychische vlak (Parsons, 2011).

5.1 Sociale gevolgen

EHS wordt door patiënten benoemd als een 'eenzame ziekte'. Door de overal aanwezige EMV in de hedendaagse stedelijke omgeving, komen EHS patiënten in een extreem sociaal isolement terecht. Door de ernstige symptomen zijn ze aan huis gekluisterd. Door de aanwezigheid van draadloze routers, mobiele telefoons, zendmasten en andere bronnen van EMV is het vaak een hachelijke onderneming om naar winkel, bibliotheek, theater, ziekenhuis of arts te gaan. Bovendien is het vaak voor vele patiënten niet meer mogelijk om op bezoek te gaan bij familie i.v.m. de daar aanwezige EMV. Dit levert voor relatie en gezin veel stress op – in het bijzonder als gezinsleden niet bereid zijn om EMV te verminderen in de thuissituatie. Fysieke en psychische symptomen leiden er vaak toe dat EHS patiënten zich ziek melden en velen stoppen uiteindelijk zelfs met werken. Het niet meer kunnen deelnemen aan vrijetijdsactiviteiten, waar ze voorheen nog van genoten, of aan zinvolle bezigheden, wordt verergerd door het gebrek aan inleving en verstoorde relaties met familie, collega's en de gezondheidszorg.

5.2 Lichamelijke en psychische gevolgen

Mensen met EHS vertonen vaak symptomen die een ondermijnende invloed hebben op lichamelijke regelsystemen zoals het centraal zenuwstelsel, stofwisseling en hormoonhuishouding. Die symptomen leiden tot voortdurende stress en inten-

se angst om op ieder moment 'getroffen' te worden door EMV, waar men ook is. Velen worden arbeidsongeschikt door die angst – wetende dat onzichtbare draadloze systemen overal en op ieder moment grote problemen kunnen veroorzaken in hun lichaam. Deze aanhoudende angst en constant bezig zijn met gezondheid, heeft een grote invloed op het welbevinden, zoveel zelfs dat mensen met EHS een fobie ontwikkelen en een wantrouwen tegen alles wat met elektriciteit te maken heeft en een verlangen naar het ontsnappen aan de moderne manier van leven.

Onderzoekers in Zweden ontdekten dat mensen met EHS een verhoogde status van angst, hyper-waakzaamheid en stress vertonen (Johansson e.a.,2010). Deze psychische factoren verergeren de ziekte en leiden tot een verhoogd risico op andere psychische stoornissen (De Luca e.a.,2010; Johansson e.a., 2010). Verder leidt het gebrek aan steun en acceptatie van hun naasten ertoe dat ze vaak gaan twijfelen aan hun eigen gezondheid en eigenwaarde. Uiteindelijk worden patiënten, door de onderliggende toxische belasting van EHS, vatbaar voor andere aandoeningen gerelateerd aan overgevoeligheid zoals fibromyalgie, het chronische vermoeidheidssyndroom en meervoudig chemische overgevoeligheid (Genuis, 2010a).

6. Discussie over de "echtheid" van EHS

Ondanks het feit dat EHS in de internationale literatuur in toenemende mate wordt herkend als een echte klinische aandoening (World Health Organization, 2011a;McCarty et al., 2011; Havas et al., 2010; Havas, 2000; World Health Organization, 2011b; Chemical Sensitivity Network, 2011), zijn er veel mensen die sceptisch blijven omtrent de geloofwaardigheid van het idee, dat een minderheid van de bevolking ziekte en gehandicapt zijn ervaart door de huidige "alledaagse" niveaus van EMV (Levallois, 2002). Sommigen beschouwen de "EHS-conditie" als een puur psychosomatische aandoening. (Rubin et al.,2010; Das-Munshi et al., 2006). Zij zien de term 'EHS" als een "verzonnen term die door mensen met hypochondrie én door alternatieve genezers wordt gebruikt om ongerelateerde medische problemen weg te verklaren" (National Post, 2011).

Dit standpunt wordt ondersteund door het feit dat veel studies niet in staat blijken om bij mensen een relatie aan te tonen tussen zelf gerapporteerde EHS en de werkelijke blootstelling aan EMV (Nam et al., 2009; Mortazavi et al., 2007). In feite blijkt dat veel van de studies laten zien dat mensen met zelfgerapporteerde EHS meer sensitief blijken bij apparaten die géén EMV afgeven dan bij die waarin dat wel het geval is (Frick et al., 2005).
In tegenstelling tot de meer recente dubbelblind studies, waarin wordt aangetoond dat er meetbare fysiologische veranderingen te constateren zijn als reactie op blootstelling aan EMV (McCarty et al., 2011), vinden Rubin et al. (2011) dat proefpersonen die zeggen te lijden aan EHS, geen abnormale fysiologische reacties vertonen ten gevolge van directe blootstelling aan EMV.
Uit 29 enkel en/of dubbelblind studies, waarin mensen zijn blootgesteld aan wél of géén EMV conditie (lees: ze zijn wel of niet bestraald) moet worden geconcludeerd dat de meeste studies geen significante verbanden laten zien tussen EMV en consistente symptomen, zoals gerapporteerd door de proefpersoon die zegt EHS te zijn. (Rubin et al., 2011).
Ten tweede: veel EHS patiënten, waarvan de functie van bepaalde hersengedeelten is afgenomen als gevolg van het bestralen met EMV, laten ook symptomen zien aan het centrale zenuwstelsel (zie par. 2.3), zoals op het gebied van stemming, cognitieve vaardigheden, waarneming en gedrag. Door de grillige natuur van deze conditie, die dus afhankelijk is van blootstelling van een stimulus (lees: EMV), worden veel EHS patiënten als onvoorspelbaar en onbetrouwbaar gezien, waardoor sceptici geneigd zijn de EHS-conditie als psychogeen te bestempelen. Als gevolg van deze verschillende factoren, hebben veel artsen, politici en groepen uit de industrie ervoor gekozen om EHS te bestempelen als een fictieve ziekte.

Echter: na het analyseren van al het beschikbare bewijs heeft de WHO in 2004 een fact sheet (artikel) uitgebracht, waarbij een 'niet-specifieke multisysteem ziekte" als gevolg van EMV blootstelling werd geïdentificeerd als 'elektromagnetische hypersensitiviteit" (EHS) (World Health Organization, 2011b). In mei 2011 heeft een groep medische wetenschappers een ontmoeting gehad met vertegenwoordigers van de WHO, die verantwoordelijk zijn voor de ontwikkeling van de International Classification of Diseases (ICD). De WHO liet weten bereid te zijn om kennis, komend van professionele en publieke bronnen, over het bewijs van het bestaan van EHS in hun beoordeling mee te willen nemen, teneinde de opname van EHS in de 11e versie van de ICD (die in 2015 zal uitkomen) te ondersteunen (Chemical Sensitivity Network, 2011).

Verschillende nationale regeringen hebben EHS erkend als een opkomend medisch probleem. Zweden (met een kwart miljoen mensen met EHS, zoals gerapporteerd in 2004 (Johansson, 2006)) classificeert EHS als een functionele handicap (of belemmering) (Johansson, 2006). Het Zweeds Chemisch Agentschap heeft om het risico op blootstelling aan giftige producten te verminderen (de 'bron" oorzaak van SRI en EHS) aanbevelingen gedaan in de vorm van een 'Substitutie Principe". In het betreffende artikel wordt de volgende aanbeveling gedaan: 'Als het risico van schade aan de omgeving en op menselijke gezondheid en veiligheid kan worden verminderd door een chemische stof of product te vervangen door een andere substantie of door een niet-chemische technologie, dan zal deze vervanging plaats moeten vinden" (Swedish Chemicals Agency, 2007).

Andere landen zijn ook begonnen met het introduceren van regel- en wetgeving in relatie tot EHS. Spanje bijvoorbeeld, beschouwt EHS als een permanente handicap (Grupo Medico Juridico, 2011), en de Canadese Commissie voor de Rechten van de Mens heeft EHS, als behorend bij de groep mi-

lieuziektes, als een handicap gezien dient te worden door de Canadese Federal Legislation (Sears, 2007a). Echter met de huidige tegenstrijdige resultaten van wetenschappelijk onderzoek over EHS, komen acties rond wetgeving en volksgezondheid bij veel overheden langzaam van de grond.

Welke overwegingen zouden de kennelijke tegenstellingen en tegenstrijdigheden in de resultaten en conclusies van wetenschappelijk onderzoek rond de legitimiteit van de EHS diagnose kunnen verklaren?

6.1. Antwoord op discussies rond de diagnose van EHS

❖ **Gebrek in bepaalde studies aan klinische respons (= reactie) op EMV**

Mensen die lijden aan EHS kunnen gevoelig zijn voor verschillende frequenties; niet alle elektromagnetische frequenties zijn hetzelfde. Precies zoals mensen met voedselintoleranties niet gevoelig zijn voor élk voedingsmiddel en 'chemisch" gevoelige personen niet reageren op blootstelling aan élke chemische stof, reageert een persoon met EHS niet noodzakelijkerwijs op alle frequenties in het elektromagnetische spectrum. Met andere woorden: als men een EHS patiënt test op meetbare fysiologische veranderingen door hem/haar bloot te stellen aan één bepaalde frequentie, dan kan het zijn dat men precies die frequentie mist, waar hij of zij nu juist gevoelig voor is. Het is dan hetzelfde alsof iemand wordt getest voor een voedsel intolerantie door hem/haar bloot te stellen aan één soort voedingsmiddel; of dat men een patiënt tracht te testen voor alle allergieën met slechts één allergeen.

❖ **Wisselende klinische reacties op EMV in bepaalde onderzoeken**

Voor degenen met SRI (zie par. 2.3) kunnen niveaus en intensiteit van intolerantie veranderen, zowel over de korte als de lange termijn (Genuis, 2010a; Ashford and Miller, 1998; Miller and Ashford, 2000). De intensiteit van de reactie kan wisselen afhankelijk van het veranderende niveau van de totale belasting van het lichaam, de (stralings) dosis die wordt toegediend, de algehele "ontstekingstoestand" van het lichaam, gerelateerde triggers, medicatie of het gebruik van natuurlijke gezondheidsmiddelen, algemene gezondheid, emotionele toestand en verscheidende andere zaken.

❖ **Vertraagde klinische reactie op EMV, zoals gevonden in bepaalde onderzoeken**

Klinische veranderingen na blootstelling aan een EMV stimulus/prikkel hoeft niet noodzakelijkerwijs direct op te treden, maar kunnen zich pas later openbaren. Evenals sommige ontstekingsreacties tijd nodig hebben om zichtbaar te worden, is het willen testen van een onmiddellijke reactie (als doel van wetenschappelijk onderzoek) niet altijd betrouwbaar.

❖ **Verschillende klinische resultaten bij verschillende proefpersonen**

Sommige studies die het bestaan van EHS willen weerleggen gebruiken een reductionistische benadering van het lijden van de proefpersoon. Elke persoon met EHS is een uniek individu die functioneert in een complexe omgeving en niet een machine in een laboratorium. In veel studies wordt getracht om een gecontroleerde (laboratoriumachtige) omgeving te scheppen, en dan worden conclusies getrokken; maar de conclusies die daaruit worden getrokken zijn echter niet zomaar te generaliseren naar de complexe omgeving waarin biochemisch- en genetisch unieke personen gewoonlijk leven en waar een veelvoud van, met elkaar samenhangende factoren, op de kwetsbare persoon van invloed kan zijn.

❖ **Psychische oorzaken (etiologie)**:

Nogal wat patiënten met EHS zijn in staat gebleken om te herstellen en hebben een aanhoudende gezondheid bereikt door middel van fysiologische behandelingen, zonder dat men gebruik heeft gemaakt van psychologische behandelingen. M.a.w. correctie van lichamelijke ziekteoorzaken lijken meer te werken dan behandelingen die zich richten op psychologische ziekte oorzaken. Dit suggereert dat er een lichamelijke basis bestaat voor op zijn minst een gedeelte van de EHS

❖ **Gebrek aan objectief bewijs**:

Anders dan bijvoorbeeld bij hoge bloeddruk of diabetes, waar geïsoleerde en vooraf bepaalde klinische markers een diagnose bepalen, is EHS niet gemakkelijk te meten door te kwantificeren criteria. Zonder objectieve markers zijn sommige professionals in de gezondheidszorg geneigd om de EHS diagnose niet serieus te nemen. In het algemeen komt EHS niet geïsoleerd voor. Het is vaak één onderdeel van een complex en meerdere gebieden betreffend gezondheidsprobleem dat voorkomt uit SRI (zie par. 2.3) (Genuis, 2010a; Dahmen et al., 2009; Sears, 2007b). EHS is een persoonsspecifiek ziektebeeld (syndroom) dat gebaseerd is op de totale omgevingsbelasting van deze persoon, op zijn of haar algehele gezondheid, en hoe hun unieke bio-elektrisch cellulaire chemie reageert op externe EMV. Personen met EHS kunnen lijden aan (ermee samenhangende) biochemische tekorten, een bioaccumulatie van toxische stoffen, evenals aan genetisch bepaald polymorfisme dat op cellulair niveau het ontgiftingsproces beïnvloedt, cognitieve neurologie en andere kenmerken van gezondheid en ziekte. (Landgrebe et al., 2008).

❖ **EHS druist in tegen de ervaring en snijdt geen hout:**

Omdat veel gezonde mensen EMV niet in hun omgeving kunnen waarnemen, kan het tegen de intuïtie in gaan om te accepteren dat er personen zijn die wel hinderlijke en negatieve fysieke symptomen ervaren als gevolg van kennelijk incidentele

blootstelling. Als gevolg daarvan willen veel wetenschappers en artsen niet de mogelijkheid overwegen of een dergelijke gevoeligheid zou kúnnen bestaan en wordt daarmee de ziekte als vanzelfsprekend en automatisch in de psychische hoek geplaatst. Het is instructief om in ogenschouw te nemen dat net als bij bepaalde gevoelige personen met een pinda allergie een levensbedreigende anafylactische shock kan ontstaan door blootstelling aan minuscule hoeveelheden alledaagse pinda's, mensen met EHS ziek kunnen worden van alledaagse niveaus van EMV.

❖ **Tegenstrijdige belangen**:

Gevoeligheid voor omgevingsfactoren heeft enorme implicaties voor bijvoorbeeld zaken die gerelateerd zijn aan verzekeringen, werkgelegenheid, mensenrechten, juridische kwesties, politieke initiatieven, wetgeving, industriële besluitvorming, levensstijl enz. Allemaal zaken van groot economisch belang. Zowel in de wetenschap en de medische wereld, als bij andere disciplines, zijn er mensen die zo nauw met bepaalde gevestigde belangen geassocieerd zijn, dat ze immuun lijken voor de waarheid, de resultaten van betrouwbaar onderzoek en voor waarneembare feiten (Michaels, 2008; Moynihan, 2003). Hoe overtuigend het bewijs van het tegenovergestelde ook mag zijn, sommige immorele of niet goed geïnformeerde wetenschappers blijven de belangen dienen van hun geldschieters. Of ze dienen de vastgeroeste ideeën en ideologieën die hen drijven. (Michaels, 2008; Angell, 2000). Er is gesuggereerd dat misschien sommige feiten over EHS zijn verdonkermaand en dat "bewijs" is gemanipuleerd om twijfel te zaaien; en om publieke gezondheidsmaatregelen tegen te houden ten aanzien van de regulering van zaken die te maken hebben met blootstelling (Genuis, 2008; Michaels,2008).

❖ **Vergelijkbare gevallen uit het verleden**

De geschiedenis laat keer op keer zien dat een ziekte/stoornis, die op een bepaald gebied niet past binnen het bestaande wetenschappelijke paradigma, niet automatisch als psychosomatisch of metafysisch niemendalletje kan worden afgedaan. Zo zijn er veel aandoeningen, van Parkinson tot maagzweren, die in de eerste instantie werden beschouwd als veroorzaakt door psychologische factoren, maar later moesten worden gezien als ziekten ten gevolge van fysieke oorsprong (Pall, 2007; Marshall, 2002

❖ **Het opnemen van nieuwe kennis binnen de klinische praktijk**

De medische geschiedenis laat consequent zien dat het incorporeren van nieuwe kennis binnen de klinische geneeskunde buitengewoon traag is. (Genuis, 2012; Genuis and Genuis, 2006; Doherty, 2005; Grol and Grimshaw, 2003). Momenteel wordt EHS algemeen genegeerd, belachelijk gemaakt of ontkend en wel op dezelfde manier zoals dat in verleden het geval is geweest met aandoeningen zoals darmzweren, migraine, multiple sclerose, en post traumatische stress stoornis (Pall, 2007).

7. Conclusies

De laatste 50 jaar is er een "man made" elektromagnetische revolutie op ontstaan, die een brede uitrol van elektronische apparatuur, draadloze systemen, elektrische machines, hoogspanningskabels en telecommunicatie zenders op gang heeft gebracht. In de komende 50 jaar zullen we getuige zijn van de gevolgen van deze ontwikkelingen. We hebben een ethische verantwoordelijkheid om de invloed van deze technologie op het menselijk lichaam te bepalen en om methoden te ontwikkelen om negatieve invloeden van deze technieken te onderzoeken en te behandelen.

Als patiënten met EHS worden blootgesteld aan bepaalde EMV frequenties ervaren ze niet-specifieke symptomen die verschillende systemen in het lichaam beïnvloeden. Velen raken gehandicapt en kunnen niet meer effectief functioneren in de maatschappij. Er komt echter steeds meer bewijs dat veel EHS patiënten succesvol klinisch behandeld kunnen worden en zij daardoor substantieel herstel kunnen bereiken.
Algemene aanbevelingen om mensen met SRI (zie Par. 2.3) en daarmee EHS te behandelen houden in dat men belastende omgevingsfactoren vermindert en vermijdt, de biochemische toestand verbetert, de voeding optimaliseert en zoveel mogelijk ontgift van toxische belasting (Genuis, 2010a). Daarnaast blijken sommige patiënten baat te hebben bij cognitieve therapie en neuro-feedback om psychologische stress aan te pakken en om vaardigheden aan te leren om beter om te gaan met EHS.

Nader onderzoek is nodig om de gedetailleerde patiofysiologie van EHS volledig te begrijpen en om de huidige therapieën te verbeteren om het lijden van de mensen die met deze aandoening te maken hebben te verlichten.
Er zijn dringend maatregelen nodig rond volksgezondheid, die ook publieksvoorlichting inhouden, evenals goede overheidsregulatie met betrekking tot het blootstellen van de bevolking aan chemisch giftige stoffen en EMV, om de volksgezondheid te bewaken en het stijgen van –te voorkomen- medische ziekten te stoppen. Het door Zweden geïntroduceerde 'Substitutie Principe" (zie par. 6.1), waarbij de minst risicovolle en meest duurzame strategie wordt aanvaard, is een logische benadering om innovatieve technologieën te promoten ter bescherming van de volksgezondheid en die van het individu.

In de wetenschappelijke literatuur is er recent bewijs gevonden voor het feit dat na blootstelling aan bepaalde elektromagnetische frequenties verscheidene objectief meetbare veranderingen zijn waar te nemen in sommige mensen die zeggen EHS te zijn (McCarty et al., 2011; Havas et al., 2010). Ten gevolge hiervan erkennen nu veel wetenschappers dat overgevoeligheid voor EMV een slopende medische conditie is die in toenemende mate mensen over de hele wereld treft.
Terwijl EHS patiënten enerzijds stappen kunnen

ondernemen wanneer ze eenmaal begrijpen hoe belangrijk dat is, om de blootstelling aan EMV te verminderen, zijn er anderzijds steeds meer artsen nodig die het ziekmakende mechanisme van EHS en SRI begrijpen (Genuis, 2010a) en die het vermogen hebben om de aandoening te diagnosticeren. Die in staat zullen zijn om het groeiende aantal lijdende mensen, die niet (of nauwelijks) gehoor krijgen voor hun verschillende ziektesymptomen, te helpen en te behandelen.

Of men nu gelooft of EHS een feit is of fictie, elke ethische hulpverlener in de gezondheidszorg, heeft uiteindelijk de plicht om oprecht te luisteren naar zijn of haar patiënten, met of zonder EHS, en om alles te doen, wat in zijn of haar vermogen ligt, om het lijden te verlichten.

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Planetary electromagnetic pollution: it is time to assess its impact

As the Planetary Health Alliance moves forward after a productive second annual meeting, a discussion on the rapid global proliferation of artificial electromagnetic fields would now be apt. The most notable is the blanket of radiofrequency electromagnetic radiation, largely microwave radiation generated for wireless communication and surveillance technologies, as mounting scientific evidence suggests that prolonged exposure to radiofrequency electromagnetic radiation has serious biological and health effects. However, public exposure regulations in most countries continue to be based on the guidelines of the International Commission on Non-Ionizing Radiation Protection[1] and Institute of Electrical and Electronics Engineers,[2] which were established in the 1990s on the belief that only acute thermal effects are hazardous. Prevention of tissue heating by radiofrequency electromagnetic radiation is now proven to be ineffective in preventing biochemical and physiological interference. For example, acute non-thermal exposure has been shown to alter human brain metabolism by NIH scientists,[3] electrical activity in the brain,[4] and systemic immune responses.[5] Chronic exposure has been associated with increased oxidative stress and DNA damage[6,7] and cancer risk.[8] Laboratory studies, including large rodent studies by the US National Toxicology Program[9] and Ramazzini Institute of Italy,[10] confirm these biological and health effects in vivo. As we address the threats to human health from the changing environmental conditions due to human activity,[11] the increasing exposure to artificial electromagnetic radiation needs to be included in this discussion.

Due to the exponential increase in the use of wireless personal communication devices (eg, mobile or cordless phones and WiFi or Bluetooth-enabled devices) and the infrastructure facilitating them, levels of exposure to radiofrequency electromagnetic radiation around the 1 GHz frequency band, which is mostly used for modern wireless communications, have increased from extremely low natural levels by about 10^{18} times (figure). Radiofrequency electromagnetic radiation is also used for radar, security scanners, smart meters, and medical equipment (MRI, diathermy, and radiofrequency ablation). It is plausibly the most rapidly increasing anthropogenic environmental exposure since the mid-20th century, and levels will surge considerably again, as technologies like the Internet of Things and 5G add millions more radiofrequency transmitters around us.

Unprecedented human exposure to radiofrequency electromagnetic radiation from conception until death has been occurring in the past two decades. Evidence of its effects on the CNS, including altered neurodevelopment[14] and increased risk of some neurodegenerative diseases,[15] is a major concern considering the steady increase in their incidence. Evidence exists for an association between neurodevelopmental or

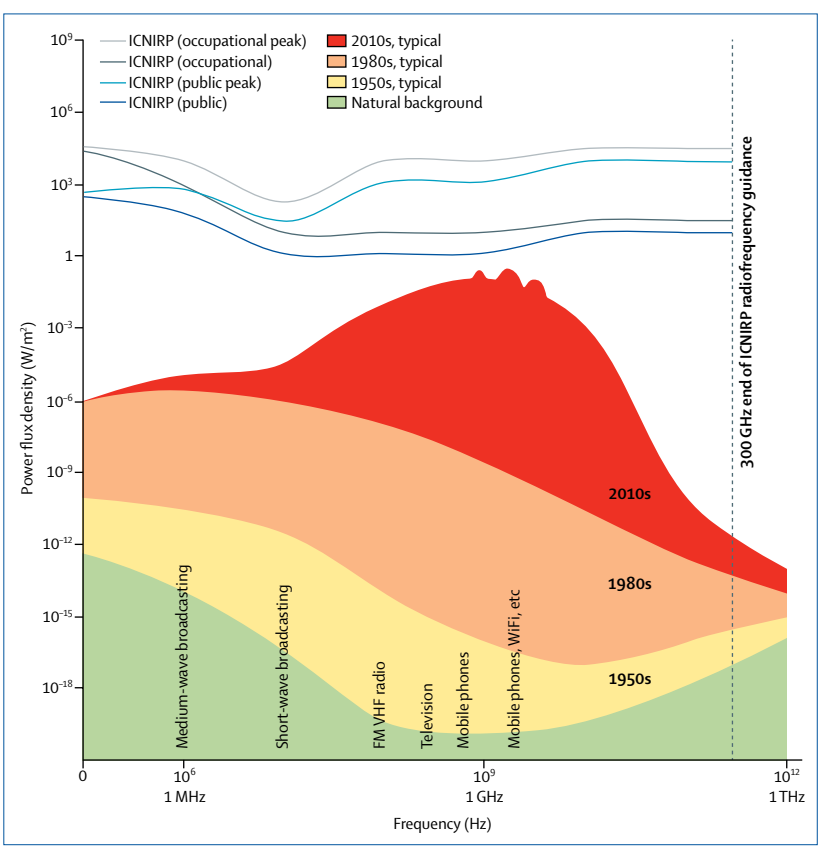

Figure: **Typical maximum daily exposure to radiofrequency electromagnetic radiation from man-made and natural power flux densities in comparison with International Commission on Non-Ionizing Radiation Protection safety guidelines[1]**

Anthropogenic radiofrequency electromagnetic radiation levels are illustrated for different periods in the evolution of wireless communication technologies. These exposure levels are frequently experienced daily by people using various wireless devices. The levels are instantaneous and not time-averaged over 6 minutes as specified by International Commission on Non-Ionizing Radiation Protection for thermal reasons. Figure modified from Philips and Lamburn[12] with permission. Natural levels of radiofrequency electromagnetic radiation were based on the NASA review report CR-166661.[13]

behavioural disorders in children and exposure to wireless devices,[14] and experimental evidence, such as the Yale finding, shows that prenatal exposure could cause structural and functional changes in the brain associated with ADHD-like behaviour.[16] These findings deserve urgent attention.

For the **Oceania Radiofrequency Scientific Advisory Association** see www.orsaa.org

At the Oceania Radiofrequency Scientific Advisory Association, an independent scientific organisation, volunteering scientists have constructed the world's largest categorised online database of peer-reviewed studies on radiofrequency electromagnetic radiation and other man-made electromagnetic fields of lower frequencies. A recent evaluation of 2266 studies (including in-vitro and in-vivo studies in human, animal, and plant experimental systems and population studies) found that most studies (n=1546, 68·2%) have demonstrated significant biological or health effects associated with exposure to anthropogenic electromagnetic fields. We have published our preliminary data on radiofrequency electromagnetic radiation, which shows that 89% (216 of 242) of experimental studies that investigated oxidative stress endpoints showed significant effects.[7] This weight of scientific evidence refutes the prominent claim that the deployment of wireless technologies poses no health risks at the currently permitted non-thermal radiofrequency exposure levels. Instead, the evidence supports the International EMF Scientist Appeal by 244 scientists from 41 countries who have published on the subject in peer-reviewed literature and collectively petitioned the WHO and the UN for immediate measures to reduce public exposure to artificial electromagnetic fields and radiation.

For the **International EMF Scientist Appeal** see www.emfscientist.org

Evidence also exists of the effects of radiofrequency electromagnetic radiation on flora and fauna. For example, the reported global reduction in bees and other insects is plausibly linked to the increased radiofrequency electromagnetic radiation in the environment.[17] Honeybees are among the species that use magnetoreception, which is sensitive to anthropogenic electromagnetic fields, for navigation.

Man-made electromagnetic fields range from extremely low frequency (associated with electricity supplies and electrical appliances) to low, medium, high, and extremely high frequency (mostly associated with wireless communication). The potential effects of these anthropogenic electromagnetic fields on natural electromagnetic fields, such as the Schumann Resonance that controls the weather and climate, have not been properly studied. Similarly, we do not adequately understand the effects of anthropogenic radiofrequency electromagnetic radiation on other natural and man-made atmospheric components or the ionosphere. It has been widely claimed that radiofrequency electromagnetic radiation, being non-ionising radiation, does not possess enough photon energy to cause DNA damage. This has now been proven wrong experimentally.[18,19] Radiofrequency electromagnetic radiation causes DNA damage apparently through oxidative stress,[7] similar to near-UV radiation, which was also long thought to be harmless.

At a time when environmental health scientists tackle serious global issues such as climate change and chemical toxicants in public health, there is an urgent need to address so-called electrosmog. A genuine evidence-based approach to the risk assessment and regulation of anthropogenic electromagnetic fields will help the health of us all, as well as that of our planetary home. Some government health authorities have recently taken steps to reduce public exposure to radiofrequency electromagnetic radiation by regulating use of wireless devices by children and recommending preferential use of wired communication devices in general, but this ought to be a coordinated international effort.

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