Powerfrequency EMFs and Health Risks

This article is separated into 12 sections, each of which can be individually downloaded. It is a 'work in progress' incorporating new information whenever time permits.

Section 9

Heart problems, depression, dementia and other effects

1. Introduction; electricity consumption; measuring meaningful exposure; static electric field from high voltage direct current transmission; precautionary recommendations; EMFs interacting with the environment or other substances; geomagnetic field (GMF) changes; a French study in 2009; residential exposure; mitigating biological effects; campaigning organisations
2. Occupational exposure; occupational research
3. Cancer; leukaemia; Sources of magnetic field exposure and cancer risk; brain cancer; breast cancer; neuroblastoma; other cancer; immune system effects; tamoxifen, doxorubicin and other drug effects; similarities to other chemical effects
4. Cellular changes and potential mechanisms; DNA breaks and changes; EEG changes; other cellular changes; potential mechanisms for interaction between exogenous EMFs and biological processes; free radical effects; effects on other cellular processes; airborne pollutant effects; other potential synergistic effects
5. MRI; contrast enhancement; individual experiences of reactions; MRI vs CT; cardiac scan; the European Physical Agents Directive; research
6. Electronic surveillance systems in shops, airports, libraries, etc.
7. Light at Night and Melatonin; circadian rhythm disruption; clock genes; plant, animal and insect effects
8. General reproductive effects; miscarriage and other effects of female exposure; powerfrequency exposure and male sperm; protective treatments
9. Other effects; ageing; amyotrophic lateral sclerosis (ALS); animal effects; anxiety; asthma; autism; bacteria; behaviour changes; birth defects; effects on blood; bone changes; brain damage; cardiovascular effects; dementia; developmental effects; depression and suicide; EEG changes; energy metabolism; eye effects; gastric effects; genetic defects; hearing effects; heart; insulin and electric fields; interference problems; kidney effects; learning and memory effects; lung, spleen and liver; medical implants; mental health problems; nervous system; neurobehavioural effects; neurodegenerative effects
10. Other effects; obesity; olfactory effects; other neurological and psychological effects; pain perception; Parkinson’s disease; protective effects of EMFs; skin; sleep; spleen; synergistic effects; teeth; thyroid; weight change; some experimental problems; government advisory bodies

11. Positive health effects; apoptosis; cancer treatment; cell survival and differentiation; wound healing

12. References – 937 references

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).

In a study by Bolte (2014) women's exposure to extremely low frequency magnetic fields was associated with an increased score on non-specific physical symptoms.

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. Koeman (2017) found a positive association between occupational ELF-MF exposure and ALS. *"Jobs with relatively high extremely low frequency electromagnetic fields levels include electric line installers, welders, sewing-machine operators, and aircraft pilots; these are essentially jobs where workers are placed in close proximity to appliances that use a lot of electricity."*

Animal effects

It is now an accepted fact that many animals, including bats (Tian 2015), sense the always-on, very weak magnetic field of Earth. This light-dependent magnetic compass is thought to be mediated by photochemical transformations in cryptochrome proteins (Dodson 2013, Bialas 2016, Hiscock 2016, Pinzon-Rodriguez 2018). Giachello (2016) and Fusani (2014) provided evidence to show that the activity of cryptochrome is sensitive to an external MF that is capable of modifying animal behaviour. Birds, fish, and other migratory animals dominate the list; it makes sense for them to have a built-in compass for their globetrotting journeys. Putman (2015) suggests that the magnetic navigation behaviour of sea turtles is intimately tied to their oceanic ecology and is shaped by a complex interplay between ocean circulation and geomagnetic dynamics.

In recent years, researchers have found that less speedy creatures—lobsters, worms, snails, frogs, newts—possess the sense. Mammals, too, seem to respond to Earth's field: In experiments, wood mice and mole rats use magnetic field lines in siting their nests; cattle and deer orient their bodies along them when grazing; and dogs point themselves north or south when they urinate or defecate. Shakhparonov & Ogurtsov (2017) found that some frogs can obtain directional information from the Earth's magnetic field, but only in the breeding migratory state.

In a study by Diego-Rasilla (2017) two species of lizard exhibited a highly significant bimodal orientation along the north-northeast and south-southwest magnetic axis. The evidence from this study suggests that free-living lacertid lizards exhibit magnetic alignment behaviour, since their body alignments cannot be explained by an effect of the sun's position. On the contrary, lizard orientations were significantly correlated with geomagnetic field values at the time of each observation.

Any exogenous magnetic fields may affect the behaviour, and in some cases, wellbeing and even survival of animals whose magnetic sense is interfered with.

In a study by Wyszkowska (2016) ELF EMF exposure caused dramatic changes in behaviour, physiology and protein expression in desert locusts, and this study lays the foundation to explore the ecological significance of these effects in other flying insects.

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). Fijałkowski (2015) found that exposure of bacteria to extremely low frequency magnetic fields could affect growth (Bayır 2015), metabolic activity and biofilm formation.

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.

Immediately after the end of ELF EMF exposures, locomotor activity significantly decreased compared to sham group (Rostami 2016). Proteome analysis also revealed global changes in whole brain proteome after treatment. However, Shin (2007) found that exposure to extremely low frequency magnetic field for one or seven days enhanced locomotor activity in a time-dependent manner. Dimitrijević (2013) and Zmejkoski (2017) found exposure to ELF magnetic fields decreased locomotor activity in flies depending on their genetic background.

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). Sihem (2006) concluded that sub-acute exposure to magnetic fields induced elevations in haematocrit, haemoglobin, plasma fuel metabolites and tissue enzymes release within the blood.

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).

Brain damage

Electromagnetic fields have toxic effects on brain cells by increasing the number of dead cells and degeneration of brains' tissues of exposed chicken embryos. These findings suggest that the electromagnetic fields induce brain damages at different levels (Lahijani 2011).

Samiee & Samiee (2016) found that exposure of Cyprinus carpio to artificial ELF-EMF caused severe histopathological changes in the brain at field intensities equal to or greater than 3 mT leading to brain necrosis.

Cardiovascular effects

Occupational studies into cardiovascular effects and EMFs have found a negative association (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. It may depend on the quality of the ELF EMFs, as shown from a study by Fang (2016) that a short time exposure to ELF-PEMF can affect the properties of ECG signals.

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 (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.

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."*

The accumulation of iron oxides-mainly magnetite-with amyloid peptide is a key process in the development of Alzheimer's disease (AD). This has strong implications for MF induced Alzheimer's (Tahirbegi 2016).

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. The California report, 2002, previously referred to, also suggested a possible link between suicide and magnetic fields.

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). The mechanism underlying ELF-MF-induced depression is considered to involve adrenal steroidogenesis, which is triggered by ELF-MF exposure. Kitaoka (2016) found that ELF-MF exposure stimulates adrenal steroidogenesis.

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.

Energy metabolism

In a study by Sedghi (2006) exposed guinea pigs' total lipid and cholesterol levels were significantly decreased as well as the triglyceride levels. An exposure for 4 hours daily led to a significant increase in the levels of lipoproteins, cortisol, and glucose in the serum. Bahaoddini (2008) found that the glucose level in a group of rats exposed to EMFs was significantly higher and the body weight gain, insulin and cholesterol levels were decreased.

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 Neodymium-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). The risk of severe electromagnetic interference was 3.5 times higher with pacemakers than with implantable cardioverter defibrillators in facilities using clinical dentistry equipment (Miranda-Rius 2016).

In patients with CIEDs (cardiac implantable electronic devices), EMIs (electromagnetic interferences) may cause potentially serious and even life-threatening complications (inappropriate shocks, device malfunctions, inhibition of pacing in pacemaker-dependent patients) and may dictate device replacement. The association of inappropriate shocks with increased mortality highlights the importance of minimizing the occurrence of EMI (Corzani 2015).

Exposure to magnetic fields may affect the pressures of programmable cerebrospinal fluid (CSF) shunts (Altun 2017).

Kidney effects

Tunik (2013) found that both pulsed and sinusoidal EMFs changed the molecular component of kidneys adversely. A significantly lower body weight as well as liver and kidney weights were found in young, male mice (Svedenstål & Johanson 1998). The authors conclude that the observed effects depend on exposure time, as well as gender & age.

Learning and memory effects

Extremely low frequency magnetic field exposure from high-voltage power lines and substations near schools had a negative impact on the working memory of children (Ghadamgahi 2016).

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). Foroozandeh (2013) showed that the exposure to an 8 mT, 50 Hz magnetic field for 4 hours had adverse effects on memory consolidation in male and female mice. Che (2007) found that exposure to 50 Hz magnetic fields significantly impaired memory if for 20 hours a day, but not for 50 minutes per day. 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. Low-frequency fields induced an increase in the level of corticosterone in blood plasma and was associated with impairment in discrimination between familiar and novel objects (Mostafa 2002).

Appropriately pulsed magnetic field during the refutation process of what one has been told or has heard can increase the probability a person will accept a false statement as true (Ross 2008). Stevens (2007) suggested that this effect may be due to exposure to a 0-5 microT magnetic field within EEG alpha-band frequencies (8-12 Hz), results in a reported change in emotional state. However, the Ross study found that true statements were not more likely to be accepted as false, so triggering of an emotional state is less probable unless one-sided.

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, spleen 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). Yoon (2014) concluded that extremely low frequency magnetic fields could induce DNA damage in human lung fibroblasts and human lung epithelial cells.

Cabrales (2001) found that chronic exposure of mice to a 60 Hz magnetic field could influence some hematologic parameters and the weight of liver and spleen. Ibrahim (2008) and BL Li (2015) determined that chronic exposure of rats to a 50 Hz magnetic field might have detrimental effects on the liver and immunologic parameters and could induce oxidative stress in serum, liver and spleen.

The spleen is involved in the removal of bacteria, especially those without antibodies, and waste from the blood, the making of antibodies, and the making of red blood cells.

Bayat (2011) found that spleen volume was reduced in newborns after prenatal exposure to EMFs, especially early on in pregnancy.

Chicken eggs were exposed to ELF-MFs. This had created changes in the spleens of hatched chickens which could impair immune functions (Lahijani 2013).

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. ELF-MFs were found to tune redox homeostasis and epigenetic control of gene expression in vitro and shed light on the possible mechanism(s) producing detrimental effects and predisposing neurons to degeneration (Consales 2018).