Radiofrequency EMFs and Health Risks

This article is separated into 8 sections, each of which can be individually downloaded. It is a 'work in progress' incorporating new information whenever time permits.

Section 4

Reproductive Problems

1. Introduction; RF broadcast transmitters (radio & TV); DAB transmitters; radar; mobile phone masts; Internet of Things (IoT); safety zones; Lloyd's of London insurance refusal

2. The research – General; addiction; autism; behaviour changes; blood-brain barrier; blood changes; blood pressure; bone and muscle development; brain activity; cancer; Non-Hodgkin's lymphoma; cellular changes; central nervous system; cognitive changes; dementia; diabetes; DNA; emotional effects; epilepsy; eyes; headaches; hearing

3. The research – heart; effects on heart pacemakers; immune system; kidney effects; lifespan; limb changes in utero; liver damage; medical interference; microwave therapy; multiple sclerosis; neurological changes; effects on the nose; occupational exposure, including pulsed RF; oxidative stress; pain; psychiatric symptoms; skin effects; effects on sleep; spine; spleen and thymus; synergistic effects; thyroid effects; other biological changes; protection; the need for precaution with respect to children; synergistic effects; campaigning organisations

4. General reproductive effects; Radiofrequency (microwave) (RF) exposure and reproductive effects; Mobile phones or phone-type exposure and male sperm; Radiofrequency exposure and effects on female reproduction; Radiofrequency exposure and effects during pregnancy

5. Driving – car systems; tracking vehicles; when your car lock doesn't work; driverless vehicles; road trains; charging electric vehicles; mobile phones; motorbikes; speed limiting devices; traffic control sensors; other in-car devices; interference with electric vehicles

6. Animals; birds and bats; tadpoles; fishes; insects; ants; bees; cockroaches; flies; effects on plants

7. References – 595 references

8. Appendix; table of symptoms, by study; Santini 2002; Freiburger Appell 2002; Navarro 2003; Oberfeld 2004; open letter to Edmund Stoiber, President of Bavaria; Balmori 2005; Hutter 2006; Abdel-Rassoul 2007; Preece 2005; UK Parent-Teacher study 2000; Bortkiewicz 2004; Eger 2004; Wolf & Wolf 2004;

Eberhardt 2008; Augner 2010; Alazawi 2011; Santini 2003; Eger & Jahn 2010; Singh 2016; Kato & Johansson 2012; Gomez-Perretta 2013; Bortkiewicz 2012

General reproductive effects

A review of studies of EMF exposure (Asghari 2016), both pulsed and continuous (Solek 2017), and effects on both male and female reproduction systems concluded that electromagnetic fields can have destructive effects on sex hormones, gonadal function, foetal development, and pregnancy. The authors suggested that people must be aware of the negative effects of EMFs and recommended that they stay as far away as possible from their origin because of the risks associated with exposure.

Trying to identify what may be the cause of the effect on reproductive organs or gestation can be difficult, as it may be more complex than some of the studies allow for, possibly explaining why there are conflicting findings.

As many as one in five healthy young men between the ages of 18 and 25 produce abnormal sperm counts. Only 5 to 15% of their sperm is good enough to be classed as 'normal' under World Health organisation rules, proving that infertility is not just a female problem. Indeed, among those experiencing difficulty with conception, a male fertility problem is considered important in about 40% of couples.

But women trying to get pregnant have also become aware of the fact that the core problems of male fertility start in the womb. There is a 'window' of testicular development that begins in the growing foetus and ends in the first 6 months after birth. Problems during this time may mean that the baby boy may not be able to produce children (Hancı 2013).

In this section we concentrate on the effects of high frequency EMFs on reproduction. We summarise some of the research findings below. The research situation changes frequently, so this is just a 'snapshot' in time.

Workers in radio-location and television and radio broadcasting facilities, were found to have essential modifications of sperm cell morphology which were caused by mechanical damage of the microwave radiation (Nikolaev & Loginov 2015).

Radiofrequency (microwave) (RF) exposure and reproductive effects

Mobile telephone and wireless technology produce high frequency, radiofrequency or microwave electromagnetic fields (EMFs). There has been increasing concern that EMFs are not as safe as they were first thought to be. Exposure limits were put in place by the government to prevent us getting electric shocks, or being cooked. No acknowledgement by the regulators has been made that health effects are possible from very low levels of exposure.

A study replicating previous Soviet studies on RF exposure found adverse effects of the blood serum from exposed rats on pregnancy and foetal development of intact rats (Grigoriev 2010).

Two studies looking at occupational exposure to RF in the Norwegian navy (Møllerløkken & Moen 2008, Baste 2008) showed an increased risk of infertility in men exposed to radiofrequency fields; the higher the exposure, the greater the risk for infertility. Where children were born to exposed men, there were a greater number of girls born than boys. Paternal work aboard fast patrol boats during an acute period was associated with perinatal mortality and preeclampsia (Baste 2012). Ye (2007) found that radar radiation damages sperm quality, as shown in the reduction of sperm motility and elevation of sperm abnormality.

Male RF heater operators experienced changes in semen quality and hormonal differences including a slightly higher mean follicle-stimulating hormone level, despite the RF levels not exceeding standard levels and guidelines (Grajewski 2000).

Cell phone radiation can lead to detrimental effects in human male and female reproductive cells (Boga 2016). Long-term exposure of adult male frogs to GSM-like radiation at 900MHz resulted in 3% abnormal and 8% dead embryos; long-term exposure of adult females led to 12% abnormal and 12% dead embryos; long-term exposure of both adult males and females led to 12% abnormal and 15% dead embryos.

Mobile phones or phone-type exposure and male sperm

Sperm counts in UK men have fallen by 29% in the last decade. Mobile phones have been used, increasingly, in the last decade and a half. Sperm quality has decreased and the incidence of testicular cancer has increased in Finnish men between 1998 and 2006 (Jørgensen 2011). The authors suggest that the underlying causes are environmental as these findings were simultaneous and rapidly developing. In the annual meeting of the American Society for Reproductive Medicine as early as October 2006, US researchers and doctors in Mumbai, India, reported that the more men used a mobile phone, the worse their sperm count and the poorer the quality of their sperm would be, also reported in the research by Agarwal (2008) and Falzone (2011). Using the phone for more than 4 hours a day caused a 25% drop in the number of sperm produced and only 20% of these looked normal. In a study of males attending an infertility clinic in Poland, Wdowiak (2007) found an increase in the percentage of sperm cells of abnormal structure and a decrease in sperm movement associated with the duration of exposure to mobile phone radiation. Jurewicz (2013) found that using a mobile phone for more than 10 years decreased the percentage of motile sperm cells.

The results of a study by Odacı (2015) show that exposure to 900 MHz EMF causes alterations in adult rat testicular morphology and biochemistry. A further study by Odacı (2016) found that sixty-day-old rat testes exposed to 900 MHz EMF exhibited altered sperm quality and biochemical characteristics.

A review of 11 studies of human males showed that mobile phone use is possibly associated with a number of deleterious effects on the spermatozoa (Dama & Bhat 2013).

We cannot recommend that men carry a phone in their front trouser pockets. Aitken (2005), Fejes (2005), Erogul (2006), Yan (2007), Agarwal (2008, 2009, Agarwal & Durairajanayagam 2015) Falzone (2008) Gutschi (2011), Rago (2013), Adams (2014), Ghanbari (2014) and Duan (2015) concluded that usage of mobile phones, exposure to mobile phone signals, or storage of a mobile phone close to the testes affected DNA fragmentation, sperm counts, movement, viability and structure. "*In addition to these acute adverse effects of electromagnetic radiation (EMR) on sperm motility, long-term EMR exposure may lead to behavioural or structural changes of the male germ cell. These effects may be observed later in life, and they are to be investigated more seriously.*" Agarwal & Durairajanayagam in their 2015 review, recommended that those with subfertility issues or seeking assisted reproduction minimise their exposure to environmental RF-EMW radiation to alleviate its potential negative impact on sperm quality.

Houston (2016) reported that among a total of 27 studies investigating the effects of RF-EMR on the male reproductive system, negative consequences of exposure were reported in 21. Within these 21 studies, 11 of the 15 that investigated sperm motility reported significant declines, 7 of 7 that measured the production of reactive oxygen species (ROS) documented elevated levels and 4 of 5 studies that probed for DNA damage highlighted increased damage due to RF-EMR exposure.

Al-Ali (2013) found a potential correlation with mobile phone usage and a negative impact on human erectile function. Total time spent talking on the mobile phone per week was not significantly higher in the men with erectile dysfunction, but these were found to carry their 'switched on' mobile phones for a significantly longer time than those without the problem.

Why should EMFs affect the movement of sperm? One study points to a possible explanation. Lishko (2010) showed that human sperm move to the egg in an electrically created pathway. This may well be affected by external EMFs. Mice, often used as experimental subjects have much larger sperm (relatively speaking) than humans, so they may not be affected as much, and could explain some of the different laboratory findings. This could be significant when many of the laboratory studies are carried out on mice.

Susa & Pavicić (2007) reviewed research into the effects of RF on reproduction. They concluded *"A number of in vivo and in vitro studies indicated that RF fields could interact with charged intracellular macromolecular structures. Results of several laboratory studies on animal models showed how the RF fields could affect the mammalian reproductive system and sperm cells. Inasmuch as, in normal physiological conditions spermatogenesis is a balanced process of division, maturation and storage of cells, it is particularly vulnerable to the chemical and physical environmental stimuli. Especially sensitive could be the cytoskeleton, composed of charged proteins; actin, intermedial filaments and microtubules. Cytoskeleton is a functional and structural part of the cell that has important role in the sperm motility, and is actively involved in the morphologic changes that occur during mammalian spermiogenesis."*

In studies by Mailankot (2009) and Zhang (2016), rats exposed to mobile phones emissions had impaired semen quality and the authors believed this may impair male fertility. Kesari (2010) found a decrease in sperm count and an increase in apoptosis (Kesari & Behari 2009, Q Liu 2015) after 2 hours a day for 35 days. Ghanbari (2013) found that exposure to mobile phone radiation could decrease sperm viability and motility in rats. These emissions could also decrease sperm total antioxidant capacity in rats and result in oxidative stress (Kuzay 2017). Celik (2012) found no significant changes after 3 months in the testes parameters they investigated. They did conclude that because of the changes observed, significant changes may occur if the study period were to be extended, though Dasdag (1999) had found changes in the testicular tissue and seminiferous tubular diameter of rats after one month's exposure for 2 hours a day, and Almášiová (2014) found structural changes in rat testes after 3 hours a day for 3 weeks. Tas (2013) found some reproductive parameters were changed by long-term (one year) exposure to 900 MHz RF. Houshyari (2015) reported three cases of seminoma in a person who was exposed to radio frequency (RF) waves in his place of work. The authors suggested that the association between radiofrequency and testicular damage and cancer is unproved, but clinical and experimental data are suggestive of such possibility.

Atasoy (2013) found DNA damage and decreased enzyme activity in rat testes as a result of RF exposure. They concluded *"These findings raise questions about the safety of radiofrequency exposure from Wi-Fi Internet access devices for growing organisms of reproductive age, with a potential effect on both fertility and the integrity of germ cells."*

Shahin (2014) observed that MW irradiation induced a significant decrease in sperm count and sperm viability along with the decrease in seminiferous tubule diameter and degeneration of seminiferous tubules in mice. Radiofrequency EMFs produced genotoxicity through oxidative DNA base damage in mouse male germ cells (Liu 2013).

A study by Lukac (2011) indicated a negative time-dependent effect of 1800 MHz RF-EMW radiation on bovine spermatozoa motility.

Sperm head abnormalities were found in mice as a result of exposure from mobile phone base stations (Otitoloju 2010). The effects were dose-dependent. L Chen (2014) found that microwave

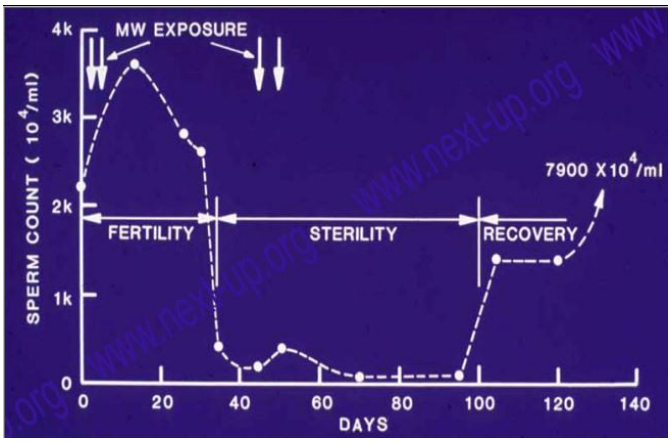
radiation induced reduced level in testicular sperm head count and serum testosterone, while the level of serum estradiol increased. The authors concluded that 1800 MHz microwave radiation may disturb the level as well as circadian rhythmicity of the reproductive functions in male mice.

Panagopoulos' team (2007) found that when looking at the reproductive capacity of flies, 900 MHz radiation was more bioactive than 1800 MHz. It is interesting that the experiment included only head exposure. It may be that positioning the radiating source nearer to gonads may have had a different effect, explaining some of the conflicting findings in different studies.

A review of the studies by Desai (2009) concluded that RF EMFs from mobile phones might affect the fertilising potential of sperm. It was concluded that microwave exposure could adversely affect male fertility (Kumar 2011, 2012) though the mechanism remains unclear (Falzone 2010). A review of studies (La Vignera 2012) on human sperm and human exposure to RFs concluded that RF reduced sperm concentration, motility, morphology and vitality, and the damage was directly related to the length of mobile phone use. The motility of sperm samples exposed to mobile phone jammer RF radiation for 2 or 4 hours was significantly reduced (Mortazavi 2013). The authors concluded that mobile jammers may significantly decrease sperm motility and couples' chances of conception.

Microwave radiation has resulted in degeneration, apoptosis or necrosis in germ cells at different stages. Sertoli cells play crucial roles in mammalian spermatogenesis and cytokines produced by microwave-radiated Sertoli cells may disrupt spermatogenesis. Data from a study by H Wu (2012) suggested ways by which microwave radiation could damage the mechanism of germ cells.

The graph below is taken from a study by C K Chou (from an article in Chinese). It shows clearly that the effect of microwave exposure on sperm persists for a considerable time, not just for the duration of the exposure.



De Iuliis (2009) found not only changes in movement and vitality of human spermatozoa exposed to radiofrequency EMFs, but also DNA fragmentation. Avendano (2012) also found these effects on in vitro samples of sperm exposed for 4 hours to a wireless internet-connected laptop. Changes in DNA may not only affect any children born after such a change, DNA changes can be inheritable, and the changes may affect future generations in ways that are completely unpredictable. Such fragmentation is not always found (Ogawa 2009, Sommer 2009).

Fructose is an important component in semen that facilitates sperm movement. A significant drop in fructose levels was observed in rabbits exposed to pulsed radio frequency emitted by a mobile phone kept in the standby position, affecting sperm motility (Salama 2009). Another study (Salama 2010) showed that standby signals could affect testicular function and structure,

although some of the results could do with careful checking, as there seem some odd claims. The team also found changes in sexual behaviour including ejaculatory success (Salama 2010).

Kesari (2011), Kumar (2011) and Liu (2014) found many changes in fertility patterns following mobile phone exposure, which seemed to arise as a result of increased reactive oxygen species (ROS). Kesari (2012) believes that the reduction in testosterone, the increase in caspase-3 and distortion in spermatozoa could be caused by an overproduction of ROS under mobile phone radiation exposure. The study concludes that there is a significant effect of microwave radiations on the reproductive pattern in male rats. Meo (2010) and Z Wang (2016) also found a reduction in testosterone levels which they felt could have devastating implications for reproductive and general health. A further study (Meo 2011) found long-term exposure to mobile phone radiation can cause hypospermatogenesis and maturation arrest in the spermatozoa in the testis of Wistar albino rats.

Reproductive hormone levels were disturbed as a result of RF-EMF exposure which could possibly affect reproductive functions. Testosterone and inhibin B concentrations as a fertility marker and spermatogenesis were decreased significantly (Sepehrimanesh 2014).

Ozlem Nisbet (2012) found that exposure to RF EMFs caused an increase in testosterone level, epididymal sperm motility (forward), and normal sperm morphology of rats. The authors concluded that 1800 and 900 MHz EMF could be considered to be a cause of precocious puberty in growing rats.

Rats exposed to RF exhibited a disruption of circadian rhythms, decreased testosterone levels, lower daily sperm production and sperm motility, depending at which point in the circadian rhythm they were exposed (Qin 2014).

Radiofrequency electromagnetic fields such as that from a mobile phone had a negative effect on testicular architecture and enzymatic activity (Al-Damegh 2012) in rats.

Panagopoulos (2004) found that exposure to voice messages decreases the reproductive capacity of both male and female Drosophila Melanogaster by 50%-60%, whereas the corresponding nonspeaking field emission decreases the reproductive capacity by 15%-20%. The authors suggested that this field-radiation decreases the rate of cellular processes during gonad development in insects.

GSM radiation decreased the reproductive effect in flies by cell death induction. The effect diminished with the distance from the antenna and decreasing intensities. An increased bioactivity 'window' was seen at 20-30 cm from the antenna, where the effect became highest, in relation to shorter or longer distances (Panagopoulos 2010a). A further study (Panagopoulos 2010b) showed that the reproductive capacity decreased almost linearly with increasing exposure duration to both GSM 900 and DCS 1800 radiation, suggesting that short-term exposures to these radiations have cumulative effects on living beings.

Effects of GSM 900 MHz cellular phone radiation on early embryogenesis of Japanese quails can either damage DNA or decrease damage to DNA depending on the duration of exposure (158 hours exposure and 38 hours exposure respectively) (Tsybulin 2013).

However, research does not always find evidence of effects. In a study by Ribeiro (2007), rats exposed to GSM phone radiation at just over 1800 MHz showed no changes in testicular function, neither were there effects on rat spermatogenesis found by Lee (2012) as a result of CDMA and WCDMA exposure simultaneously combined.

Luo (2013) found degeneration and shrinkage of testicular tissue along with a significant increase in apoptotic rate in cells exposed to electromagnetic pulses.

Nazıroğlu (2013) found that oxidative stress from exposure to WiFi and mobile phone-induced EMF radiation is a significant mechanism affecting male and female reproductive systems, though not necessarily resulting in infertility.

Talking for 1 hour or more a day on a mobile phone and during device charging were associated with higher rates of abnormal semen concentration. Among men who reported holding their phones 50 cm or less from the groin, a higher rate of abnormal sperm concentration was found. Talking while charging the device was a risk factor for abnormal sperm concentration (Zilberlicht 2015).

Radiofrequency exposure and effects on female reproduction

Gul (2009, Türedi 2016) found that intrauterine exposure to RF radiation had a toxic effect on rat ovaries, and concluded that *"the microwaves of mobile phones might decrease the number of follicles in rats by several known and, no doubt, countless unknown mechanisms."*

A Chinese study (Xu 2009) showed toxic changes to female rats' reproductive organs with exposure to RF radiation. However, the frequency (30 MHz) used experimentally is likely to be from military radar and uncommonly encountered, and at signal levels where an individual, to be exposed, would have to be working nearby, or in the main beam.

RF EMF under conditions of repeated short-term exposures affects the course of pregnancy in female mice, the number of litters, fertility and preservation of offspring and morphometric characteristics of the offspring of experimental animals at different models of irradiation (exposure of animals to RF EMF prior to mating and during pregnancy) (Shibkova 2015).

Hou (2015) found that exposure of mouse embryonic fibroblasts to an 1800 MHz electromagnetic field could promote oxidative stress and apoptosis.

A low level of MW irradiation-induced oxidative stress not only suppresses implantation, but it may also lead to deformity of the embryo in case pregnancy continues (Shahin 2013).

Margaritis (2014) found that RF EMFs had statistically significant effects on Drosophila flies regarding fecundity and cell death. The EMF sources included GSM 900/1800 MHz mobile phone, 1880-1900 MHz DECT wireless base unit, DECT wireless handset, mobile phone-DECT handset combination, 2.44 GHz wireless network (WiFi), 2.44 GHz blue tooth, 92.8 MHz FM generator, 27.15 MHz baby monitor, 900 MHz CW RF generator and microwave oven's 2.44 GHz RF and magnetic field components. Manta also found (2014) free radical increase in the ovaries of flies after exposure to DECT radiation from the base unit when not in use. S. Kumar (2013) found that rat sperms could be injured by 10 GHz electromagnetic fields.

Radiofrequency exposure and effects during pregnancy

In view of the fact that foetal testicular development occurs in the first 6 months of pregnancy, it may be worth pregnant women being very careful where they carry a mobile when not in use.

In environments where pregnant women might wear portable radios near their abdomens, the foetal SAR exposure could be higher than the RF safety guidelines for occupational exposure (Akimoto 2010).

When applying the reference levels for the general public, the foetus is sufficiently shielded by the mother. However, the basic restrictions for general public exposure can be exceeded in the foetus when the mother is exposed at reference levels for occupational conditions (Cabot 2014). For plane wave exposure at occupational levels, the whole body SAR in the foetus can exceed the basic restrictions for the general population by at least 1.8 dB, and in the near-field of professional devices, the 10 g SAR can be non-compliant with the product standard for the general public by more than 3.5 dB.

Zarei (2015) found a significant association between either the call time or history of mobile phone use (months used) and speech problems in the offspring and exposure to mobile phones during pregnancy was found to adversely affect the cognitive performance of both female and male offspring (Razavinasab 2016).

Han (2010) found that watching TV and using a mobile phone during the first 3 months of pregnancy may increase the risk of embryo growth ceasing significantly, in particular for high-risk pregnant women with embryo-growth ceasing history. Lee (2009) found that a combined exposure to CDMA and WCDMA RF had no effect on developing mouse foetuses.

900 MHz exposure during the prenatal period caused pathological changes in kidney tissue in 21-day-old male rats owing to oxidative stress and decreased antioxidant enzyme levels (Odacı 2015). 1800 MHz exposure during prenatal and postnatal periods may lead to oxidative stress and changes in some blood chemistry parameters (Ozgur 2013). In a study by Jing (2012), the authors concluded that microwave radiation from cellular phones during pregnancy harmed the development of foetal rat brains.

Liu (2007) found that the use of a microwave oven or a mobile phone were risk factors for early spontaneous abortion. Abad (2016) found a significant likelihood of miscarriage in women who were exposed to a significant level of RF EMFs. Pregnant women exposed to high radiation levels from sources like cell phones, wireless devices and cell towers miscarried at nearly three times the rate as those exposed to low levels (D-K Li 2017). Professor Li commented "*We really want people to start rethinking the assumption that magnetic-field exposure is safe*."

Exposure to 2450 MHz EMF, particularly in the prenatal period, resulted in postnatal growth restriction and delayed puberty in female Wistar rats (Sangun 2015).

Neurobehavioral disorders are increasingly prevalent in children, though the reason for this is not entirely certain. In a study by Aldad (2012) mice which had been exposed in utero to mobile phone radiation were hyperactive and had impaired memory. Ikinci (2013) found that exposure during the prenatal period affected subsequent learning behaviour, but only in male pups (Zhang 2015). Divan (2008) found that exposure to mobile phones prenatally-and, to a lesser degree, postnatally-was associated with behavioural difficulties such as emotional and hyperactivity problems around the age of school entry and at age 7 (Divan 2012).

Female pregnant rats injected with blood serum from other RF-exposed rats resulted in adverse effects on foetal and offspring development, including higher mortality rates in utero and postnatally (Liaginskaia 2010).

Ferreira (2006) found that exposure to RF during pregnancy resulted in damage to the tissue that makes blood cells, though the mechanism was unknown. Zhou (2017) found that pregnant women who lived within 100 metres of a mobile phone mast were more likely to suffer with an early spontaneous abortion.

A study by Haghani (2013, Odacı 2015) found that prenatal mobile phone exposure results in altered electrophysiological properties of Purkinje neurons, in the cerebellum in the brain of rat offspring. The authors were uncertain as to whether the changes were severe enough to alter cerebellum-dependent functional tasks.

In a study by Buchner (2014) the sex ratio changed significantly in newborn piglets after initiation of the mobile phone base station towards an increased number of female animals, malformations of newborn piglets and fertility problems in sows in the vicinity of the farm.

After studying rat dams and the succeeding offspring Yüksel (2016) concluded that mobile phone- and Wi-Fi-induced EMR may be one cause of increased oxidative uterine injury in growing rats and decreased hormone levels in maternal rats.

Deaths of embryos after exposure in the egg rose from 16% (unexposed eggs) to 75% (exposed to mobile phone electric field (Grigoriev 2003).

Some laboratory experiments use creatures further away on the evolutionary ladder from us than rats and mice. This may make the experiments non-comparable to human experience; but the fact that there is a change at all in the biology of living systems may give us pause for thought.

De Pomerai found changes in growth rate and maturation in the reproductive stage of nematode worms, when the larvae were exposed to weak microwave fields (2002).

Although we cannot assume that what happens to animals in a laboratory experiment, will also happen to human beings living their normal lives, rat biology is surprisingly similar in many ways to human. If the same thing ***is*** true for human beings, it may well be worthwhile considering taking precautions in case.

The following graph shows an increase in risk of miscarriage for pregnant physiotherapists who have increased exposure to microwaves, as a result of their occupation. The microwave levels are not particularly high and are similar to those which will be found in many places near mobile phone base stations and in homes and workplaces with DECT phones and wireless LAN systems.

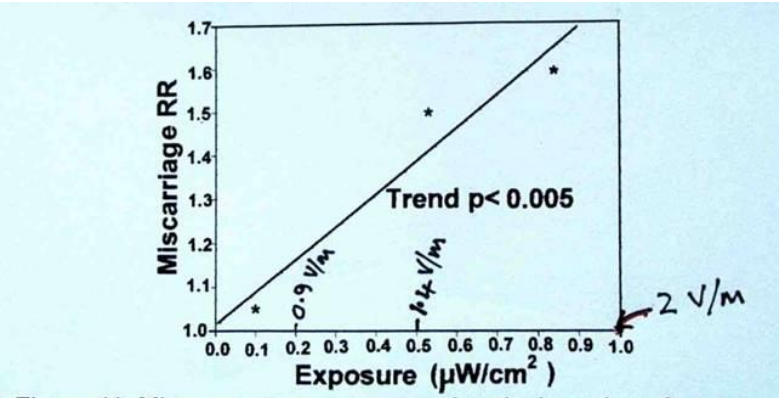


Figure 41: Microwave exposure associated miscarriage for pregnant physiotherapists, Ouellet-Hellstrom and Stewart (1993).

Shah & Farrow (2014) reported as a result of a literature review that physiotherapists' exposure to microwave diathermy devices were statistically significantly associated with spontaneous abortion.

At a cellular level, (W Sun 2012) found that RF interacted with human amniotic cells membrane receptors at relatively low SAR levels (0.1-0.5 W/kg).