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Effects of Electromagnetic Waves on male reproduction

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Abstract

Human race have been relished sophisticated life with technology. One of these, wireless technology facilitates drastic changes in human life. Wireless technology is the transfer of information between two or more points that are not connected by an electrical conductor, which includes telecommunications systems (radio, televisions, receivers, remote controls, Bluetooth, base stations, and Wi-Fi adapters). However, high levels of radiofrequency electromagnetic fields (RF-EMFs) have been emitted by increasing use of devices for wireless communication and causing various adverse health effects. The list of such adverse effects is sleep disturbances, reproductive disorders, headaches, tinnitus, high blood pressure, endocrine disorders, DNA damage, Alzheimer's disease and cancer. This field of research is notoriously difficult for various reasons, and experiments should be planned and performed with experts from the respective areas. The present review is revealed that effects of RF-EMFs on male reproductive health in mammals.

Key-Words: Reproduction, Male, EMW

Introduction

Discovering of electromagnetic waves by German physicist Heinrich Rudolf Hertz in 1888 leads a rapid development in technology and industry. By This reason humans have been leading beautiful life. Till the discovery of wireless technology, wireless devices abundantly emitting radio frequency electromagnetic waves (RF-EMW) signals. The wireless devices include PDAs, mobile phones, MP3 players, gaming devices, wireless LANs, MRI scanners, and a wide variety of devices utilizing Bluetooth technology. 300 MHz–300 GHz radiofrequency field radiation (RFR) has been leading atmospheric pollution. Moreover, recent studies demonstrated emitting of microwaves (RF-EMW) do not produce thermal effect at specific absorption rate (SAR) of 1.6 Watts/Kg (Anderson and Rowley, 2007; Yan *et al.*, 2007). Federal Communications Commission (FCC), have already attempted to set safety limits for these signals. The World Health Organization (WHO) was published Environmental Health Criteria (EHC) risk assessment of magnetic field (MF) exposures could be <100 kHz frequency (WHO, 2007). In addition, Litvak *et al.*, (2002) determined that the primary hazard identification and quantitative risk evaluation of intermediate frequency (IF) MFs between 300 Hz to 100 kHz.

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This electromagnetic pollution has been causing a threat to human and animal lives. Studies related to the biologic effects of EMF include a broad spectrum of systems, from bacteria to the cell level (Rojavin and Ziskin, 1995; Atmaca *et al.*, 1996), mitochondria, apoptosis pathway, heat shock proteins, free radical metabolism, cell differentiation, DNA damage and the plasma membrane (WHO, 2006; Leszczynski *et al.*, 2002; McNamee *et al.*, 2003), the chromosome and DNA level (Lai and Singh, 1995, 1997), the nervous, endocrine, immune, cardiovascular, hematopoietic, and ocular systems (Roberts *et al.*, 1986; Kolosova *et al.*, 1996) and results of *in vitro* and *in vivo* experiments revealed negative effects on male fertility (Alexander Lerchl. 2013; Al-Akhras *et al.*, 2001; Heredia-Rojas *et al.*, 2004; Lee *et al.*, 2004). In this review, we review the effects of RF-EMW on reproduction in mammals in *in vitro* and *in vivo* that have assessed the effect of RF-EMW on male fertility.

Effects of EMW emitted from Cell phones

In recent, the usage of mobile phones and expansion of their service networks worldwide have widely increased. Cell phones are transmitting signals from the cellular phones to base station by emitting radio frequency electromagnetic waves. The frequency of RF-EMW is 800-2200 MHz. SAR is the rate of absorption of energy by the body when the body is exposed to electromagnetic fields. This can be defined as the radiating power absorbed per mass of exposed tissues (Jin, 1999). SAR, that unit is watts per kilogram

(W/kg), is usually averaged over 1 or 10 g of tissue. Moreover, the frequency range of mobile phones is 0.8–2.8 GHz, the reference levels are approximately 33–62 V m⁻¹ (general public) and 49–92 Vm⁻¹ (occupational). Several researchers have determined the harmful effects of EMW radiation including several genetic defects (Pacini *et al.*, 2002; Tice *et al.*, 2002), decreasing sperm quality (Fejes *et al.*, 2005; Davoudi *et al.*, 2002), damaging effects on the testicular function and male germ line (Dasdag *et al.*, 1999; Aitken *et al.*, 2005),

The preliminary cell phone system, Analogue NMT (Nordic Mobile Telephone) system, was introduced in the 1980s, and operated at an ER of 902.5 MHz. A decade later, the GSM (global system of mobile communications) was launched and operated at an ER of 902.4 MHz, pulsing at 217 Hz. The most recent DCS (digital cellular system) operates at a RF of 1800 MHz (Roelandts, 2003). Advances in cell phone telecommunication systems are obviously associated with an increasing signal frequency, which correlates with higher energy radiofrequency waves.

Nisbet *et al.* (2011) was conducted a study to evaluate the possible effects of whole-body electromagnetic field (EMF) exposure on reproduction in growing male rats. 2 days old male Wistar rats were exposed to EMF 1800 and 900 MHz for 2 h continuously per day for 90 days. Control was kept under normal conditions for the same period. After completion of treatment period animals were sacrificed and blood samples were collected. The levels of plasma total testosterone were significantly higher in experimental rats when compared with control rats. The percentage of epididymal sperm motility was significantly higher in the 1800 MHz group (P<0.05). The tail abnormality in spermatozoa, total percentage abnormalities and histopathological parameters were higher in the 1800 MHz group (P<0.05). In conclusion, this study indicated that exposure to electromagnetic wave caused an increase in testosterone level, epididymal sperm motility (forward), and normal sperm morphology in rats exposed to 1800 MHz EMF when compared with rats exposed to 900 MHz EMF.

The study of exposure to radiofrequency radiations from mobile phone (GSM) base stations at a workplace complex and residential quarters was carried out by Otitoloju *et al.* (2010). Male mice were exposed to 900 to 1,800 MHz Radiofrequency radiations from mobile phone base stations. Field Strength measuring meter at distances of 0, 50, 100, 150, 200, 250 and 300 m over a 6 months period for the different locations. After completion of exposure male mice were sacrificed and tissues were collected and used for sperm analysis.

There was a significant increase in sperm head abnormalities (2.13%) when compared to control group. The major abnormalities, such as knobbed hook, pin-head and banana shaped sperm head were observed. In conclusion, RF radiation emitted by base stations caused an increase sperm head abnormalities in humans living in close proximity to GSM base stations. The effects of EMW (900 MHz) emitted by mobile phones on male reproduction in guinea pigs were investigated by Uslu *et al.* (2012). Twelve healthy male guinea pigs were exposed to electromagnetic field of 900 MHz (SAR 0.95 w/kg) emitted by a mobile phone for 20 min per day for 60 days. Control group was maintained under normal conditions. After completion of exposed period rats were necropsied and tissues were taken. There was no significant (P>0.05) decrease in testis weight, sperm motility, and abnormal sperm rate in treated males over to control males. However, a significant (P<0.05) decrease in sperm number was observed in treated males. According to the findings achieved, it was suggested that the EMW radiation emitted by mobile phones (900 MHz) in daily use caused decrease in the number of spermatozoa and adversely affected sperm characteristics in male guinea pigs.

Kesari *et al.* (2010) was investigated effects of mobile phone exposure on male fertility in wistar rats. 70 days old wistar rats were exposed to 0.9 w/kg SAR radiation released from mobile phone. The exposed period was 2 h/day for 35 days at 0.9 W/kg specific absorption rate. At the end of the treatment male rats were sacrificed and collect the tissues. A significant decrease in protein kinase C was observed in male Wistar rats exposed to mobile phone frequencies (0.9 w/kg SAR). There was a significant decrease in total sperm count due to increased apoptosis in exposed males over to control males. The results suggest that a reduction in protein kinase activity may be related to overproduction of reactive oxygen species (ROS) under microwave field exposure. The results were concluded, that decrease in sperm count and an increase in apoptosis may be causative factor due to mobile radiation exposure leading to infertility.

Salama *et al.* (2010) was investigated the effects of exposure to electromagnetic radiation emitted by a conventional mobile phone on the testicular function and structure. For this study 24 adult male rabbits were randomly and equally divided into three groups. Rabbits in the first group were exposed to radio frequency emitted from the mobile phone (800 MHz) in a standby position for 8 h daily for 12 weeks. The second group consisted of the stress controls which were kept in the same kind of cages to appreciate any

cage-induced anxiety. The third group included the normal controls in normal conditions. Semen analysis and sperm function tests (viability, hypo-osmotic swelling and acridine orange) were conducted weekly. Histological testicular sections and serum total testosterone were also evaluated. Sperm motility was significantly decreased in second group when compared to first group. Histological examination also showed the diameter of seminiferous tubules was reducing in the second and first group rabbits. These results have been concluded that low intensity pulsed radio frequency could affect the testicular function and structure in the adult rabbit.

Possible consequences of the cellular phone usage on human sperm parameters have been investigated adequately by Erogul *et al.* (2006). A total number of 27 males were enrolled in the study. The semen sample obtained from each participant was divided equally into two parts. One of the specimens was exposed to EMR emitted by an activated 900 MHz cellular phone, whereas the other was not. There was a significant decrease was observed in the rapid progressive, slow progressive and no-motility categories of sperm movement. EMR emitted by cellular phone influences human sperm motility. In addition to these acute adverse effects of EMR on sperm motility, long-term EMR exposure may lead to behavioral or structural changes of the male germ cell. These results can conclude that EMR produced by the cellular phone caused diminish sperm motility in humans exposed to EMR.

Another retrospective study was investigated the link between the men reproductive age and the effect of EMR on male fertility by Fejes *et al.* (2005). In this study analyzed 371 men and took their reproductive age, the duration of using cell phone usage and the daily transmission. Thus, results were showed a significant decrease in progressive motile sperm gradually in men spent long time with cell phones. The results were concluded, that men performed very poor reproductive performance due to the longer duration of using cell phones in daily leads to infertility.

The effect of cell phone use on various markers of semen quality was investigated by Agarwal *et al.* (2007). Three hundred sixty-one infertility men were divided into four groups according to their active cell phone use. Group A served as control, men exposed to EMF less than 2 h/day treated as group B, men exposed to EMF 2-4 h/day treated as group C and men exposed to EMF more than 4 h/day treated as group D. Although, sperm motility, viability, and normal morphology were significantly different in cell phone user groups within two sperm count groups. The sperm

parameters (volume, liquefaction time, pH, viscosity, sperm count, motility, viability, and morphology) were decreased in all cell phone user groups as the duration of daily exposure to cell phones increased. The results have been concluded that use of cell phones decrease the semen quality, which was dependent on the duration of daily exposure to cell phones.

De Iuliis *et al.* (2009) study was proven the EMW radiation has caused to damage sperm morphological and molecular level. In this study 22 men with a mean age of 24 years were used. Men were exposed to high intensity EMW radiation (1.8 GHz X 0.4 W/kg- 27.5 W/kg SAR) and some are exposed normal conditions. Sperm samples were collected from normal as well as exposed men. There was a significant decline in both motility and viability in men exposed to high intensity EMW radiation. In addition, a significant increase in the rate of mitochondrial ROS production and the level of 8-OHdG was observed in exposed men. However, the results revealed, that the intensity of the EMW caused to declaim sperm quality due to increased ROS production in mitochondria leads to weaken the males reproductive efficiency.

A Prospective pilot study was conducted by Agarwal *et al.* (2009). In this study evaluates effects of cellular phone radiofrequency electromagnetic waves (RF-EMW) during talk mode on unprocessed ejaculated human semen. Neat semen samples from normal healthy donors (n = 23) and infertile patients (n=9). After liquefaction, neat semen samples were divided into two aliquots. One aliquot treated as experimental (from each patient was exposed to cellular phone radiation in talk mode for 1 h) and the second aliquot served as the control. There was a significant decrease in sperm motility and viability, increase in ROS level, and decrease in ROS-TAC score. Levels of TAC and DNA damage was observed in Samples exposed to RF-EMW when compared to control. In conclusion, radiofrequency electromagnetic waves emitted from cell phones may lead to oxidative stress there by affect spermatozoa and impair male fertility.

Another study was revealed that the effect of radiations on ejaculated human semen and speculate the contribution of these harmful radiations in male infertility by srinivas and vasan (2012). Semen samples were collected from 20 healthy donors who volunteered for the study. After completion of liquefaction, each sample was divided into two aliquots: Exposed group (sample exposed to cell phone radiation) and control group. A significant decrease in sperm motility and viability, increase in reactive oxygen species (ROS) and DNA fragmentation index (DFI) was observed in Samples exposed to EMR

compared to control group. In conclusion, mobile phones emit electromagnetic waves which lead to oxidative stress in human semen and also cause changes in DNA fragmentation. We extrapolate these findings to speculate that these radiations may negatively affect spermatozoa and impair male fertility. Substantial evidence indicates that exposure to common sources of EMF such as mobile phones, laptops or wireless internet-connected laptops or wireless internet-connected laptops decreases human semen quality. Mortazavi *et al.* (2013) was carried out a study on the effect of short term exposure of human sperm samples to RF radiation emitted by mobile jammers. Thirty healthy infertility donors gave fresh semen samples were used to investigate effect of RF radiations. There was a significant decrease in sperm motility was observed in samples exposed to jammer RF radiation for 2 or 4 hours. These findings help to come a conclusion that RF radiation emitted by mobile jammers caused declaim in sperm motility in humans.

The WHO indicated a lack of scientific evidence needed to assess the health risk of exposure to IF MFs. Nishimura *et al.* (2012) was determined the toxic effects of exposure to IF MFs on fertility and/or early embryonic development. Male and female rats were exposed to a 20 kHz or 60 kHz sinusoidal MF for 22 h/day from 14 days before mating. Copulated females were exposed until gestation day 7. After conformation of pregnancy males were sacrificed to examine MF exposure effects on spermatogenesis. There were no significant changes in the estrous cycle, copulation and fertility indices, numbers of corpora lutea and implantation sites, or pre- and post-implantation loss. Moreover, no significant decrease was observed in sperm count, motility, morphological abnormality, the weights of testes and epididymides and histopathology of reproductive organs in MF exposure group. MF exposure during the pre-implantation period was not toxic to fertility or early embryogenesis under the experimental condition. In conclusion, exposure to 20 kHz or 60 kHz sinusoidal MFs during the rat pre-implantation period showed no reproducible, reproductive and developmental toxicity in rats and IF MF exposure carries a significant risk to mammalian reproductive and developmental functions.

Effects of EMW emitted by Wi-Fi

IEEE 802.11b describes the full form of Wi-Fi, is Wireless Fidelity (IEEE, 1999). The non-profit organization WECA (Wireless Ethernet Compatibility Alliance) was formed in 1999. At the moment (2001/04/18) more than 80 companies have joined the WECA. All Wi-Fi devices are operating at 2.4 GHz, are increasingly common technology employing

radiofrequency energy for communication. Communication devices using wifi technology are low cost and operate in the unlicensed spectrum at 2.40–2.48 GHz, popularly called the industrial, scientific and medical (ISM) band of 2.4–2.5 GHz in many part of the world. A recent release by a commercial firm reported that there are presently more than 100,000 wireless local area network (WLAN) “hotspots” in operation around the world.

Foster, (2007) was reported that little quantitative information is available to the public or to health physicists and other professionals about the levels of exposure that they produce to the public. These concerns are not unconnected to the fact that wifi devices are placed in close contact with the body when in use. Recently, numerous studies have highlighted the role of exposure of RF at 900 MHz on sperm motility, morphology and viability. Despite the results of the studies, indicating a decrease in fertility due to RF exposure on semen parameters, it is imperative to conduct a scientifically robust study involving use of people who are not using and have never used RF devices in the past, as control group (Baste *et al.*, 2008). However, selection of such control groups is extremely difficult; thus making a study involving in-vivo human exposure not feasible.

In addition, investigation was conducted to know the long-term effects of radiofrequency radiation (RFR) emitted from a Wireless Fidelity (Wi-Fi) system on testes by Dasdag *et al.* (2014). 16 Wistar Albino adult male rats were used in this study and dividing them into two groups such as control (n: 8) and exposure (n: 8). Rats in the exposure group were exposed to 2.4 GHz RFR radiation for 24 h/d during 12 months (1 year). Rats in control group were exposed normal conditions. After the completion of exposure, rats were sacrificed and reproductive organs were removed. The sperm Motility and sperm morphological abnormalities were determined. Sperm head defects increased in the exposure group ($p < 0.05$) while weight of the epididymis and seminal vesicles, seminiferous tubules diameter and tunica albuginea thickness were decreased in the exposure group ($p < 0.01$, $p < 0.001$, $p < 0.0001$). However, other alterations of other parameters were not found significant ($p > 0.05$). the results are concluded that, the long-term exposure of 2.4 GHz RF emitted from Wi-Fi (2420 $\mu\text{W}/\text{kg}$, 1 g average) affects some of the reproductive parameters of male rats.

To evaluate the effects of laptop computers connected to local area networks wirelessly (Wi-Fi) on human spermatozoa study was carried out by Avendano *et al.* (2012). Semen samples were collected from 29 healthy

donors. Each sperm suspension was divided into two aliquots. One sperm aliquot (experimental) from each patient was exposed to Wi-Fi for 4 hours, whereas the second aliquot was used as control with normal conditions. A significant decrease in progressive sperm motility and an increase in sperm DNA fragmentation was observed in men exposed to Wi-Fi for 4 hours and normozoospermic sperm was increased in men exposed to Wi-Fi for 4 hours. In conclusion, Ex vivo exposure of human spermatozoa to Wi-Fi decreased motility and induced DNA fragmentation.

The in-vitro pilot study of the effect of 2.4 GHz RFR exposure on human ejaculated semen had been conducted by Oni *et al.* (2011). Ten samples of the semen, collected from donors between the ages of 20 and 30 years were exposed when the source of the RFR was in active mode. Sequel to the exposure, both the exposed samples and another ten unexposed samples from same donors were analysed for sperm concentration, motility and morphology grading. There was a significant decrease in sperm parameters in men exposed to RFR. In conclusion, RFR emitted from laptops caused savior decrease in sperm concentration and parameters.

Another study was conducted to investigate the effect of non-ionizing radiofrequency field on delivery and general condition of young rats exposed in utero and postnatal periods by Aissa *et al.* (2012). Pregnant rats were exposed to, a 2.45 GHz Wi-Fi signal for 2 h/day for 5 days/week. The whole experiment was done in reverberation chamber at whole-body specific absorption rates (SAR) of 0, 0.08, 0.4, and 4 W/kg (with 10, 10, 12, and 9 rats, respectively). The control rats were kept in the normal conditions. Dams were exposed from days 6 to 21 of gestation and then three newborns per litter were further exposed from birth to day 35 postnatal. On day 35 after birth, all pups were sacrificed and serum collected. Although, the number of pups per litter and anogenital distance was significantly decreased in dams exposed to 2.45 GHz Wi-Fi signals. Under these experimental conditions, it is concluded that effects of Wi-Fi exposure on delivery and general condition of the animals.

In contrast, Gannes *et al.* (2012) was reported teratology and development studies have not detected any noxious effects of exposures to Wi-Fi at exposure levels below standard limits. The pregnant rats and their pups were exposed to 2450 MHz Wi-Fi signal for 2 hr/day for 6 days/week for 18 days. Three levels in terms of whole-body specific absorption rate were used: 0.08, 0.4, and 4 W/kg. At the day 20th pregnant rats were delivered the pups by caesarean. Although, no abnormalities were noted in the pregnant rats and no

significant signs of toxicity were observed in the pre- and postnatal development of the pups, even at the highest level of 4 W/kg. The results have been concluded that no teratogenic effect of repeated exposures to the Wi-Fi wireless communication signal was demonstrated even at the highest level of 4 W/kg.

Effects of EMW emitted by Magnetic Resonance Imaging (MRI) scan

In recent, an increase incidence of taking magnetic resonance imaging (MRI) scans for diagnostic purposes. In worldwide, approximately 20000 MRI machines are there. In MRI persons are exposed to high electromagnetic fields (EMF) (ICNIRP, 2009). In order to obtain good resolution images in MRI scanners inventers should increasing field strengths of both the static Band the switched gradient B fields. It emits high RF field by increasing power. According to International Commission on non-ionizing radiation protection (ICNIRP) guidelines MRI monitored and follows (Guidelines, 2010; Guidelines, 2009). ICNIRP is suggested that exposure to EMF on a period of 0.1 h which should not increase the body temperature. The RF field frequency in MRI is around 63.4 (MHz) for a 1.5 T device and around 127 MHz for a 3 T device.

Another extreme study was carried out by Tenorio *et al.* (2014) to investigate risk of exposed to low-frequency magnetic fields (60 Hz and 1 mT) on spermatogenesis and recovery after reversible testicular damage. Adult male rats were subjected to a single testicular heat shock (HS, 43 °C for 12 min) and then exposed to the magnetic field for 15, 30 and 60 d after HS. Magnetic field exposure during the spermatogenesis recovery induced changes in testis components volume, cell ultrastructure and histomorphometrical parameters. Control animals had a reestablished and active spermatogenesis at 60 d after heat shock, while animals exposed to magnetic field still showed extensive testicular degeneration. Magnetic field exposure did not change the plasma testosterone. In conclusion, extremely low-frequency magnetic field may be harmful to fertility recovery in males affected by reversible testicular damage.

Li *et al.* (2009) was conducted a population-based case-control study to examined effects of magnetic fields (MFs) on sperm quality. All participants wore a meter to capture daily MF exposure. MF exposure caused two-fold increased risk of abnormal sperm motility and morphology who exposed to MF radiation. In addition, increasing duration of MF exposure above 1.6 mG further increased the risk. Importantly, the association and dose-response relationship were strengthened when restricted to those whose measurement day reflected their typical day of the

previous 3 months. Age-adjusted Spearman Rank Order Correlations showed an inverse correlation between MF exposure and all semen parameters. The data provides some evidence for the first time that MF exposure may have an adverse effect on sperm quality. Another questionnaire-based descriptive pilot study was conducted to study MRI effects among all nurses routinely working with MRI in the Northern part of Sweden by Wilen and de Vochet. (2011). Fifty-nine nurses (88% response rate), with on average 8 (\pm 6) year experience with MRI scanning procedures were examined in the study. In total, 9 nurses (15%) reported regularly experiencing in the MRI scanning room. However, reporting of health complaints was related to the strength of the magnet(s) the nurses worked with, with 57% of symptoms reported by those nurses working with the strongest systems. The results indicate that the prevalence of reported health complaints is not related to perceived work load or occupational stress, but does confirm data from other occupational sectors and indicates that the prevalence of adverse health complaints increases with the strength of the MRI system for nurses as well.

Magnetic resonance imaging (MRI) is increasing around the world and the possible adverse effects on reproductive health of electromagnetic fields (EMFs). Møllerløkken *et al.* (2012). 24 healthy male volunteers was participated in the prospective randomized balanced cross-over study using a head scan in real MRI. Serum-blood samples were taken before and after the different scans to estimate the activity levels of inhibin B, testosterone, prolactin, thyrotropin, Luteinizing hormone, Follicle stimulating hormone, sex-hormone binding globulin and estradiol. There was no significant difference in the hormone levels in men exposed to MRI when compared to control men. The results have been concluded that MRI scans caused adverse effects on male reproduction or possible chronic effect of multiple in males.

Epidemiologic study was conducted to investigate the potential risks from exposure to the static and time-varying magnetic fields used in magnetic resonance (MR) imaging by Kanal *et al.* (1993). This study was carried out women workers in more than 90% of clinical MR facilities in the United States addressed menstrual-reproductive experiences, work activities, and potential confounders (eg, age, smoking, alcohol use). There was spontaneous abortions; for conception taking more than 12 months, 0.90 for delivery before 39 weeks, 1.19 for birth weight below 5.5 lb (2.5 kg), 1.01 and for male gender of the offspring, 0.99 in women exposed to radiation in their working sites. These results have been concluded that there is not a

substantial increase in these common adverse reproductive outcomes

Effects of EMW emitted by Microwave oven

Since 1950, the usage of domestic microwave ovens has been drastically increased. Giruere *et al.* (1986) was demonstrated, that microwave energy is also suitable for accelerating organic reactions, leads to enhancing interest in the microwave assisted processes as tools in the synthesis of organic and inorganic substances. Generally, the energy is transferred through convection, conduction and radiation of heat from the surfaces of the material. In contrast, the energy is delivered directly to materials through molecular interaction with electromagnetic field in microwave ovens. Microwave heating involves the transfer of electromagnetic energy to thermal energy, but in conventional thermal processing energy is transferred as a result of thermal gradient between two points. The difference in the way energy is released can result wide usage of microwaves for processing of materials (Thostenson and Chou 1999). Though, Microwave ovens are emitted ultra high frequencies (300 MHz-3 GHz) radiation. (McRee, 1972). They emit a form of EM energy similar to radio and light waves. However, very little data is available on reproductive effects of irradiation of microwave oven in males.

Athermal effects due to microwave radiation in a number of chemical, biochemical and microbial systems was examined by Shazmann *et al.* (2006). The possibility of an athermal effect was tested in 2.45 GHz, up to 1000 W/kg, with continuous radiation up to 48 h (high radiation intensity system). Surprisingly, no athermal effects were detected in any of the tested systems. By this results have been concluded that microwave radiation cannot induce the athermal effects.

In other hand, Quan *et al.* (1992) was carried out experiments to investigate the effects of microwaving on breast milk at high temperatures (72°C to 98°C). *E. coli* growth at >98°C was 18 times that of control human milk. Microwaving at low temperatures (20°C to 53°C) had not significant effect on total IgA, but did significantly decrease lysozyme. However, the results concluded that microwave irradiation was caused a marked decrease in activity of all the tested anti-infective factors. Moreover, Lusec *et al.* (1989) has been demonstrated that the conversion of trans to cis forms could be hazardous because when cis-aminoacids are incorporated into peptides and proteins instead of their trans isomers this can lead to structural, functional, and immunological changes. Number of studies was demonstrated that food had been cooked in a microwave oven caused significant changes in blood

and these changes caused to beginning of cancer (Blanc and Hertel. 1992; 1992). Czernski and Leach. 1974 have been proven that microwaves cause cancer in animals.

Extensive research has needed to determine whether athermal effects on reproduction are associated with microwave radiation, and to measure the extent of the phenomenon if it exists.

Effects of EMW emitted by Bluetooth

Bluetooth is a short-range wireless technology, or wireless network, that allows wireless communication between different remote devices, such as cellular phones, computers, and PDAs. The IEEE 802.15 has developed a wireless personal area networking (PAN) based on the Bluetooth specifications (Karygiannis and Owens, 2002). Bluetooth and wireless LANs use the same frequency range as that of microwave ovens. The Bluetooth devices, which many people are using these days because of health or safety concerns, may not be always so safe. Most people regularly use Bluetooth technology on a weekly, if not daily basis. This short-range wireless technology enables the simple transfer of data between mobile phones, laptops, and an array of other electronic devices. However, there is a mounting body of evidence that suggests this technology may be harming fertility, especially the sperm in men.

Bluetooth works in the electromagnetically noisy 2.4–2.484 GHz band. In general, Bluetooth output power is low compared to cellular phones. There are three classes of Bluetooth. The three classes differ in sensitivity, output power, and range. Class 1 has a maximum output power of 100 mW (20 dBm). Class 1 supports an unobstructed line-of-sight range up to 100 meters (328 ft). Class 2 has a maximum output power of 2.5 mW (4 dBm). Class 2 supports up to a 10 meter (33 ft) range. Class 3 has a maximum output power of 1mW (0 dBm) with a very limited range from 0.1 to less than 10 m (less than 30 ft).

Merhi, (2012) suggested use of hands-free kits lowers the exposure to the brain, but it might theoretically increase exposure to the reproductive organs. This report summarizes the potential effects of RF-EMR on reproductive potentials in both males and females. Few data exist regarding specific health hazards of this technology, as it is believed that the SAR levels caused by such systems are usually too low to pose health hazards [(Berggren and Magnus, 2001). However, given the development of high power Bluetooth devices and the potential for high accumulated exposure, these systems may need to be tested.

Conclusion

Nowadays, general population is exposed chronically to non-thermal MWs from different types of communication including GSM and UMTS/3G phones, WLAN (Wireless Local Area Networks), Bluetooth (WPAN), scans (MRI) and microwave ovens. By this reason, several scientists in different parts of the world are more interested to investigate the non-thermal effects due to micro wave radiation on human health. In light of recent reports about MW effects (particularly athermal effects) on different life forms, the safety standard of exposure needs to be re-evaluated.

Several researchers have been documented that adverse effects in reproduction leads to infertility in both males and females due to high electromagnetic radiance emitted by different kinds of devices including cell phones, Bluetooth, Wi-Fi, microwave ovens and magnetic resonance imaging scans. The current review reveals the adverse effects of electromagnetic radiance emitted by cell phones, Bluetooth, Wi-Fi, microwave ovens and magnetic resonance imaging scans on male reproductive tract and leads to infertility. Infertility is the profanity to any kind of race and which is a hurdle to develop the race.

It is believed that electromagnetic field emitted by devices (cell phones, Wi-Fi and MRI scans) is caused to decrease in testicular weight, sperm quality and quantity and increase in sperm morphology in mammals. There is an increase in non-motile sperm in males exposed to MF. There is a significant decrease in epididymis weight in animals exposed to both 900 and 1800 MHz MFs. Testicular histopathology has proven that MF exposure caused damage the testicular architecture, leads to poor spermatogenesis. In addition, MF exposure during the pre-implantation period was caused to decrease fertility or early embryogenesis under the experimental condition. Also, MF emitted from cell phones may lead to oxidative stress in testis leads to changes in DNA fragmentation. It is well known that free radical action leading to adverse changes in hormones essential in male reproduction, DNA damage, which in turn causes damage to sperm motility, viability, and sperm morphology.

The usage of microwave ovens and Bluetooth is enormously increased in general population. Very little data is available on effect of MF emitted by microwave ovens and Bluetooth. Further research is needed on the exact mechanism(s) behind non-thermal effects of MW emitted by these devices. Before study to large scale epidemiological studies for possible health hazards of MW radiation at low-level, is necessary for studying

the non-thermal effects alone and availability of unexposed controls is almost impossible for such experiments because people are continuously exposed to various signals/frequencies including non-effective ones. Children and pregnant women may represent the most sensitive group to non-thermal effects of MW.

References

1. Agarwal A., Deepinder F., Rakesh K., Geetha Ranga S., Li J. (2008). Effect of cell phone usage on semen analysis in men attending infertility clinic: an observational study. *Fertil Steril.* 89: 124-128.
2. Agarwal A., Desai N.R., Makker K., Varghese A., Mouradi R., Sabanegh E., Sharma R. (2009). Effects of radiofrequency electromagnetic waves (RF-EMW) from cellular phones on human ejaculated semen: an *in vitro* pilot study. *Fertil. Steril.* 92: 1318-1325.
3. Aït-Aïssa S., Billaudel B., Pouletier de G.F., Ruffié G., Duleu S., Hurtier A., Haro E., Taxile M., Athané A., Geffard M., Wu T., Wiart J., Bodet D., Veyret B., Lagroye I. (2012). In utero and early-life exposure of rats to a Wi-Fi signal: screening of immune markers in sera and gestational outcome. *Bioelectromagnetics.* 33: 410-20.
4. Aitken R., Bennetts L., Sawyer D., Wiklendt A., King B. (2005). Impact of radiofrequency electromagnetic radiation on DNA integrity in the male germline. *Int. J. Androl.* 28: 171-179.
5. Al-Akhras M.A., Elbetiha A., Hasan M.K., Al-Omari I., Darmani H., Albiss B. (2001). Effects of extremely low frequency magnetic field on fertility of adult male and female rats. *Bioelectromagnetics.* 22: 340-344.
6. Alexander Lerchl. (2013) Electromagnetic pollution: another risk factor for infertility, or a red herring? *Asian J. Androl.* 15: 201-203.
7. Anderson V. and Rowley J. (2007). Measurements of skin surface temperature during mobile phone use. *Bioelectromagnetics.* 28: 159-162.
8. Atmaca S., Akdag Z., Dasdag, Ç.S. (1996). Effect of microwave on survival of some bacterial strains. *Acta. Microbiol. Immunol. Hungarica.* 43: 371-378.
9. Avendano C.M.A., Sarmiento C.A.S., Doncel G.F. (2012). Use of laptop computers connected to internet through Wi-Fi decreases human sperm motility and increases sperm DNA fragmentation. *Fertil. Steril.* 97: 39-45.
10. Baste V., Riise T., Moen B.E. (2008). Radiofrequency electromagnetic fields; male infertility and sex ratio of offspring. *Eur. J. Epidemiol.* 23:369- 377.
11. Blanc B.H. and Hertel, H.U. (1992). Comparative study about the influence on man by food prepared conventionally and in the microwave-oven.
12. Blanc B.H. and Hertel, H.U. (1992). Hande weg vom mikrowellenherd!- raum & zeit special nr. 6, ehlers, sauerlach.
13. Czerski P., Stonka P.E., Siekierzynski M., Stolarska A. (1974). Influence of microwave radiation on the hematopoietic system In Biological effects and health hazards of microwave radiation. Proceedings of an international symposium, October 15-18, 1973. Polish medical publishers, Warsaw.
14. Dasdag S., Ketani M.A., Akdag Z., Ersay A.R., Sari I., Demirtas O.C. (1999). Whole body microwave exposure emitted by cellular phones and testicular function of rats. *Urol Res.* 27: 219-223.
15. Dasdag S., Taş M., Akdag M.Z., Yegin K. (2014). Effect of long-term exposure of 2.4 GHz radiofrequency radiation emitted from Wi-Fi equipment on testes functions. *Electromagn Biol Med.* [Epub ahead of print].
16. Davoudi M., Brossner C., Kuber W. (2002). The influence of electromagnetic waves on sperm motility. *Urol. Urogynaecol.* 19:18-22.
17. De Iuliis G.N., Newey R.J., King B.V., Aitken R.J. (2009). Mobile phone radiation induces reactive oxygen species production and DNA damage in human spermatozoa *in vitro*. *PLoS One.* 4: e6446.
18. Eroglu O.E.O., Yildirim I., Kir T., Aydur E., Komesli G., Cem Irkilata H., Irmak M.K., Peker A.F. (2006). Effect of electromagnetic radiation from cellular phone on human sperm motility: An *in vitro* study. *Arch. Med. Res.* 37: 840-843.
19. Fejes I., Zavaczki Z., Szollosi J., Koloszar S., Daru J., Kovacs L. (2005). Is there a relationship between cell phone use and semen quality? *Arch. Androl.* 51: 385-393.
20. Foster K.R. (2007). Radiofrequency exposure from wireless lans utilizing Wi-Fi technology. *Heal Physics.* 92: 280-289.
21. Gannes F.P.D., Haro E., Hurtier A., Taxile M., Athane A., Aissa A.S., Masuda H., Percherancier Y., Ruffié G., Billaudel B., Dufour P., Veyret B., Lagroye I. (2012).

- Effect of in utero wi-fi exposure on the pre- and postnatal development of rats. *Birth Defects. Res. B. Dev. Reprod. Toxicol.* 95: 130-136.
22. Giguere R.J., Bray T.L., Duncan S.M., Majetich G. (1986). Application of commercial microwave ovens to organic synthesis. *Tetrahedron Letters.* 27: 4945-4948.
23. Guidelines for limiting exposure to time-varying electric and magnetic fields (1 Hz to 100 kHz). (2010). *Health Physics.* 99: 818-836.
24. Guidelines on limits of exposure to static magnetic fields. (2009). *Health Physics.* 96: 504-514.
25. Heredia-Rojas J.A., Caballero-Hernandez D.E., Rodriguez-de la Fuente A.O., Ramos Alfano G., Rodriguez-Flores L.E. (2004). Lack of alterations on meiotic chromosomes and morphological characteristics of male germ cells in mice exposed to a 60 Hz and 2.0 mT magnetic field. *Bioelectromagnetics.* 25: 63-68.
26. ICNIRP. (2009). Exposure to high frequency electromagnetic fields, biological effects and health consequences (100 kHz-300 GHz). ICNIRP.
27. IEEE. (1999). IEEE Std 802.11 and various amendments. Piscataway, NJ: The Institute of Electrical and Electronics Engineers, Inc.
28. Jin J (1999) Electromagnetic analysis and design in magnetic resonance imaging. CRC Press, USA.
29. Kanal E., Gillen J., Evans J.A., Savitz D.A., Shellock F.G. (1993). Survey of reproductive health among female MR workers. *Radiology.* 187: 395-399.
30. Karygiannis Tom. (2002). Owens, Les; "Wireless Network Security"; NIST 800-848.
31. Kesari K., Kumar S., Behari J. (2010). Mobile phone usage and male infertility in Wistar rats. *Ind. J. Exp. Biol.* 48: 987-992.
32. Kolosova L.I., Akoev G.N., Avelev V.D., Riabchikova O.V., Babu K.S. (1996). Effect of low-intensity millimeter wave electromagnetic radiation on regeneration of sciatic nerve in rats. *Bioelectromagnetics.* 17: 44-47.
33. Lai H. and Singh N.P. (1995). Acute low intensity microwave exposure increases DNA single-strand breaks in rat brain cells. *Bioelectromagnetics.* 16: 207-210.
34. Lai H. and Singh N.P. (1997). Melatonin and a spin-trap compound block radiofrequency electromagnetic radiation-induced DNA strand breaks in rat brain cells. *Bioelectromagnetics.* 18: 446-454.
35. Lee J.S., Ahn S.S., Jung K.C., Kim Y.W., Lee S.K. (2004). Effects of 60 Hz electromagnetic field exposure on testicular germ cell apoptosis in mice. *Asian J. Anrol.* 6: 29-34.
36. Leszczynski D., Joenvaara S., Reivinen J., Kuokka R. (2002). Non-thermal activation of the hsp27/p38M APK stress pathway by mobile phone radiation in human endothelial cells: molecular mechanism for cancer- and blood-brain barrier-related effects. *Differentiation* 70: 120-129.
37. Li D.K., Yan B., Zheng L.I., Gao E., Miao M., Gong D. (2009). Exposure to magnetic fields and the risk of poor sperm quality. *Reprod. Toxicol.* 29: 86-92.
38. Litvak E., Foster K.R., Repacholi, M.H. (2002). Health and safety implications of exposure to electromagnetic fields in the frequency range 300 Hz-10 MHz. *Bioelectromagnetics.* 23: 68-82.
39. McNamee J.P., Bellier P.V., Gajda G.B., Lavalley B.F., Marro L., Lemay E., Thansandote A. (2003). No evidence for genotoxic effects from 24 h exposure of human leukocytes to 1.9 GHz radiofrequency fields. *Radiat. Res.* 159: 693-697.
40. McRee D.I. (1972). Environmental aspects of microwave radiation. *Environ. Heal. Persp.* 2, 41-53.
41. Møllerløgken O.J., Moena B.E., Baste V., Magerøy N., Oftedal G., Netoe E., Ersland L., Bjørge L., Torjesen P.A., Mild K.H. (2012). No effects of MRI scan on male reproduction hormones. *Reprod. Toxicol.* 34: 133-139.
42. Mortazavi S.M.J., Parsanezhad M.E., Kazempour M., Ghahramani P., Mortazavi A.R., Davari M. (2013). Male reproductive health under threat: Short term exposure to radiofrequency radiations emitted by common mobile jammers. *J. Hum. Reprod. Sci.* 6: 124-128.
43. Nisbet H.O., Nisbet C., Akar A., Cevik M., Karayigit M.O. (2011). Effects of exposure to electromagnetic field (1.8/0.9 GHz) on testicular function and structure in growing rats. *Res. Vet. Sci.* 93: 1001-1005.

44. Nishimura I., Oshima A., Shibuya K., Mitani T., Negishi T. (2012). Absence of reproductive and developmental toxicity in rats following exposure to a 20-kHz or 60-kHz magnetic field. *Regul. Toxicol. Pharmacol.* 64: 394-401.
45. Oni O.M., Amuda D.B., Gilbert C.E. (2011). Effects of radiofrequency radiation from wifi devices on human ejaculated semen. *Int. J. Res. Rev. Appl. Sci.* 19: 292-294.
46. Otitolaju A.A., Obe I.A., Adewale O.A., Otubanjo O.A., Osunkalu V.O. (2010). Preliminary study on the induction of sperm head abnormalities in mice, *Mus musculus*, exposed to radiofrequency radiations from global system for mobile communication base stations. *Bull. Environ. Contam. Toxicol.* 84: 51-54.
47. Pacini S., Ruggiero M., Sardi I., Aterini S., Gulisano F., Gulisano M. (2002). Exposure to global system for mobile communication (GSM) cellular phone radiofrequency alters gene expression, proliferation, and morphology of human skin fibroblasts. *Oncol. Res.* 13: 19-24.
48. Quan R., Yang C., Rubinstein S. (1992). Effects of microwave radiation on anti-infective factors in human milk. *Pediatrics.* 89: 667-669.
49. Roberts M.R., Michaelson J.S.M., Lu S.T. (1986). The biological effects of radiofrequency radiation: a critical review and recommendations. *Int. J. Radiation Biol.* 50: 379-420.
50. Roelandts R. (2003). Cellular phones and the skin. *Dermatology.* 20:3-5.
51. Rojavin M.A., Ziskin M.C. (1995). Effect of millimeter waves on survival of UVC-exposed *Escherichia coli*. *Bioelectromagnetics.* 16: 188-196.
52. Salama N., Kishimoto T., Kanayama H.O. (2010). Effects of exposure to a mobile phone on testicular function and structure in adult rabbit. *Int. J. Androl.* 33: 88-94.
53. Shazman A., Mizrahi S., Cogan U., Shimoni E. (2007). Examining for possible non-thermal effects during heating in a microwave oven. *Food Chem.* 103: 444-453.
54. Srinivas B.V. and Vasani S.S. (2012). Mobile Phone Electromagnetic Waves and Its Effect on Human Ejaculated Semen: An *in vitro* Study. *Int. J. Infertil. Fetal Med.* 3: 15-21.
55. Tenorio B.M., Ferreira Filho M.B., Jimenez G.C., de Moraes R.N., Peixoto C.A., Nogueira Rde A., da Silva Junior V.A. (2014). Extremely low-frequency magnetic fields can impair spermatogenesis recovery after reversible testicular damage induced by heat. *Electromagn. Biol. Med.* 33: 139-146.
56. Thostenson E.T. and Chou T.W. (1999). Microwave processing: Fundamentals and applications. Composites. Part A: *App. Sci. Manufac.* 30: 1055-1071.
57. Tice R.R., Hook G.G., Donner M., McRee D.I., Guy A.W. (2002). Genotoxicity of radiofrequency signals. I. Investigation of DNA damage and micronuclei induction in cultured human blood cells. *Bioelectromagnetics.* 23: 113-126.
58. Uslu B.A., Kilic D.K., Gulyus F., Deger Y., Ucar O. (2012). Effect of electromagnetic wave emitted from mobile phone on some reproductive parameters in adult male guinea pigs. *Vet. Bil. Derg.* 7: 77-84.
59. WHO (World Health Organization), 2007. Extremely Low Frequency Fields. Environmental Health Criteria Monograph No. 238.
60. Wilen J. and de Vocht F. (2011). Health complaints among nurses working near MRI scanners a descriptive pilot study. *Eur. J. Radiol.* 80: 510-513.
61. World Health Organization (WHO). (2006). WHO research agenda for radio frequency fields.
62. Yan J.G., Agresti M., Bruce T., Yan Y.H., Granlund A., Matloub H.S. (2007). Effects of cellular phone emissions on sperm motility in rats. *Fertil. Steril.* 88: 957-964.

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