# Powerfrequency EMFs and Health Risks

This article is separated into 11 sections, each of which can be individually downloaded. It is a 'work in progress' incorporating new information whenever time permits.

## Section 9

## Animal effects, heart problems, depression, dementia and other effects

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# Animal effects, heart problems, depression, dementia and other effects

The ICNIRP reference levels aimed to protect the general public can be exceeded in people who have a conductive implant following surgery (Valič 2009).

Prenatal exposure to electric fields during pregnancy until the prenatally exposed rats reached puberty resulted in growth restriction, delayed puberty and reduced growth hormone levels (Dundar 2009).

## Ageing

Exposure to ELF magnetic fields may act as a risk factor for the occurrence of oxidative stress-based nervous system pathologies associated with ageing (Falone 2008).

## Amyotrophic lateral sclerosis (ALS)

A hypothesis suggested by Milham (2010) is that some cases of ALS (a type of motor neurone disease) are a result of extensive use of trans-cutaneous electric stimulation (TENS) machines in athletes. Possible other uses of acute shocks to the body, such as electrical diathermy, ECT and electro-surgery may also be implicated. Football, baseball and soccer players have a significantly high risk of ALS, indeed Lou Gehrig's disease, as it is also known as, takes the name of the baseball player in whom it was first diagnosed. Johansen & Olsen (1998) found an increased risk of ALS associated with above-average levels of exposure to electromagnetic fields and possibly due to repeated episodes with electric shocks.

## Animal effects

Eggs deposited by nesting female loggerhead **turtles** were permitted to develop in situ either in the natural ambient magnetic field or in a magnetic field distorted by magnets placed around the nest. In orientation experiments, hatchlings that developed in the normal ambient field oriented approximately south when exposed to a field that exists near the northern coast of Portugal, a direction consistent with their migratory route in the northeastern Atlantic. By contrast, hatchlings that developed in a distorted magnetic field had orientation indistinguishable from random when tested in the same north Portugal field. The authors (Fuxjager 2014) suggested that the magnetic environment present during early development can influence the magnetic orientation behaviour of a neonatal migratory animal.

A review of the effects of powerfrequency radiation on **birds** was carried out by Fernie & Reynolds (2005). They found that *"most studies indicate that EMF exposure of birds generally changes, but not always consistently in effect or in direction, their behavior, reproductive success, growth and development, physiology and endocrinology, and oxidative stress under EMF conditions."* In a previous study she had reported increased levels of oxidative stress in American kestrels exposed to EMFs (Fernie & Bird 2001).

In a study looking at the mortality rates in endangered **raptors** due to power lines (Guil 2011), pylons with cable insulation showed higher electrocution rates than unimproved pylons, both for raptors and eagles. DeGregorio (2014) found that only indigo **buntings** (Passerina cyanea) decreased with proximity to power lines, that landscape features are likely to be specific to both the local predators and landscape. Decades after the problem was first identified, power line electrocution continues to be a cause of avian mortality. Currently, several federal laws protect

eagles and other migratory birds, meaning that utility companies may be liable for electrocution-related deaths (Kagan 2016).

Gonet (2009) found that magnetic fields had negative reproductive effects on **flies** for three generations from exposure.

ELF magnetic field significantly decreases locomotor activity of adult **flies** at all developmental stages (Dimitrijevic 2014).

Many light thin **bumblebee** hairs respond to the electrical field surrounding a flower. This provides key evidence for electrosensitivity to ecologically relevant electric fields. It is possible that other terrestrial animals use such sensory hairs to detect and respond to electric fields.

Oriental hornet workers build brood combs of hexagonal cells. Magnetic field exposure in oriental hornets caused (a) 35-55% smaller number of cells and fewer eggs in each comb, (b) disrupted symmetry of building, with many deformed and imperfectly hexagonal cells, and (c) more delicate and slender comb stems (Ishay 2007).

Nishimura (2010) found that **lizards** responded to low frequency electromagnetic fields, but that the effects seem to be mediated by light as they stopped when the parietal eye (at the top of the head, photoreceptive and associated with the pineal gland) was covered. This adds further evidence to the protective effect of melatonin which is produced by the pineal gland.

**Foxes** attack their prey from the north, a case of magnetic alignment (Cerveny 2011). Do the fox victims have reduced sensitivity from some directions? They may use the magnetic fields as a 'range finder' or targeting system to measure distance and increase accuracy. Some of the same team had found that **rodents** (mole-rats) navigate by means of neurons responsive to magnetic stimuli (Burger 2010). As some people can navigate using inbuilt magnetic directions it is difficult to know what biological effects may be triggered by magnetic disturbance.

The discovery means that foxes join migratory animals (**pigeons**, turtles and **whales**) in being able to sense magnetic direction.

The magnetic compass orientation of European **robins** could not be disrupted by any of the relatively strong narrow-band electromagnetic fields employed in a study by Schwarze (2016), but weak broadband field very efficiently disrupted their orientation.

## Anxiety

Chronic exposure to ELF EMFs produced anxiety-type behaviour in rats whilst increasing learning and memory (LH He 2011). ELFMF significantly induced anxiety behaviour, and indicated the involvement of NMDA receptor in its effect (Salunke 2014).

## Asthma

In a study by Li (2011), pregnant women wore a small EMF meter during pregnancy to measure their daily exposure to magnetic fields. The researchers followed the 626 children born to these women for 13 years and found that women exposed to the highest levels of magnetic fields were 3½ times more likely to have a child later diagnosed with asthma.. Those with known risk factors were more likely to have a child with asthma, if they were also exposed to high magnetic field levels. Dr Li said *"You should avoid electromagnetic fields as much as you can, especially during pregnancy."*

Beale (2001) found significantly elevated odds for asthma and combined chronic illnesses in people living near high-voltage power lines.

## Autism

Alsaeed (2014) concluded that his study results were supportive of the hypothesis of a causal link between exposure to ELF-EMF and autism spectrum disorders, and that further tests were recommended.

## Bacteria

At 4, 6 and 8 hours of incubation, the number of cells, including E.Coli, was significantly decreased in bacteria exposed to EMFs. At 24 hours incubation, the percentage of cells increased, suggesting a progressive adaptive response (Segatore 2012).

## Behaviour changes

Behaviour changes were observed in young male gerbils (Janac 2012) to a range of low frequency signal values. The changes varied according to the animal's age, suggesting the effects were at least in part due to the changes in brain structure responsible for a control of motor behaviour. Regardless of the ELF-MF signal level, increased motor behaviour was observed 3 days after the exposure had stopped, showing a delayed effect. Legros (2012) found that that 1 h of 60 Hz magnetic field exposure may modulate human involuntary motor control, but that the levels were way above levels that the general public is normally exposed to.

Exposure to a fairly high magnetic field reduced activity in planaria by about 50% which was comparable to the non-specific effects of morphine (Murugan & Persinger 2014).

Prenatal exposure to magnetic fields within a specific "window" of intensities that overlap with values found in many human habitats may produce long-term changes in behaviours (St-Pierre & Persinger 2008). Interestingly, the higher exposure levels had fewer effects than the lower ones.

## Birth Defects

Malagoli (2012) found no evidence of very low levels of PF EMFs (equal to or greater than 0.1 microtesla) causing birth defects. It may be that there were insufficient people cases in levels of 0.3 microtesla or above, but 0.1 does seem to be very low. The authors say that small or moderate effects may have gone undetected, but they concluded that there were unlikely to be major effects due to magnetic field exposure during early pregnancy.

## Effects on blood

Exposure to ELF-EMFs before incubation produced a loss in the mobility of red blood cells in the blood of hatching chicks (Mohamed 2015).

## Bone changes

The study by Akdag (2010) demonstrated that 100 microT-MF and 500 microT-MF can affect biomechanical and geometrical properties of rats' bone. Long-term ELF-MF exposure was found to affect the chemical structure and metabolism of bone by changing the levels of some important elements such as calcium, zinc and magnesium in rats (Ulku 2011). Long-term exposure to EMFs

was found to affect bone and thyroid metabolism and also increased oxidative stress index (Kunt 2016).

Juutilainen (2005) reviewed studies on EMF effects on development. The author concluded that the only finding that showed some consistency was an increase of minor skeleton alterations in several experiments. Bone marrow stem cell growth was affected by EMF exposure (Yu 2014).

## Cardiovascular effects

Many of the occupational studies into cardiovascular effects and EMFs have found a negative association (Baris 1996, Kelsh & Sahl 1997, Cooper 2009). This has primarily been put down to the 'healthy worker effect' rather than a general protective effect of EMFs. Heart rate variability (HRV) and arrhythmia have been used as indicators of biological effects as a result of EMF exposure. Borjanovic (2005) and Bortkiewicz (2006) found significant changes in studies of people occupationally exposed to EMFs. Many workers are not only exposed to levels of EMFs in an intermittent or continuous way, but they may also be exposed to a variety of other harmful agents (chemicals, etc.) which may modify or confound any association between EMF exposure and cardiac function (Feychting 2005). The problem of studies using mortality data is that cardiovascular deaths are not reported accurately (Sington & Cottrell 2002), so good information is hard to obtain.

A study by Kheifets (2007) found no relation between low-frequency electric and magnetic fields and cardiovascular disease, or cardiovascular effects (McNamee 2011). McNamee (2009) suggests that the heart itself is an unlikely candidate site for biological interaction with EMFs from the perspective of direct electrical stimulation of the muscle tissue. However, Savitz (1999) hypothesised that cardiac control may be implicated, as a longer period of employment in positions with elevated EMF exposure was associated with an increased risk of mortality from arrhythmia-related conditions and from acute myocardial infarction (AMI). The relationship between risk and genetic susceptibility may add to the complexity, as Håkansson (2003) found that the risk of AMI was strengthened among ELF magnetic field-exposed subjects with genetic susceptibility to the disease.

Korpinen (2013) believed that implantable cardioverter defibrillators might malfunction within 11.5 metres from 400 kV power lines.

Sastre (2000) suggested that EMF exposure at brain frequencies may have more of an effect than 60 Hz fields, given the central origin of autonomic cardiac control.

A study by Bellieni (2008) found that the electromagnetic fields produced by incubators influenced the HRV in newborn babies. This variability could impede the development of the nervous system which can lead to cot death. As children may be exposed to high EMFs from incubators for some considerable time, it was felt that further research should be undertaken to establish whether there are any long-term health consequences. The fields are low and are similar to those that babies could be exposed to as a result of electrical equipment near their bed or the presence of electricity powerlines near their home. A previous study (2005) had shown that screening of the incubators by iron or mu-metal significantly reduced exposure for both babies and caregivers.

Calcium ions and nitric oxide activity have been proposed as possible mechanisms of EMF interaction from a cardiovascular perspective (Bauréus Koch 2003).

Research (Okubo 2001, Kim 2006) has shown a strong correlation between myocardial calcium handling and the function of HSP70 (a family of heat shock proteins, helping protect cells from

stress) and George (2008) found that EMF exposure induced the production of HSP70 which helped improve tolerance to reduced blood flow.

Investigations into blood pressure changes as a result of magnetic field exposure have, by and large, been negative (Korpinen & Partanen 1996, Ghione 2005). A previous study by Ghione (2004) had shown an increase in blood pressure as a result of exposure, but the protocol used was different. The different frequency used in the 2004 study may, of course, suggest a genuine window effect. Support for the window effect has been seen in the results of Whittington (1996).

Scientific evidence on possible effects of EMF exposure on heart rate (HR) and HRV is inconclusive; small sample sizes make the detection of subtle effects difficult; differences in applied field homogeneity between experiments and the application of the field in an intermittent versus a continuous manner may account for some of the variation in results. In a study by Baldi (2007), the results show a heart rate variation in all the subjects when they are exposed to the same ELF-PEMF.

When magnetic fields were applied to quail embryos aged between 48 and 72 h, in sessions of 2 h (6 h/day) and 3 h (9 h/day) with exposure intervals between 6 and 5 h, respectively, blood vascular formation was inhibited, but not other exposure timings. The authors felt that the results show a "window effect" regarding exposure time, which could explain the variance in study findings (Costa 2013).

A recent Russian study (2012) showed evidence of a possible correlation between increasing electromagnetic pollution and the risk of cardiovascular disease.

At greater EMF strengths or shorter exposures, the ability of the body to develop compensation mechanisms is reduced and the potential for heart-related effects increases. The author of the review (Elmas 2016) concluded that *"until the effects of EMF on heart tissue are more fully explored, electronic devices generating EMFs should be approached with caution"*.

Kiray (2013) found that magnetic field exposure caused oxidative stress, apoptosis and morphologic damage in the myocardium of adult rats. The authors felt that magnetic field-related changes could be the result of increased oxidative stress.

## Dementia

SCENHIR (the Scientific Committee on Emerging and Newly Identified Health Risks) in 2009, concluded that exposure to ELF could result in a possible increase in Alzheimer's disease. Huss (2009) found that Alzheimer's disease and general senile dementias were associated with living near powerlines; there was a dose-response relation with respect to years of residence. The longer people lived there, the greater the risk. They did not find the same risk for ALS or Parkinson's which have been linked to occupational exposure. Maybe this is an example of the 'window' effect. The study looked at mortality data rather than diagnosis, which can underestimate numbers as chronic conditions are not always listed on death certificates, instead you find the acute condition responsible for death, such as pneumonia.

High exposures to EMFs increased the risk of developing dementia amongst twins in a Swedish study, but not lower exposures (Andel 2010). 50 Hz ELF-MF increased the frequency of cells with (large) micronuclei and nuclear buds indicating that fields above 50 µT might induce chromosome instabilities such as those found in AD patients (Maes 2015). Alzheimer's disease is characterized by a number of events that have, at least partially, a genetic origin. In particular, trisomy of chromosomes 17 and 21 seems to be involved. Overall ELF-EMFs have not been identified as genotoxic agents, but there are some papers in the scientific literature that indicate

that they may enhance the effects of agents that are known to induce mutations or tumours. There are also some indications that ELF-EMFs may induce aneuploidy. This opens some perspectives for investigating the possible association between ELF-EMFs and Alzheimer's (Maes & Verschaeve 2012).

Feychting (2003) suggested that *"EMF exposure increases the risk of early-onset Alzheimer's disease, and suggests that magnetic field exposure may represent a late-acting influence in the disease process."*

There were weak indications of an increased risk for persons diagnosed with Alzheimer's disease by the age of 75 years living within 50 m of a power line (Frei 2013).

## Developmental effects

EMF exposure of pregnant mice was found to affect reelin and Dab1 expression (Hemmati 2014). The Dab1 gene and the reelin glycoprotein play a part in the developing cerebral cortex's neuronal connections. In humans, reelin mutations are associated with brain malformations and mental retardation.

## Depression and Suicide

There have been some studies looking at the possibility of magnetic field exposure from powerlines being associated with an increased risk of depression, and even suicide (Verkasalo 1997 - a five fold increase). The California report, 2002, previously referred to, also suggested a possible link between suicide and magnetic fields. Baris (1996) found an increased risk of suicide amongst electrical utility workers in Canada.

The mechanism by which this effect can occur is not clear, but Szemerszky (2009) suggests that long and continuous exposure to a relatively high electromagnetic field could count as a mild stress situation and could be a factor in the development of a depressive state or metabolic disturbances. Madjid Ansari (2016) concluded that long term ELF MF exposure could increase the depressive disorder in mice, reversing the anti-depressant activity of L-NAME indicating a probable increase in the brain nitric oxide.

High intensity and chronic exposure to ELF-MF induces an increase in corticosterone secretion, along with depression- and/or anxiety-like behaviour (Kitaoka 2013). Short-term exposure to an ELF EMF increased situational anxiety (Balassa 2009).

Some of the researchers suggested that magnetic fields affect the action of the pineal gland and interfere with its production of the neurotransmitter serotonin (Janac 2009) and the hormone melatonin (see the article "Melatonin"). Melatonin levels are low in depressed people end EMFs reduce the production of melatonin, so this hypothesis seems very promising.

## EEG changes

Cvetkovic & Cosic (2009) found that EEG activity changed with exposure to different ELF frequencies. One of the uses this could be put to, the authors suggested was for treatment of neurophysiological abnormalities such as sleep and psychiatric disorders. No comment was made as to whether such abnormalities could be induced in this way.

## Eye effects

High levels of EMF exposure for more than 24 hours might induce DNA double-strand breaks in human lens epithelial cells in vitro (Du 2008).

## Gastric effects

Hong's study (2011) found that ELF magnetic field exposure could influence the activity of endocrine cells, an important element of the intrinsic regulatory system in the digestive tract.

When a new powerline was erected and put into operation, a significant increase in incidence of musculoskeletal and gastrointestinal symptoms was found in those living close by (Porsius 2015).

## Genetic defects

Larger and abnormal brain cavities, spina bifida, monophthalmia, microphthalmia, anophthalmia, and growth retardation were reported in a study by Lahijani (2007) as a result of EMF exposure during the incubation of chicks. Other studies had also reported defects (Lahijani & Ghafoori 2000, Lahijani & Sajadi 2004).

## Hearing effects

A study on rabbits (Budak 2008) found that ELF EMFs affected hearing functions.

## Insulin and electric fields

Studies (Li X 2001, Li L 2005, Budi 2005) have found effects of both oscillating and static electric fields, which may be frequency dependent (Budi 2007) on insulin's biological activity.

## Interference problems

Irnich (2011) suggested that the sensitivity setting of pacemakers should be set to protect patients from the adverse effects of electromagnetic interference (EMI).

Identifiable electromagnetic sources turned an implantable pulse generator off in 20 patients, necessitating the replacement of the unit with a magnetically shielded one. Electromagnetic interference may, in rare cases, constitute a severe threat to the well-being of patients implanted with a deep brain stimulator, to ease tremors (Blomstedt 2006).

Swiss cardiologists have said that magnets with Neodynium-Iron-Boron (NdFeB) which are increasingly being used in hard drives, mobile phones and personal jewellery, can be dangerous to patients with heart pacemakers or with implantable cardioverter-defibrillators. Temperature increases due to the presence of a generic implant indicate that demonstrating compliance with basic restrictions may not be enough to safeguard against interference, especially in the case of novel, emerging technologies that feature strong near-fields at frequencies below 10 MHz (Kyriakou 2011).

Patients with cardiovascular implantable electronic devices (CIEDs) may be subject to EMI from electronic equipment used in dental offices, as they remain turned on throughout the treatment (Dadalti 2016).

## Kidney effects

Tunik (2013) found that both pulsed and sinusoidal EMFs changed the molecular component of kidneys adversely.

## Learning and memory effects

Lotus seedpod procyanidins prevented learning and memory damage and oxidative damage caused by high levels (8mT) of EMF exposure, most likely through their ability to scavenge free radicals and to stimulate antioxidant enzyme activity (Duan 2013). Zhao (2015) found that exposing mice to a 50 Hz magnetic field could impair their memory and alter their hippocampal neuronal morphology (Deng 2013). Magnetic field exposure affected memory consolidation in rats in an experiment by Jadidi in 2007. Prior exposure to 60 Hz magnetic fields affected spatial learning in rats (Sienkiewicz 1998). Manikonda (2007) suggested that perturbed neuronal functions caused by ELF exposure (including memory) may involve altered Ca(2+) signaling events contributing to aberrant NMDA receptor activities.

## Lung and Liver

Exposure to an electromagnetic field for 5 minutes every other day for 6 months caused cellular damage in rat lung and liver tissues and zinc supplementation inhibited the inflicted cellular damage. An important result of this study was that exposure to an electromagnetic field led to a significant decrease in zinc levels in lung and liver tissues (Baltaci 2012). Liver hydroxyproline level was significantly diminished in the group of guinea pigs exposed to power frequency electric field (Güler 2009).

## Medical implants

For workers at 110 kV substations with medical implants, the exposure may be high enough to cause interference (Korpinen & Pääkkönen 2016).

## Mental Health problems

Yamazaki (2006) found that people living within 300 metres of a high-voltage powerline were more likely to develop mental health problems, and those within 100 metres were nearly twice as likely.

## Nervous system

SCENHIR (the Scientific Committee on Emerging and Newly Identified Health Risks) in 2009, concluded that recent animal studies showed effects on the nervous system as a result of ELF exposure.

## Neurobehavioural effects

Children in primary schools near to high voltage powerlines showed a poorer performance on computerized neurobehavioral tests than children attending a school without such lines nearby. Huang (2013) suggested that long-term low-level exposure to EMF from HVT lines might have a negative impact on neurobehavioral function in children.

## Neurodegenerative effects

Kudo (2014) suggested that multiple sclerosis (MS), Alzheimer's, Parkinson's and amyotrophic lateral sclerosis (ALS), possibly other neurodegenerative diseases are caused by high energy EMFs.

Reale's review and further studies (2014) supported the evaluation of ELF-EMF exposure to define mechanisms potentially involved in the development of neurodegenerative diseases.