Sudbury to Hudson Reliability Project - EMF Position Paper

Protect Sudbury
December 2020

The plans that Eversource has established for the integration of a high voltage transmission line and recreational trail could expose recreational users to unsafe levels of EMF, in excess of EFSB guidelines, for prolonged periods of time and should be rejected. As the Exponent Report in Eversource's Petition indicates, the magnetic field above the transmission line could be as high as 88 mG and 99 mG during peak load periods, and 24mG – 28 mG during average load periods.[1] Though the Study provides lower EMF exposure at distances of 25 feet from centerline,[2] the proposed recreational path would either be directly above the transmission line, or directly adjacent to it.[3] It is reasonable to assume that users of the recreational path would be exposed to the maximum EMF levels produced by the transmission line for the entire duration of the time spent on the recreational path. That exposure could last upwards of hours each time the trail is accessed. Further, since the recreational path will be in use during peak electric hours during the day, it is reasonable to assume that recreational users will be exposed to peak loadings on the line.

The Siting Board has established a guideline of 85 mG of magnetic field at the edge of the ROW in its Decision in Massachusetts Electric Company/New England Power Company, 13 DOMSC 119, at 228-242 (1985), and has used this guideline in successive cases to determine whether anticipated magnetic field levels were "unusually high".[4] This guideline is widely recognized as an upper limit for acceptable prolonged exposure to EMF in Massachusetts. Indeed, Eversource has listed this standard in its response to Protect Sudbury data requests in Attachment Protect-50(1).

Though, the Siting Board has not held this guideline out to be an upper limit, it is clear through the reasoning in its Decisions that its intent is that prolonged exposure to the public should remain at levels below 85 mG. For example, in EFSB 00-3, the Siting Board determined that EMF levels were acceptable as they dropped below 85 mG at the edge of the ROW:

> Because the proposed transmission line would lie almost entirely in city streets, there is no well-defined edge-of-ROW for the project; however, the record shows that the street and sidewalk areas provide

[1] Eversource Petition EFSB17-02, Appendix 5-10, Exponent, Sudbury to Hudson Transmission Line Reliability Project, Electric Field and Magnetic Field Assessment (March 27, 2017) Table 3, at page 15.

[2] EMF falls off to between 12 mG to 16 mG during peak periods at a distance of 25 feet, and 3.4 mG to 4.4 mG at 25 feet during periods of average loading.

[3] Eversource Petition EFSB-17-02, Section 5, at 5-13 and 5-14, indicating that the 4-foot wide duct banks that house the transmission line, will be offset from the 14 foot multi-use access road (bike path) by 2 feet (also shown at Exhibit 5-16 with an offset of only 1 foot, and proposed splice vaults will be partially under the multi-use access road, and the transmission line will traverse directly under bridges. Also see Exhibit EV-18, Appendix 2-1, at 15.

[4] EFSB Decision 00-3; D.T.E. 00-103, Cambridge Electric Light Company, at 37.

> an "effective ROW" of at least 10 feet in width. Outside this effective ROW, magnetic fields associated with the transmission line would drop below 85 mG. Thus, although the Company has not specifically designated a ROW for its proposed transmission line, the magnetic field levels associated with the proposed project appear to be consistent with levels approved in the 1985 MECo/NEPCo Decision."[5]

Also, in EFSB 08-1, the Siting Board found that ROW levels would remain below the guideline.

> Here, the record shows that outside the facility site, electric field would be essentially unchanged by the project, and edge-of-ROW levels for both fields would remain below levels previously accepted by the Siting Board."[6]

The EFSB Tentative Decision in this (Sudbury to Hudson Reliability Project) case, listed EMF metrics at average loadings at distances of 5 and 10 feet from the transmission line, and found that exposure levels were acceptable.[7] First, as indicated above, the multi-use path will either be at a 1-foot offset from the duct bank, or will be either partially or fully above the transmission line, e.g., in the cases of splice vaults and bridges. According to Eversource's response to interrogatories by the Sudbury Conservation Commission, 33 percent of the transmission line in Sudbury will run down the center of the ROW (the center of the proposed multi-use path). The bridges will literally house the transmission line, with zero offset. Second, it is unclear why the Siting Board would disregard the peak loadings at 88 to 99 mG in its Decision, which are clearly in excess of the Siting Board's 85 mG safety guideline. Unless it is known what the loading durations of the line will be, it cannot be assumed that the line would not violate the Siting Board's safety guideline or consistently operate at average loading. This is particularly important because the recreational path will be most heavily used during the day when electric consumption is at its peak. For this reason, it is prudent to assume peak loading. The information presented by Eversource to the EFSB ignores the fact that users of the recreational path will receive continuous exposure to levels of EMF beyond acknowledged safety guidelines.

It is important to note that the EFSB's application of its safety guideline mentioned above do not pertain siting of transmission lines adjacent to or underneath public recreational trails. The Siting Board's decisions imply that exposure to EMF would be measured in seconds, not hours. Because the transmission line will be integrated with a recreational path, the general public will spend many hours on the ROW. Some may use it for hours every day, perhaps pushing an infant in a baby stroller. The EMF that will be emitted from the multi-use path in one hour would exceed levels that many states and countries consider acceptable. For example, Sweden and Switzerland limit EMF exposure to 1.0 mG and 2.5 mG, respectively, averaged over a 24-hour period; and California limits EMF levels in schools to 1.2 mG and some American cities limit indoor residential levels

[5] Ibid.

[6] EFSB Decision EFSB 08-1, at 37.

[7] EFSB Tentative Decision EFSB 17-02, at pp. 154-155.

(e.g. Brentwood, TN and Irvine, CA) to 4mG.[8] That is, one should not be exposed to greater than those levels averaged over a 24-hour period. It is possible that one hour spent on the multi-use path at peak loading, in itself, would cause a violation to the above referenced safety thresholds.

Though the science on the potential health effects of EMFs is generally considered inconclusive, there have been a multitude of epidemiological studies conducted that clearly identify an association between EMFs and certain forms of cancer, particularly leukemia in children, neurodegenerative disorders, and brain cancer in adults. The inconclusive aspect of these studies is that they have failed to pinpoint a clear causal factor in high voltage transmission lines that results in the associated greater incidence of cancer and neurological impacts. However, the results of the epidemiological studies have consistently found an association between leukemia, brain cancer and neurodegenerative disorders associated with EMF exposure. Below is a summary of epidemiological studies on the impacts of EMF, chronicled by Dr. David Carpenter, a Professor in the Department of Environmental Health Sciences at the University of Albany, in his testimony before the New Jersey Board of Public Utilities:[9]

- U.S. National Academy of Science (1997) found that relationship between power line wire-code rating and childhood leukemia "is statistically significant (unlikely to have arisen from chance) and is robust."
- National Institute of Environmental Health Sciences EMF-RAPID program (1999) found "strongest evidence for health effects comes from associations observed in human populations with two forms of cancer: childhood leukemia and chronic lymphocytic leukemia in occupational exposed adults. While the support from individual studies is weak, the epidemiological studies demonstrate, for some methods of measuring exposure, a fairly consistent pattern of a small, increased risk with increasing exposure that is somewhat weaker for chronic lymphocytic leukemia than for childhood leukemia."
- World Health Association (2007) found that epidemiological data "show an association between ELF magnetic field exposure and an increased risk of childhood leukemia."
- Wattenberg (1998) concluded that "the observed results identify a consistent risk that cannot be explained by random variations."
- Greenland et al. (2000) reported a significantly elevated risk of 1.68 (68% increase in childhood leukemia).
- Ahlbom et al. (2000) found an elevated risk of 2.0 (doubling of incidence) of childhood leukemia from exposures equal or greater than 4 mG as compared with less than 1 mG.
- Draper et al. (2005) found a dose-dependent relationship, with relative risk of leukemia in children being 1.69 (69% increase) for children living within 200 meters from the line, and the relative risk being 1.23 (23% increase) for children living from 200 to 600 meters from the line, as compared to those more than 600 meters away. The trend of increased risk based on closeness to the power line was statistically significant ($p<.01$).

---

[8] Data re.: EMF exposure limits can be found at EMF & RF Safety Levels – A Comparative Guide, www.scantech7.com.

[9] Reply Testimony of David O. Carpenter, in the Monmouth County Reliability Project Docket PUC-12098-16, Exhibit RAGE-2 [not all studies were listed due to redundancy or lack of relevance].

- Foliart et al. (2006) examined the relation between magnetic field exposure and the survival of children with acute lymphoblastic leukemia and found a hazard ratio of 4.5 times the risk for children exposed to greater than 3 mG magnetic fields as compared to less than 1 mG.
- Svendsen et al. (2007) found a hazard ratio of 2.6 times the risk for the survival of children with acute lymphoblastic leukemia exposed to 2 mG during recovery as compared to those exposed to less than 1 mG.
- Lowenthal et al. (2007) found an increased risk of 3.23 times of adult lympho-proliferative and myeloproliferative cancers for adults who lived within 300 meters of a high-voltage power line during the first 15 years of life; and rose to 4.74 times for those who lived within 300 meters of a power line in the first 5 years of life.
- Infante-Rivard and Deadman (2003) found that maternal exposure during pregnancy increased the risk of children 0-9 years of age of developing leukemia by a risk factor of 2.5 times for children of mothers in the highest 10% of exposure.
- Li et al. (2009) found that maternal occupational exposure to ELF-EMF resulted in a 2.3 times, statistically significant risk of offspring developing brain cancer.
- Savitz and Ahlbom (1994) reported elevated leukemia mortality among Swiss railway employees exposed to magnetic fields.
- Kehifets et al. (1995) performed a meta-analysis of 29 reports of brain cancer and found statistically significant elevations for electrical engineers, welders, and power station workers with high occupational EMF exposure.
- Zhao et al. (2014) reported a statistically significant 1.25 times elevated risk of breast cancer in post-menopausal women for women that were occupationally exposed to elevated magnetic fields.
- Soffritti et al. (2016) found that ELF-EMF increased risks of breast cancer, malignant schwannomas and lymphoma/leukemia in a dose dependent fashion in rats; and the ELF-EMF promotes carcinogenic effects of ionizing radiation.
- Reif et al. (1995) found that pet dogs living in homes characterized by high or very high wire codes have increased rates of lymphoma at a level that is statistically significant.
- Qiu et al. (2004), Feychting et al. (2003) and Hakansson et al. (2003) found a statically significant elevated risk for Alzheimer’s disease with ELF-EMF exposure, approximately two or three times the incidence in a control population.
- Lichtenstein et al. (2000) found that environmental factors were the initiating event in the majority of cancers.
- Yang et al. (2008) found that children who live within 100 meters of a power line or transformer and have a certain gene (the XRCC! Ex9 + 16A allele of a DNA repair gene) have an increased risk 4.31 times greater (400+ increase) of developing leukemia than children with the same exposure that did not have this gene.
- Leszczynski et al. (2002,2004), Olivares-Banuelos et al. (2004), Lupke et al. (2006), Zhao et al. (2007) all found that EMFs alter cell physiology and function and that EMF inhibit differentiation of an erythroleukemia cell line, affect gene transcription, induce the synthesis of stress proteins (Goodman and Blank, 2002; Tokalov and Gutzeit, 2004), and cause breakage of DNA (Svedenstal et al., 1999; Invanscits et al., 2003), probably through the generation of reactive oxygen species (Lai and Singh, 1995, 2004).

The World Health Organization takes a clear stand on the risks presented by EMF, in its Report it states:

> "New human, animal, and in vitro studies published since the 2002 IARC Monograph, 2002 [*sic*] do not change the overall classification of ELF (EMF) as a possible human carcinogen." [10]

The epidemiological studies' findings are consistent and clear. There is an increased dose-related risk of cancer and neurodegenerative disorders due to increased and elevated EMF exposure above 4 mG in children, adults, fetuses and animals. Though there have been studies that have reported dissimilar or weaker findings, this does not forestall the findings of peer-reviewed studies that have proven statistical associations between EMF and cancers and neurodegenerative diseases. As a result, there is a need to continue to study; and policy makers must exercise caution so as not to put the public at risk. The answers are undoubtedly complex. Cancer and Alzheimer's disease are complicated diseases that are likely caused by many combinations of factors. However, the clear association that study after study finds between increased EMF exposure and disease cannot be ignored.

Until there is a better understanding of the health effects of EMFs, it is incumbent on our public officials to err on the side of caution to protect the public safety and place transmission lines at a safe distance from residences and public access ways, where children are likely to be playing. A recreational path that poses a potential health risk to the citizens of Sudbury could never be in the public interest. This project as proposed will expose users of the recreational path to unsafe levels of EMF (as high as 99 mG in one hour) – well in excess of the daily dosages generally considered safe of between 2 mG to 4 mG averaged over a 24-hour period, and above the level the EFSB has previously accepted to be safe (85 mG). Co-locating a rail trail with a transmission line could, under the appropriate circumstances, provide a unique and beneficial solution to both electric reliability and community enhancement, without endangering the community. But in this case, the ROW is too narrow, the recreational path too close to the transmission line, and the EMF exposure too high. This Sudbury to Hudson Reliability transmission line that is proposed to traverse beneath or adjacent to a Sudbury recreational path, as currently planned, must be rejected on the basis of elevated EMF exposure levels and the potential risk to public safety.

---

[10] WHO 2007, at 347.

Toxicological & Environmental Chemistry, Apr.–June 2006; 88(2): 287–299

Taylor & Francis
Taylor & Francis Group

The incidence of electromagnetic pollution on the amphibian decline: Is this an important piece of the puzzle?

ALFONSO BALMORI

Direccion General del Medio Natural, Consejería de Medio Ambiente, Junta de Castilla y Leon, C/Rigoberto Cortejoso, 14, 47014 Valladolid, Spain

(Received 26 October 2005)

Abstract
A bibliographical review on the possible effects of radiofrequency radiation (RFR) from wireless telecommunications on living organisms and its impact on amphibians is presented. The technical characteristics of this new technology and the scientific discoveries that are of interest in the study of their effects on wild fauna and amphibians are described. Electromagnetic pollution (in the microwave and in the radiofrequency range) is a possible cause for deformations and decline of some amphibian populations. Keeping in mind that amphibians are reliable bio-indicators, it is of great importance to carry out studies on the effects of this new type of contamination. Finally, some methodologies that could be useful to determine the adverse health effects are proposed.

Keywords: *Athermal effects, electromagnetic pollution, effects on amphibians, microwaves, phone masts*

Introduction

Amphibians are important components of the ecosystem and reliable bio-indicators; their moist skin, free of flakes, hair or feathers, is highly permeable to water chemicals (particularly larvae) and air pollutants (especially adults). Amphibian eggs are also directly exposed to chemicals and radiation. These characteristics make amphibians especially sensitive to environmental conditions, changes of temperature, precipitation or ultraviolet (UV) radiation and reliable monitors of local conditions [1].

A recent report from the International Union for Conservation of Nature (IUCN), prepared by 500 scientists from 60 countries, analyzed populations of 5743 amphibian

Correspondence: Alfonso Balmori, Direccion General del Medio Natural, Consejería de Medio Ambiente, Junta de Castilla y Leon, C/Rigoberto Cortejoso, 14, 47014 Valladolid, Spain. Tel.: 983/419439. Fax: 983/419933. E-mail: balmaral@jcyl.es; abalmori@ono.com

ISSN 0277-2248 print/ISSN 1029-0486 online
DOI: 10.1080/02772240600687200

species in the world and concluded that 1856 (32%) of them were considered threatened of extinction. Nine species have become extinct since 1980 and another 113 have not been observed in the recent years, and probably are also extinct [2]. The results demonstrate that amphibians are far more threatened than either birds or mammals, and the factors causing 'enigmatic' declines are driving the species toward extinction particularly rapidly. Unless these declines are quickly understood and reversed, hundreds of amphibian species can be expected to become extinct over the next few decades [3]. The disappearance of amphibians together with other organisms is a part of the global biodiversity crisis [4,5].

An associated phenomenon is the appearance of large numbers of deformed amphibians, with absent or extra limbs [5]. From 1995, at least 60 different species were affected with a high incidence of deformities, with several species affected in one place, in 46 states of United States and in regions of Japan, Canada, and several European countries [5,6]. The problem seems to have become more prevalent, with deformity rates of up to 25% in some populations, which is significantly higher than in previous decades [6].

The problem of deformities is complex because it is related to water quality, physiology, development, anatomy, and ecology [5]. The reduction in populations and the increase in deformities are a warning of serious environmental degradation [5].

Evidence exists that several populational declines are probably the result of complex interactions among several biotic and abiotic factors [1,4,7,8]. The proposed explanations are an increase of ultraviolet radiation (UV-B)[1,5,9–14]; chemical pollutants (pesticides, herbicides, fungicides, fertilizers, etc.) [5,15]; pathogen and parasites [1,6,16], destruction and alteration of habitat, changes in meteorological patterns (climatic change) [4,17], and introduced species [1,5].

The amphibian population declines are also occurring in relatively pristine places such as National Parks, or rural areas far from urban centers [3,14]. Humans and other animals can also be affected by the same environmental factors that damage amphibians [6].

A type of contamination whose effects on amphibians have not been studied up to now, is the electromagnetic pollution, especially microwaves and radiofrequencies from mobile telecommunications and radio station transmitters that will be discussed in this review. Before the 1990s, radiofrequencies were mainly from a few radio and television transmitters, located in remote areas and/or very high places. Since the introduction of wireless telecommunication in the 1990s, the rollout of phone networks has seen a massive increase in the electromagnetic contamination in cities and in the wilderness [18,19]. At the moment, new types of antennas are being investigated to reduce the power needed to establish communication [20,21]. Recently, there has also been an increase of other wireless transmitters (radio or television stations).

The objective of this review is to detail advances in the knowledge of biological mechanisms and effects from radiofrequencies and microwaves on animals, and some considerations are made on its possible relationship with deformations and the population decline of amphibians.

Main causes of populational decline and appearance of deformations in amphibian populations

Ultraviolet radiation

UV-B radiation (1) induces mutations and cellular death, (2) weakens the immune system, (3) reduces growth, and (4) induces several types of damage, like malformations of the limbs, body, and eyes [1,5,12,14]. Not all the species respond in the same way [14]. Embryos with higher photolyase levels (DNA photorepair enzyme) are more resistant to UV-B radiation [11,12].

The eggs of some of the amphibian species experienced high mortality that may contribute to the populational declines [9]. UV acts in conjunction with other agents like pesticides to induce defects in the development [10]. UV also decreases defense mechanisms against illnesses making individuals more susceptible to pathogen and parasites, affecting normal development and increasing mortality that consequently impacts on the decline of some populations [10]. The egg mass protected from UV-B radiation have significantly more hatching, less deformities, and develop more quickly [10].

Synergy between a pathogenic fungus and UV-B radiation increased mortality among amphibian embryos [12]. The synergy may occur when developing amphibians have reduced ability to respond to a stressor in the presence of another stressor. For example, contamination exerts more deleterious effects with UV-B [1]. Animals use molecular and physiologic mechanisms and certain behaviors [22] to limit their exposure to UV-B and repair from UV-B damage [14].

Although cellular repair mechanisms of several species are not effective in the presence of persistent increase in UV-B radiation levels [14], amphibians are relatively resistant to this radiation if they can repair the damage effectively [14]. In some species, photoreactivation is the most important repair mechanism of UV-damaged DNA [9]. Heat shock proteins may also play a role in protecting cells from UV-B damage, since they prevent the denaturation of proteins during exposure to environmental stress [14].

Chemical pollutants

Chemical pollutants appear in areas where pesticides and fertilizers are applied extensively and produce mortality and deformities in amphibians. Although on a broad scale, no correlation between pesticide contamination and amphibian deformities was found, pesticides cannot be completely ruled out as causal agents [5].

Pathogens and parasites

Three pathogens received attention recently for having produced an amphibian populational decline in some areas: *Batrachochytrium denderobatidis*, *Saprolegnia ferax*, and an iridovirus (*Ambystoma tigrinum virus*) [1]. The parasite *Ribeiroia ondatrae* is an important source of malformations of amphibian extremities in western USA [16]. Larvae with malformations experience higher mortality before and during metamorphosis than the normal ones. The relevance of infection by *Ribeiroia* and the influence of habitat alteration on the pathology and biological cycle of this trematode, requires further investigation [16]. In relative pristine environments, the incidence of snails infected with *Ribeiroia* is low, but the habitat alteration can increase the rate of infestation [16]. Infection of amphibian larvae by the trematode *R. ondatrae* may represent a threat to amphibians or species in decline. Although deformities can be the cause of declines in some places, numerous populations of amphibians have greatly declined in the absence of any deformity, for which there must be other factors [6].

Climatic change

Climatic change influences breeding patterns of certain organisms which affect their populational structure and may be reflected in the populational declines of very sensitive species such as amphibians. The pattern found up to now in the published studies is that some anurans of temperate areas show an early reproduction tendency [17]. Climate-induced reductions in water depth at egg-laying sites produced high embryo mortality by increasing their exposure to UV-B radiation which is more worrying than the reduction in ozone layer. Climate also increases their vulnerability to *S. ferax* [4].

Physical and technological characteristics of mobile telephone

Electromagnetic radiation (EMR) transmits small packages of energy denominated photons [23]. The radiofrequencies occupy the range from 10 MHz to 300 GHz. Cellsite antennae emit a frequency of 900 or 1800 MHz, pulsed at low frequencies, generally known as microwaves (300 MHz–300 GHz). Microwaves carry sound information by blasts or pulses of short duration, with small modulations of their frequency, that are transferred between wireless phones and base stations over dozens of kilometres.

The main variable that measures these radiations is 'power density' (measured in $W\,m^{-2}$, or $\mu W\,cm^{-2}$) expressing radiant power that impacts perpendicularly to a surface, divided by the surface area; and 'electric field intensity' (measured in $V\,m^{-1}$), a vectorial magnitude to the force exercised on a electric loaded particle, independent of their position in space.

For a concrete address with relationship to an antenna, the power density at a point varies inversely proportional to the square of the distance to the source. Though EMR have many and varied outputs, at a distance of 50 m the power density is about $10\,\mu W\,cm^{-2}$ [24], while at distances of 100 m at ground level it measures above $1\,\mu W\,cm^{-2}$ (pers. obs.). Between 150 and 200 m, the power density of the main lobe near the ground is typically some tenth of $1\,\mu W\,cm^{-2}$ [25].

Experimental difficulties

Experiments that study the effects of EMR on living organisms are complex, since a high number of variables exist that need to be controlled. Microwave radiation produces different effects depending on certain methodological positions such as frequency, power, modulation, pulses, time of exposure, etc. [26–28]. Some studies demonstrated different microwave effects depending on the wavelength in the range of mm, cm or m [28,29]. The dose–response relationships (of non-thermal effects), are not simple to establish since they present a non-linear relationship [30–32].

Pulsed waves (in blasts), as well as certain low frequency modulations exert greater biological activity [26,28,31,33]. These radiations also have accumulative effects that depend on the duration of exposure [19,34,35]. It is possible that each species and each individual, show different susceptibility to radiations, since the vulnerability depends on the genetic tendency, and the physiologic and the neurological state of the irradiated organism [31,36–41].

Effects and action mechanisms on biological systems

One of the well known effects of microwaves is their capacity to excite water molecules and other components in food, elevating their temperature. The resulting heating level depends on the radiation intensity and the exposure time. At a power density above $500\,\mu W\,cm^{-2}$

(microwave ovens) heating effects take place, below that level the effects are 'athermal non-heating'.

Animals are sensitive complex electrochemical systems that communicate with their environment through electrical impulses. In cellular membranes and body fluids, ionic currents and electrical potential exist [42]. Electromagnetic fields (EMFs) generated in biological structures, are characterized by certain specific frequencies. It is possible a frequency-specific, non-thermal electromagnetic influence, of an informational nature exists [25,31,43]. Some organs or systems like the brain, heart, and nervous system are especially vulnerable.

The wave systems have properties such as the frequency, which affect resonance capacity of living organisms to absorb the energy of an electromagnetic field [25]. Electromagnetic fields induce biological effects at "windows of frequency" (window effect) [44]. Living organisms are exposed to variable levels of radiofrequency electromagnetic fields, according to (1) distance to phone masts, (2) presence of metallic structures which are able to reflect or obstruct the waves (buildings or other obstacles), (3) number of phone masts, and (4) orientation and position [24].

Microwaves emitted by phone antennae affect organisms living in their vicinities, like vertebrate [45–47], insects [48–55], vegetables [56–58], and humans [25,31,59–63]. Small organisms are especially vulnerable: size approach to resonance frequency and thinner skull, facilitates an elevated penetration of radiation into the brain [24,31,64]. In a recent study carried out with bees in Germany, only few irradiated bees returned to the beehive and required more time to reach the hive. The weight of honeycombs is also smaller in the bees that were irradiated [54].

The microwave effects were investigated in a variety of living organisms, but the results found in vertebrates have special interest to amphibians. For more than 30 years, there is growing evidence on the existence of athermal effects on birds [65,66]. The exposed animals suffer a deterioration of health in the vicinity of phone masts [67,68]. Rats spent more time in the halves of shuttle boxes that were shielded from illumination by 1.2 GHz microwaves. The average power density was about $0.6\,\mathrm{mW\,cm^{-2}}$. Data revealed that rats avoided the pulsed energy, but not the continuous energy, and less than $0.4\,\mathrm{mW\,cm^{-2}}$ average power density was needed to produce aversion [69]. Navakatikian and Tomashevskaya [70] described a complex series of experiments in which they observed disruption of a rat behavior (active avoidance) by radiofrequency radiation (RFR). Behavioral disruption was observed at $0.1\,\mathrm{mW\,cm^{-2}}$ ($0.027\,\mathrm{W\,kg^{-1}}$) power density.

It has been documented that the radiofrequencies induce biological effects on biomolecules [27,51,71] that include changes in intracellular ionic concentration [72,73], cellular proliferation [74], interferences with immune system [19,75,76], effects on animals reproductive capacity [77,78], effects on stress hormones [79], in intrauterine development [80], genotoxic effects [81–87], effects on the nervous system [32,88–92], the circulatory system [93,94], and a decline in the number of births [47,95]. Firstenberg [18] proposed a connection between EMR, deformations, and the worldwide decline and extinction of amphibians.

Evidence that electromagnetic contamination may be responsible for the appearance of deformities and decline of amphibians

Some athermal effects of EMR on amphibians have been well known for more than 35 years [96,97]. The radiation of frogs with $30–60\,\mathrm{\mu W\,cm^{-2}}$ produced a change in the heart rhythm, probably due to the nervous system activation (Levitina, 1966 cited in [96]). When toad hearts were irradiated with pulses of 1425 MHz at a power density of $0.6\,\mu W\,cm^{-2}$, an increase in the heart rate and arrhythmia were observed [96]. Radiofrequency burst-type dilated arterioles were observed on the web of the anaesthetized frog (*Xenopus laevis*) by a athermal non-heating mechanism [93].

The exposure to magnetic fields on two species of amphibians induced deformities [48].

Frog tadpoles (*Rana temporaria*) developed under electromagnetic field (50 Hz, $260\,A\,m^{-1}$) have increased mortality. Experimental tadpoles developed more slowly and less synchronously than control tadpoles, remain at the early stages for a longer time. Tadpoles developed allergies and EMF causes changes in the blood counts [98].

Amphibians can be specially sensitive: thresholds of an overt avoidance response to weak electrical field stimuli down to $0.01\,V\,m^{-1}$ were found in *Proteus anguinus* and $0.2\,V\,m^{-1}$ in *Euproctus asper* at 20–30 Hz, but sensitivity covered a total frequency range of below 0.1 Hz to 1–2 kHz [99].

Deformities in nature

Ultraviolet radiation, UV-B. UV-B radiations produce deformities in amphibian embryos that go from lateral flexure of the tail to abnormal skin, eye damage, and lower survival rate [6,10]. However, numerous experiments carried out did not provide evidence that this exposure induces all types of deformities observed in nature, nor the appearance of extra limbs, one of the most frequent deformities noted [5,6]. On the other hand, most of the deformations for UV-B radiation occur in the legs or in reduction of the number of bilateral fingers. However, in the wild, amphibians exhibit a wide diversity of aberrations that are limited to only one side of the body, including problems in the skin, loss of legs, and twisted internal organs, reasons for which it was considered that this radiation is not the only source [5]. Similar abnormalities found in the wild and not induced by UV-B radiation have been obtained in laboratory studies, by exposing amphibian larvae to magnetic fields [48]. A similarity exists in the deformations of amphibians observed by Levengood [48] and Blaustein and Johnson [5]. Several studies addressed behavior and teratology in young birds exposed to electromagnetic fields [39,41]. Typical abnormalities include malformation of the neural tube and abnormal twisting of the chicken embryo. The electric currents are believed to have a significant role in the control of development and it is also possible that external EMR could influence these control systems [100]. The appearance of morphological abnormalities influenced by pulsed electromagnetic fields during embryogenesis in chickens [33,101] are similar to those produced by ultraviolet radiation [36]. The pulses are in fact a characteristic of mobile telephone radiations that have increased from 1995, when a marked rise in deformations started. Several experimental studies point out that the exposure to UV-B produced deferred effects (early exposure causes delayed effects in later stages) [1]. The exposure to electromagnetic fields also induces delayed effects and the tadpoles are the same as the control until the beginning of metamorphosis. The extra limbs and blistering were induced during the gastrula stage of the development which appeared to be the most sensitive stage [48]. The early *Rana pipiens* embryonic development was also inhibited by magnetic fields [97]. In rats, brief intermittent exposure to low-frequency EMFs during the critical prenatal period for neurobehavioral sex differentiation can demasculinize male scent marking behavior and increase accessory sex organ weights in adulthood [102]. Biological effects resulting from EMR field exposures might depend on the dose (e.g. duration of exposure). Short-term exposures up-regulate cell repair mechanisms, whereas long-term exposures appear to down-regulate protective responses to UV radiation [103].

Parasites. The parasite *R. ondatrae* is an important and extensive cause of malformations in amphibian extremities in western USA [16]. Tadpoles with malformations experience higher mortality than the normal ones before and during metamorphosis. The *Ribeiroia* infection represents a threat for amphibian populations that are in decline. However, with a growing volume of data based on the experimental evidence, the infection from parasites does not seem to be the cause of all the malformations on limbs, since in some places with the presence of deformations, the parasite *R. ondatrae* was absent [5]. Further certain deformities like the absence of eyes, limbs, and twisted internal organs was not induced by the parasite [5].

In a laboratory study, eggs and embryos of *Rana sylvatica* and *Ambystoma maculatum* were exposed to magnetic fields at several development stages. A brief treatment of the early embryo produced several types of abnormalities: microcephalia, scoliosis, edema, and retarded growth [48]. Several of the treated tadpoles developed severe leg malformations and extra legs, as well as a pronounced alteration of histogenesis which took the form of subepidermal blistering and edema [48]. In chick embryos exposed to pulsed EMR a potent teratogenic effect was observed: microphthalmia, abnormal trunkal torsion, and malformations on the neural tube [33,36,101,104]. One of the possible reasons for these deformities appearing more often [5], may be due to wireless telecommunications and exponential increase of electromagnetic contamination.

Bioelectric fields have long been suspected to play a causal role in embryonic development. The electrical field may directly affect the differentiation of some tail structures, in particular those derived from the tail bud. Alteration of the electrical field may disrupt the chemical gradient and signals received by embryo cells. It appears that in some manner, cells sense their position in an electrical field and respond appropriately. The disruption of this field alters their response. Endogenous current patterns are often correlated with a specific morphogenetic events such a limb bud formation. The most common defect in chick embryos experimental group was in tail development. Internally, tail structures (neural tube, notochord, and somites) were frequently absent or malformed. Defects in limb bud and head development were also found in experimentally treated chick embryos, but less often than the tail defects [105]. Amphibians can be especially sensitive because their skin is always moist, and they live close to, or in water, which conducts electricity easily.

Populations' decline

Deformities found in nature can directly affect embryonic mortality and survival after hatching [10]. It seems interactions that exist among UV-B radiation and additional factors contribute to embryo mortality [9]. Water pollution and excessive ultraviolet radiation act jointly, producing specific problems and alter the immune system, making amphibians more vulnerable to parasitic invasions and pathogen infections [6,8,12,14]. It is proposed that there exists a possible relationship between the decline of amphibians and exponential increase of electromagnetic pollution. Several experiments with bird eggs showed a high mortality of embryos exposed to EMR from mobile phones [36,106,107]. EMFs increases mortality of tadpoles [98]. The EMR alters the immune, nervous, and endocrine systems, and operates independent or together with other factors like UV-B radiation or chemical pollutants. Death of embryos in nature is not due to UV radiation as the capacity of DNA repair mechanisms like photolyase (photoreactivating enzyme) is effective [9]. EMR produces stress on the immune system [76,98] that obstructs DNA repair [42,108,109]. Heat shock proteins may play a role in protecting amphibians from UV-B damage [14] and animals exposed to EMR [27,51,71,110,111]. Different susceptibility to UV among species and even among populations exists [112], as seen with EMR [31,40].

Hallberg and Johansson [108,109] proposed that radiofrequencies increase the effects of UV radiation. A study on the causes of melanoma in humans conclude that the incidence increases and the mortality associated with this skin tumor cannot only be explained by the elevation in UV sun radiation, but rather by the continuous alterations on mechanisms of cellular repair, produced by EMR (radiofrequencies) resonant with the body, that amplify the carcinogenic effects of the cellular damage induced by the UV-B radiation. The cases of melanoma experienced a significant increase from the 1960–70s [108] that continues today, and also asthma and several types of cancer associated with deterioration of immune system. Data suggest there is an increase of electromagnetic pollution [108,113]. The public health situation in Sweden has become worse since the autumn of 1997. There is a correlation between the massive roll-out of GSM mobile phone antennae and adverse health effects [109].

Enigmatic decline of amphibian species are positively associated with streams at high elevations in the tropics and negatively associated with still water and low elevations [3]. In high places, the electromagnetic contamination is usually higher [47]. Microwave measurements of power density as low as $0.0006\,\mu W\,cm^{-2}$ show strong correlation with symptoms like depressive tendency, fatigue, and insomnia in humans [63].

Proposed research

To demonstrate the conclusive effect of microwave radiation on amphibians it is necessary to approach research with a control (non-exposed) and an experimental group. This methodological position is complicated at present due to the ubiquity of these radiations [98]. Studies that try to correlate populational evolution, appearance of deformities, or the presence or absence of amphibians with measurements of electromagnetic fields from radiofrequencies will be of great interest. Field investigations of urban park populations and phone masts surrounding territories need to be high-priority. A radius of $1\,km^2$ laid out in concentric circumferences at intermediate distances may be useful to investigate the differential results among areas, depending on their vicinity and corresponding levels of EMR. Laboratory studies on amphibians exposed to pulsated and modulated microwaves would also be of great interest.

Acknowledgments

The author is grateful to Denise Ward who revised the English version of this article and thanks Sam Kacew and Miguel Lizana for the valuable suggestions to a first manuscript of this article. The author would like to thank “Centro de Información y Documentación Ambiental” in Castilla y León (Spain) and Roberto Carbonell for providing some articles.

References

1. Blaustein AR, Kiesecker JM. Complexity in conservation: Lessons from the global decline of amphibian populations. Ecol. Lett. 2002;5:597–608.
2. IUCN. Global amphibian assessment. Washington, DC: Center for Applied Biodiversity Science; 2004.
3. Stuart SN, Chanson JS, Cox NA, Young BE, Rodrigues AS, Fischman DL, Waller RW. Status and trends of amphibian declines and extinctions worldwide. Science 2004;306:1783–1786.
4. Kiesecker JM, Blaustein AR, Belden LK. Complex causes of amphibian population declines. Nature 2001;410:681–684.
5. Blaustein AR, Johnson PTJ. The complexity of deformed amphibians. Front. Ecol. 2003;1:87–94.
6. Blaustein AR, Johnson PTJ. Explaining frog deformities. Sci. Am. 2003;288:60–65.
7. Kiesecker JM. Synergism between trematode infection and pesticide exposure: A link to amphibian limb deformities in nature? Proc. Nat. Acad. Sci. USA 2002;99:9900–9904.
8. Blaustein AR, Romansic JM, Kiesecker JM, Hatch AC. Ultraviolet radiation, toxic chemicals and amphibian population declines. Diversity Distribut. 2003;9:123–140.
9. Blaustein AR, Hoffman PD, Kiesecker JM, Hays JB. DNA repair activity and resistance to solar UV-B radiation in eggs of the red-legged frog. Conserv. Biol. 1996;10:1398–1402.
10. Blaustein AR, Kiesecker JM, Chivers DP, Anthony RG. Ambient UV-B radiation causes deformities in amphibian embryos. Proc. Nat. Acad. Sci. 1997;94:13735–13737.
11. Blaustein AR, Hays JB, Hoffman PD, Chivers DP, Kiesecker JM, Leonard WP, Marco A, Olson DH, Reaser JK, Anthony RG. DNA repair and resistance to UV-B radiation in western spotted frogs. Ecol. Applicat. 1999;9:1100–1105.
12. Middleton EM, Herman JR, Celarier EA, Wilkinson JW, Carey C, Rusin RJ. Evaluating ultraviolet radiation exposure with satellite data at sites of amphibian declines in Central and South America. Conserv. Biol. 2001;15:914–929.
13. Ankley GT, Diamond SA, Tietge JE, Holcombe GW, Jensen KM, DeFoe DL, Peterson R. Assessment of risk of solar ultraviolet radiation to amphibians. I. Dose-dependent induction of hindlimb malformations in the Northern Leopard Frog (*Rana pipiens*). Environ. Sci. Technol. 2002;36:2853–2858.
14. Blaustein AR, Belden LK. Amphibian defenses against ultraviolet-B radiation. Evolut. Dev. 2003;5:89–97.
15. Battaglin W, Fairchild J. Potential toxicity of pesticides measured in midwestern streams to aquatic organisms. Water Sci. Technol. 2002;45:95–102.
16. Johnson PTJ, Lunde KB, Thurman EM, Ritchie EG, Wray SN, Sutherland DR, Kapfer JM, Frest TJ, Bowerman J, Blaustein AR. Parasite (*Ribeiroia ondatrae*) infection linked to amphibian malformations in the Western United States. Ecol. Monogr. 2002;72:151–168.
17. Blaustein AR, Belden LK, Olson DH, Green DM, Root TL, Kiesecker JM. Amphibian breeding and climate change. Conserv. Biol. 2001;15:1804–1809.
18. Firstenberg A. Microwaving our planet: The environmental impact of the wireless revolution. Brooklyn, NY 11210: Cellular Phone Taskforce; 1997.
19. Galeev AL. The effects of microwave radiation from mobile telephones on humans and animals. Neurosci. Behav. Physiol. 2000;30:187–194.
20. Cooper M, Goldburg M. Intelligent antennas: Spatial division multiple access. Annu. Rev. Communicat. 1996;1:999–1002.
21. Cooper M. Antenas adaptables. Investigación y Ciencia 2003;324:41–47.
22. Marco A, Lizana M, Alvarez A, Blaustein AR. Egg-wrapping behaviour protects new embryos from UV radiation. Animal Behav. 2001;61:1–6.
23. Aguilar M. Bioelectromagnetismo: Campos eléctricos y magnéticos y seres vivos. Consejo Superior de Investigaciones Científicas; 2001.
24. Santini R, Seigne M, Bonhomme-Faibre L. Danger des téléphones cellulaires et de leurs stations relais. Pathol. Biol. 2000;48:525–528.
25. Hyland GJ. Physics and biology of mobile telephony. Lancet 2000;356:1–8.
26. Grigor'ev IUG. Role of modulation in biological effects of electromagnetic radiation. Radiat. Biol. Radioecol. 1996;36:659–670.
27. Daniells C, Duce I, Thomas D, Sewell P, Tattersall J, de Pomerai D. Transgenic nematodes as biomonitors of microwave-induced stress. Mutat. Res. 1998;399:55–64.
28. Nikolaevich N, Igorevna A, Vasil G. Influence of high-frequency electromagnetic radiation at non-thermal intensities on the human body (A review of work by Russian and Ukrainian researchers). No Place to Hide, 3. Supplement; 2001.

29. Kemerov S, Marinkev M, Getova D. Effects of low-intensity electromagnetic fields on behavioral activity of rats. Folia Med. 1999;41:75–80.
30. Monteagudo JL. Bioelectromagenetismo y salud pública efectos, prevención y tratamiento. En. J.L. Bardasano. IBASC Alcala de Henares 1997;201–210.
31. Hyland GJ. The physiological and environmental effects of non-ionising electromagnetic radiation. Working document for the STOA Panel. European Parliament. Directorate General for Research; 2001.
32. Marino AA, Nilsen E, Frilot C. Nonlinear changes in brain electrical activity due to cell phone radiation. Bioelectromagnetics 2003;24:339–346.
33. Úbeda A. Trillo MA, Chacón L, Blanco MJ, Leal J. Chick embryo development can be irreversibly altered by early exposure to weak extremely-low-frequency magnetic fields. Bioelectromagnetics 1994;15:385–398.
34. Adey WR. Bioeffects of mobile communications fields: Possible mechanisms for cumulative dose. In: Kuster N, Balzano Q, Lin JC, editors. Mobile Communication Safety. London: Chapman and Hall; 1996. pp 95–131.
35. Granlund-Lind R, Lind J. Black on white. Voices and witnesses about electro-hypersensitivity. The Swedish experience. Sweden: Mimers Brunn; 2004.
36. Farrel JM, Litovitz TL, Penafiel M. The effect of pulsed and sinusoidal magnetic fields on the morphology of developing chick embryos. Bioelectromagnetics 1997;18:431–438.
37. Mevissen M, Haübler M, Lerchl A, Loscher W. Acceleration of mammary tumorigenesis by exposure of 7,12-dimethylbenz(a)anthracene-treated female rats in a 50-Hz, 100-μT magnetic field: Replication study. J. Toxicol. Environ. Health, Part A 1998;53:401–418.
38. Flipo D, Fournier M, Benquet C, Roux P, Le Boulaire C, Pinsky C, LaBella FS, Krzystniak K. Increased apoptosis, changes in intracellular Ca^{2+}, and functional alterations in lymphocytes and macrophages after *in vitro* exposure to static magnetic field. J. Toxicol. Environ. Health, Part A 1998;54:63–76.
39. Fernie KJ, Leonard NJ, Bird DM. Behavior of free-ranging and captive American kestrels under electromagnetic fields. J. Toxicol. Environ. Health, Part A 2000;59:597–603.
40. Fedrowitz M, Kamino K, Löscher W. Significant differences in the effects of magnetic field exposure on 7,12 dimethylbenz(a)anthracene-induced mammary carcinogenesis in two sub-strains of Sprague-Dawley rats. Cancer Res. 2004;64:243–251.
41. Fernie KJ, Reynolds SJ. The effects of electromagnetic fields from power lines on avian reproductive biology and physiology: A review. J. Toxicol. Environ. Health, Part B 2005;8:127–140. (http://www.ierp.bham.ac.uk/publications/Fernie%20and%20Reynolds%202005.pdf).
42. Heredia-Rojas L, Rodríguez-Flores M, Santoyo-Stephano E, Castañeda-Garza A, Rodríguez-De la Fuente. Los campos electromagnéticos: ¿Un problema de salud pública? Respyn. 2003;4:1–10.
43. Smith CW, Bese S. Electromagnetic man. London: Dent and Sons; 1989.
44. Adey WR. Tissue interactions with non-ionizing electromagnetic fields. Physiol. Rev. 1981;61:435–514.
45. Balmori A. Aves y telefonía móvil. Resultados preliminares de los efectos de las ondas electromagnéticas sobre la fauna urbana. El ecologista 2003;36:40–42.
46. Balmori A. Posibles efectos de las ondas electromagnéticas utilizadas en la telefonía inalámbrica sobre los seres vivos. Ardeola 2004;51:477–490.
47. Balmori A. Possible effects of electromagnetic fields from phone masts on a population of white stork (*Ciconia ciconia*). Electromagnetic Biol. Med. 2005;24:109–119.
48. Levengood WC. A new teratogenic agent applied to amphibian embryos. J. Embryol. Exp. Morphol. 1969;21:23–31.
49. Carpenter RL, Livstone EM. Evidence for nonthermal effects of microwave radiation: Abnormal development of irradiated insect pupae. IEEE Trans Microwave Theory Tech. 1971;19:173–178.
50. Ramírez E, Monteagudo JL, Garcia-Gracia M, Delgado JM. Oviposition and development of Drosophila modified by magnetic fields. Bioelectromagnetics 1983;4:315–326.
51. Weisbrot D, Lin H, Ye L, Blank M, Goodman R. Effects of mobile phone radiation on reproduction and development in *Drosophila melanogaster*. J. Cell. Biochem. 2003;89:48–55.
52. Pan H, Liu X. Apparent biological effect of strong magnetic field on mosquito egg hatching. Bioelectromagnetics 2004;25:84–91.
53. Panagopoulos DJ, Karabarbounis A, Margaritis LH. Effect of GSM 900 MHz mobile phone radiation on the reproductive capacity of *Drosophila melanogaster*. Electromagnetic Biol. Med. 2004;23:29–43.
54. Stever H, Kuhn J, Otten C, Wunder B, Harst W. Verhaltensanderung unter elektromagnetischer Exposition. Pilotstudie. Institut für mathematik. Arbeitsgruppe. Bildungsinformatik. Universität Koblenz-Landau; 2005. http://agbi.uni-landau.de/.

55. Balmori A. Efectos de las radiaciones electromagnéticas de la telefonía móvil sobre los insectos. Ecosistemas./1; 2006. (URL: http://www.revistaecosistemas.net/articulo.asp?Id=396&Id_Categoria=2&tipo=portada).
56. Selga T, Y Selga M. Response of *Pinus Sylvestris* L. needles to electromagnetic fields. Cytological and ultrastructural aspects. Sci. Total Environ. 1996;180:65–73.
57. Balodis VG, Brumelis K, Kalviskis O, Nikodemus D, Y Tjarve VZ. Does the Skrunda radio location station diminish the radial growth of pine trees? Sci. Total Environ. 1996;180:57–64.
58. Balmori A. Pueden afectar las microondas pulsadas emitidas por las antenas de telefonía a los árboles y otros vegetales?. Ecosistemas 2004;3:1–10. (http://www.revistaecosistemas.net/articulo.asp?Id=29&Id_Categoria=1&tipo=otros_contenidos).
59. Santini R, Santini P, Danze JM, Le Ruz P, Seigne M. Enquête sur la santé de riverains de stations relais: I. Incidences de la distance et du sexe. Pathol. Biol. 2002;50:369–373.
60. Santini R, Santini P, Le Ruz P, Danze JM, Seigne M. Survey study of people living in the vicinity of cellular phone base stations. Electromagnetic Biol. Med. 2003a;22:41–49.
61. Santini R, Santini P, Danze JM, Le Ruz P, Seigne M. Symptoms experienced by people in vicinity of base stations: II/Incidences of age, duration of exposure, location of subjects in relation to the antennas and other electromagnetic factors. Pathol. Biol. 2003b;51:412–415.
62. Navarro EA, Segura J, Portolés M, Gómez Perretta C. The microwave syndrome: A preliminary study in Spain. Electromagnetic Biol. Med. 2003;22:161–169.
63. Oberfeld G, Navarro E, Portoles M, Maestu C, Gomez-Perretta C. The microwave syndrome – further aspects of a Spanish study. EBEA Congres Kos-Greece 2004;1:1–9.
64. Maisch D. Children and mobile phones . . . Is there a health risk? The case for extra precautions. J. Australian Coll. Nutr. Environ. Med. 2003;22:3–8.
65. Tanner JA. Effect of microwave radiation on birds. Nature 1966;210:636.
66. Tanner JA, Romero-Sierra C, Davie SJ. Non-thermal effects of microwave radiation on birds. Nature 1967;216:1139.
67. Marks TA, Ratke CC, English WO. Strain voltage and developmental, reproductive and other toxicology problems in dogs, cats and cows: A discussion. Vet. Human Toxicol. 1995;37:163–172.
68. Löscher W, Käs G. Conspicuous behavioural abnormalities in a dairy cow herd near a TV and radio transmitting antenna. Practical Vet. Surgeon 1998;29:437–444.
69. Frey AH, Feld SR. Avoidance by rats of illumination with low power non-ionizing electromagnetic energy. J. Comp. Physiol. Psychol. 1975;89:183–188.
70. Navakatikian MA, Tomashevskaya LA. Phasic behavioral and endocrine effects of microwaves of nonthermal intensity. In: Carpenter DO, editor. Biological effects of electric and magnetic fields. Vol. 1. San Diego, CA: Academic Press; 1994.
71. De Pomerai D, Daniells C, David H, Allan J, Duce I, Mutwakil M, Thomas D, Sewell P, Tattersall J, Jones D, Candido P. Non-thermal heat-shock response to microwaves. Nature 2000;405:417–418.
72. Dutta SK, Ghosh B, Blackman CF. Radiofrequency radiation-induced calcium ion efflux enhancement from human and other neuroblastoma cells in culture. Bioelectromagnetics 1989;10:197–202.
73. Paulraj R, Behari J, Rao AR. Effect of amplitude modulated RF radiation on calcium ion efflux and ODC activity in chronically exposed rat brain. Indian J. Biochem. Biophys. 1999;36:337–340.
74. Velizarov S, Raskmark P, Kwee S. The effects of radiofrequency fields on cell proliferation are non-thermal. Bioelectrochem. Bioenerg. 1999;48:177–180.
75. Chou CK, Guy AW, Kunz LL, Johnson RB, Crowley JJ, Krupp JH. Long-term, low-level microwave irradiation of rats. Bioelectromagnetics 1992;13:469–496.
76. Novoselova ET, Fesenko EE. Stimulation of production of tumor necrosis factor by murine macrophages when exposed *in vivo* and *in vitro* to weak electromagnetic waves in the centimeter range. Biofizika 1998;43:1132–1133.
77. Dasdag S, Ketani MA, Akdag Z, Ersay AR, Sar I, Demirtas ÖC, Celik MS. Whole body microwave exposure emitted by cellular phones and testicular function of rats. Urol. Res. 1999;27:219–223.
78. Davoudi M, Brössner C, Kuber W. Der Einfluss elektromagnetischer wellen auf die Spermienmotilität. J. Urol. Urogynäkol. 2002;9:18–22.
79. Vangelova KK, Israel MS. Variations of melatonin and stress hormones under extended shifts and radiofrequency electromagnetic radiation. Rev. Environ. Health 2005;20:151–61.
80. Tofani S, Agnesod G, Ossola P, Ferrini S, Bussi R. Effects of continuous low-level exposure to radio-frequency radiation on intrauterine development in rats. Health Physics 1986;51:489–499.

81. Garaj-Vrhovac V, Horvat D, Koren Z. The relationship between colony-forming ability, chromosome aberrations and incidence of micronuclei in V79 Chinese hamster cells exposed to microwave radiation. Mutat. Res. 1991;263:143–149.
82. Lai H, Singh NP. Acute low-intensity microwave exposure increases DNA single-strand breaks in rat brain cells. Bioelectromagnetics 1995;16:207–210.
83. Balode S. Assessment of radio-frequency electromagnetic radiation by the micronucleus test in bovine peripheral erythrocytes. Sci. Total. Environ. 1996;180:81–85.
84. Belyaev I, Hillert L, Markova E, Sarimov R, Malmgren L, Persson B, Harms-Ringdahl M. Microwaves of mobile phones affect human lymphocytes from normal and hypersensitive subjects dependent on frequency. presented at 26th Annual Meeting of the Bioelectromagnetics (BEMS), Washington, USA; 2004.
85. Demsia G, Vlastos D, Matthopoulos DP. Effect of 910-MHz electromagnetic field on rat bone marrow. Sci. World J. 2004;4:48–54.
86. Reflex. 2004. http://www.verum-foundation.de/cgi-bin/content.cgi?id=euprojekte01.
87. Diem E, Schwarz C, Adlkofer F, Jahn O, Rudiger H. Non-thermal DNA breakage by mobile-phone radiation (1800 MHz) in human fibroblasts and in transformed GFSH-R17 rat granulosa cells *in vitro*. Mutat. Res. 2005;583:178–183.
88. Kolodynski AA, Kolodynska VV. Motor and psychological functions of school children living in the area of the Skrunda Radio Location Station in Latvia. Sci. Total Environ. 1996;180:87–93.
89. Beasond RC, Semm P. Responses of neurons to an amplitude modulated microwave stimulus. Neurosci. Lett. 2002;33:175–178.
90. Kramarenko AV, Tan U. Effects of high-frequency electromagnetic fields on human EEG: A brain mapping study. Int. J. Neurosci. 2003;113:1007–1019.
91. Salford LG, Brun AE, Eberhardt JL, Malmgren L, Persson BR. Nerve cell damage in mammalian brain after exposure to microwaves from GSM mobile phones. Environ. Health Perspect. 2003;111:881–893.
92. Adey WR. Electromagnetic fields, the modulation of brain tissue functions – A possible paradigm shift in biology. In: Smith B, Adelman G, editors. International Encyclopaedia of Neuroscience. New York: Elsevier; 2003. pp 1–21.
93. Miura M, Okada J. Non-thermal vasodilatation by radio frequency burst-type electromagnetic field radiation in the frog. J. Physiol. 1991;435:257–273.
94. Szmigielski S, Bortkiewicz A, Gadzicka E, Zmyslony M, Kubacki R. Alteration of diurnal rhythms of blood pressure and heart rate to workers exposed to radiofrequency electromagnetic fields. Blood Press. Monit. 1998;3:323–330.
95. Magras IN, Xenos TD. Radiation-induced changes in the prenatal development of mice. Bioelectromagnetics 1997;18:455–461.
96. Frey AH, Seifert E. Pulse modulated UHF energy illumination of the heart associated with change in heart rate. Life Sci. 1968;7:505–512.
97. Neurath PW. High gradient magnetic fields inhibit embryonic development of frogs. Nature 1968;21:1358–1359.
98. Grefner NM, Yakovleva TL, Boreysha IK. Effects of electromagnetic radiation on tadpole development in the common frog (*Rana temporaria* L.). Russ. J. Ecol. 1998;29:133–134.
99. Schlegel PA. Behavioral sensitivity of the European blind cave salamander, *Proteus anguinus*, and a pyrenean newt, *Euproctus asper*, to electrical fields in water. Brain Behav. Evol. 1997;49:121–131.
100. Juutilainen J, Harri M, Saali K, Lahtinen T. Effects of 100-Hz magnetic fields with various waveforms on the development of chick embryos. Radiat. Environ. Biophys. 1986;25:65–74.
101. Úbeda A, Leal J, Trillo MA, Jimenez MA, Delgado JMR. Pulse shape of magnetic fields influences chick embryogenesis. J. Anat. 1983;137:513–536.
102. McGivern RF, Sokol RZ, Adey WR. Prenatal exposure to a low-frequency electromagnetic field demasculinizes adult scent marking behavior and increases accessory sex organ weights in rats. Teratology 1990;41:1–8.
103. Di Carlo AL, Hargis MT, Penafiel LM, Litovitz TA. Short-term magnetic field exposures (60 Hz) induce protection against ultraviolet radiation damage. Int. J. Radiat. Biol. 1999;75:1541–1549.
104. Lahijani MS, Ghafoori M. Teratogenic effects of sinusoidal extremely low frequency electromagnetic fields on morphology of 24 hr chick embryos. Indian J. Exp. Biol. 2000;38:692–699.
105. Hotary KB, Robinson KR. Evidence of a role for endogenous electrical fields in chick embryo development. Development 1992;114:985–996.
106. Youbicier-Simo BJ, Lebecq JC, Bastide M. Mortality of chicken embryos exposed to EMFs from mobile phones. Presented at the Twentieth Annual Meeting of the Bioelectromagnetics Society, St. Pete Beach, FL, June 1998.

107. Grigoriev IUG. Influence of the electromagnetic field of the mobile phones on chickens embryo, to the evaluation of the dangerousness after the criterion of this mortality. J. Radiat. Biol. 2003;5:541–544.
108. Hallberg O, Johansson O. Malignant melanoma of the skin – not a sunshine story!. Med. Sci. Monit. 2004;10:336–340.
109. Hallberg Ö, Johansson O. Mobile handset output power and health. Electromagnetic Biol. Med. 2004;23:229–239.
110. Goodman R, Blank M. Insights into electromagnetic interaction mechanisms. J. Cell. Physiol. 2002;192:16–22.
111. Leszczynski D, Joenväärä S, Reivinen J, Kuokka R. Non-thermal activation of the hsp27/p38MAPK stress pathway by mobile phone radiation in human endothelial cells: Molecular mechanism for cancer- and blood–brain barrier-related effects. Differentiation 2002;70:120–129.
112. Belden LK, Blaustein AR. Population differences in sensitivity to UV-B radiation for larval long-toed salamanders. Ecology 2002;83:1586–1590.
113. Hallberg O, Johansson O. Cancer trends during the 20th century. J. Australian Coll. Nutr. Environ. Med. 2002;21:3–8.