Anatomy Journal of Africa. 2018. Vol 7 (1): 1152 - 1161

COMMENTARY

EFFECTS OF ELECTROMAGNETIC RADIATIONS ON THE MALE REPRODUCTIVE SYSTEM

*** Adah AS[1], Adah DI [2], Biobaku KT [3], Adeyemi AB [4]**

[*1] Department of Veterinary Physiology and Biochemistry, University of Ilorin, Ilorin, Nigeria.
[2]Department of Veterinary Medicine, University of Ilorin, Ilorin, Nigeria.
[3] Department of Veterinary Pharmacology and Toxicology, University of Ilorin, Ilorin, Nigeria
[4]Department of Theriogenology and Production, University of Ilorin, Ilorin, Nigeria
[*] Corresponding Author: Dr. Adakole S. Adah, Department of Veterinary Physiology and Biochemistry, University of Ilorin, Ilorin, Nigeria. E mail: adasilva5@yahoo.com. Telephone number: +2348036848157

ABSTRACT

Electromagnetic radiation (EMR) emitting from the natural environment, as well as from the use of industrial and everyday appliances, constantly influences the body of the animal. It is expected that the interactions between electromagnetic radiation and the living organism would depend on the amount and parameters of the transmitted energy and type of tissue exposed. Electromagnetic waves exert an influence on the male reproductive system causing spermatozoa to have decreased motility, morphometric abnormalities, increased peroxidation due to oxidative stress, histological aberrations in the testes and in some cases atrophy of the testicular tissue. This review presents from literature some of effects of electromagnetic radiations on the male reproductive system.
Key Words: Electromagnetic Radiations, Male Reproductive System, Animals, Humans

INTRODUCTION

Animals and humans in modern society are exposed to an ever-increasing number of electromagnetic fields (EMFs) generated from the production and supply of electricity, television (TV) sets, personal computer (PC), radio communication, and mobile communication (Vishki et al., 2012, Wdowiak et al., 2017).

Over the years, due to rapid technological progress, radiation from man-made sources exceeded that of natural origin. There is a general concern regarding a growing number of appliances that use radiofrequency/ microwave (RF/MW) radiation. (Marjanovic et al., 2012). It is known that a living organism is a complex electrochemical system where processes of oxidation and reduction occur regularly. One of the plausible mechanisms is connected with generation of reactive oxygen species (ROS) (Panagopoulos et al., 2007). Reactive Oxygen Species are unstable reactive molecules produced continuously in several cell types exposed to electromagnetic radiation, and are involved in intracellular signal transduction pathways, regulation of gene expression determining the anti-inflammatory response, cell growth, differentiation, proliferation and stress response (Kartashev, 1992; Simko and Mattson, 2004). On the other hand, overload of ROS concentration and antioxidant deficiency leads to cellular damage affecting the membranes, lipids, proteins, and even DNA. Several diseases are associated with adverse effects caused by reactive oxygen species such as diabetes, atherosclerosis, chronic inflammation, malignant and neurodegenerative diseases and many others (Pei et al., 2015).
Electromagnetic energy is directly proportional to its frequency, with higher frequency meaning

Submitted 25th October 2017. Published online 28th February 2018. To cite: Adah AS, Adah DI, Biobaku KT, Adeyemi AB. Effects of electromagnetic radiations on the male reproductive system. Anatomy Journal of Africa. 2018. Vol 7 (1): 1152 - 1161

greater energy. The Minimum energy capable of causing ionisation by breaking the intermolecular bonds and releasing electrons from an atom or molecule is considered to be 10 eV (Marjanovic et al., 2012). Based on their ability to cause ionisation, we can distinguish two types of electromagnetic radiation; ionising and non-ionising radiation. Non-ionising radiation includes three frequency ranges; static (0 Hz) and extremely low frequency range (<300 Hz), intermediate frequency range (300 Hz-10 MHz), and radiofrequency range including RF and microwaves (10 MHz to 300 GHz) (WHO, 1993). Very low frequency electromagnetic fields particularly are likely to produce greater damage to the body systems for several reasons. One that these frequencies are close to those of physiological range and hence any overlap of these can distort on-going biological processes. When in close contact with the body the generation of eddy currents and accompanied heating are added parameters (Kesari et al., 2013). In real life, good examples of how animals are exposed to variable levels of electromagnetic fields (radiofrequencies) are their distances from a cellular bases station, the presence of passive structures to either amplify the waves (e.g., the metallic structures) or to shield them (buildings or other obstacles), the number of transmission calls within the transmitters and their position with relationship to the orientation of the antenna. (Hyland, 2000; Balmori, 2005) Whenever a body having finite conductivity (biological body) is intercepted by EMF it induces electric fields and circulating electric currents, which in turn competes with endogenous current and voltages, thus disturbing normal physiological balance (Loscher and Kas, 1998). The depth of penetration within the body depends upon its frequency and the electric properties of the exposed portion in the body (Obukhan, 1998; Makker et al., 2009). If the current density exceeds a certain threshold value, excitation of muscles and nerves due to membrane depolarization is possible. The mode of interaction of non-ionizing radiation with biological systems can be broadly divided into two parts: extremely low frequency and radiofrequency/microwaves (Anderson and Rowley, 2007).

Animals are very sensitive electrochemical complexes that communicate with their environment through electrical impulses. Ionic currents and electric potential differences exist through the cellular membranes and corporal fluids (Marks and Ratke, 1995). The intrinsic electromagnetic fields from the biological structures are characterized by certain specific frequencies that can be interfered with by the electromagnetic radiation, through induction and causing modification in their biological responses (Hyland, 2000; Wdowiak et al., 2007). Animals exposed to the EMF can suffer a deterioration of health, changes in behavior (Marks et al., 1995), and changes in reproductive success (Fernie et al., 2000). Research has shown such effects on the living organisms are at molecular (Danielles et al., 1998), cellular levels (Adey, 1996) and on the DNA (Sarkar et al., 1994), Other systems affected include the nervous, cardiac, endocrine, immune, and reproductive systems (Dasdag et al., 1999). There is also modification of sleep and alteration of the cerebral electric response (Mann and Roshkle, 1999), increase of the arterial pressure, changes in the heart rhythm, and increase in the permeability of the blood brain barrier (Fritze et al., 1997).

There are numerous sources of non- ionizing EMF in our environment and these radiations interacts with human and animal bodies. Use of electronic household items and cell phones are reported to cause infertility potential in men by decreasing sperm count, motility, viability, inducing pathological changes in sperm and testes morphology (Erogul et al. 2006). The male reproductive system is said to be one of the most sensitive to electromagnetic radiation (Liu et al., 2015)

The effects of ELF-EMF on the male reproduction are receiving heightened interest because human male fertility in the 20th century was diminished; human sperm count in 1940 was

nearly two-fold compared to the sperm count in 1990 (Giwereman et al. 1993)
The aim of this review is to identify how electromagnetic radiations potentiate their risks in the male reproductive system.

Effect of EMR on Reproductive Hormones

Exposure to EMF can influence the secreting activity of the pineal gland in several animal species just like light (Rodriguez et al., 2004, Cucurachi et al., 2013). Exposure to EMFs can affect circadian secretions of melatonin in several species (Yellon, 1994). In rats exposed to a circularly polarized 50 Hz EMF for 6 weeks, the pineal and circulating melatonin levels decreased (Rodriguez et al., 2003). In fully grown Djungarian hamster, a 60 Hz EMF exposure acutely affected the pineal and circulating melatonin concentrations (Yellon, 1994; Petrides, 2000). EMF exposure directly affects the pineal gland, deteriorating the biological effect of melatonin. Melatonin regulates the pulse of gonadotropin releasing hormones in the hypothalamus, influencing follicle stimulating hormone (FSH) and luteinizing hormone (LH) (Wang et al., 2003b; Al-Akhras et al., 2006). Eventually, this can alter the production of gonadal sex steroids, resulting in changes in spermatogenesis and masculinization (Sepehrimanesh et al., 2014; Mollerlokken and Moen, 2008).

Effects of EMR the Morphology of the Male Spermatozoa

The testes of higher animals need physiological temperatures 2 °C lower than normal body temperature for optimal spermatogenesis. High intensity electromagnetic frequency has heating properties that can lead to thermal effects on the testes. An increase in testicular or body temperature on exposure to EMF radiation may cause irreversible disruption of spermatogenesis (Kandeel and Swerdloff, 1988; Jung and Schill, 2000). Exposure to EMF enhances the generation of reactive oxygen species (ROS) and thus causes destructive effects on various cellular organelles like mitochondria sperm DNA (Agarwal and Prabakaran, 2005). It was stated that tubulin dimmers in cells have a piezoelectric property (Tuszynski and Kurzynski, 2003), and this may be a target for action of magnetic field that will affect the sperm motility and spermiogenesis resulting in sperm morphological abnormalities. There are reports that electromagnetic field exposure cause nuclear condensation and marginal hyper chromatin of germinal epithelium (Sarkar and Behari, 1994; Bushra et al., 2011) and also cause different morphological aberrations such as defective head sperms and double head sperms due to influence of ultrasound (frequency 2, 4 and 8 MHz) and constant magnetic field (7T) on gametes, zygotes and embryos of the sea urchin (Drozdov et al., 2008). Magnetic field exposure interrupts the process of the gamete fusion but did not influence gametes, embryos, or embryonic development. The nature of these two stimuli is of different type (Wang et al., 2003a, Hackney et al., 2005). Ultrasound may heat up the water if is of sufficient power, by way of increase in water temperature and cavitation temperature, which may also break the cellular structure. The effect of magnetic field is connected to the response of the cortical cytoskeleton, which consists of bundles of actin microfilaments. The rearrangement of the cortical cytoskeleton occurs during the first 20 minutes after the contact of sperm with the egg (Aitken et al., 2005; Ozguner et al., 2005).

Effects of EMR on the Biochemistry of the Male Reproductive System

Several views have been proposed to elucidate the disruption of metabolic pathways by RF-EMW. Some of these views are based on experimental evidences and some on hypothetical models (Makker et al, 2009; Ramezani et al., 2012). Isocitrate dehydrogenase, an important enzyme in the citric acid cycle, is one of the targets of non-ionizing EMF (Simko and Mattson, 2004). Nylund and Leszczynski, (2004) reported that changes in the enzyme activity leads to decreased production of adenosine triphosphate (ATP) in mammalian cells and since sperm motility depends on the active generation of ATP, such a mechanism might cause the decline in sperm motility during exposure. This makes spermatozoa lose their cytoplasm post-spermiation, leading to the loss of their antioxidant protective mechanism and rendering them inherently vulnerable to DNA damage (Lai and Sing, 1996). They are differentiated to the point that they cannot undergo apoptosis in response to any form of severe genetic damage (Aitken, 1999). In addition, during the process of maturation, spermatozoa are separated from the Sertoli cells, their nursing cells (Kesari et al., 2013).

Cucullo et al*.* (2005) found that electric field may affect cellular function by changing the structure of ion channel and the integrity of the cell membrane. Regarding sperm viability, Ayrapetyan (2006) reported that EMF causes disturbances in sperm cell membrane mechanisms that govern ion passage especially to sodium and potassium and consequently the water content and sperm viability. Apoptosis and decrease in cellular numbers in the seminiferous tubules were found that may be due to the direct effect of EMF (Ribeiro et al., 2007; Faegi et al., 2015).

Effects of EMR on the Blood-Testis barrier

The blood-testis barrier is sensitive to environmental stimulation, which can affect its permeability and then result in antisperm antibody (AsAb) generation, which is a key step in male fertility. Wang et al. (2010) reported the results of male mice exposed to electromagnetic pulse (EMP) by measuring the expression of tight-junction of associated proteins(ZO-1 and Occludin), vimentin microfilaments, and mice were sham exposed or exposed to EMF at two different intensities (200 kV/m and 400 kV/m) for 200 pulses (Susa and Pavicic, 2007).

Khaki et al., (2006) reported that following exposure to EMF field, tissue showed infoldings, which were perhaps due to the loss of collagen and reticular fibrils from the inner and outer non-cellular layers. The outer non-cellular layer, which was thinner than that of the control, was stripped away from the myoid cell layer in multiple regions, giving a "blister-like" appearance (Kodama et al., 1997). The myoid cells showed fewer polyribosomes, pinocytotic vesicles and glycogen granules (Lishko et al., 2010; Bushra et al., 2011). Most mitochondria were found to lack cristae. The connections between individual myoid cells were apparently lost. There were signs of recovery in the boundary tissue following withdrawal from EMF exposure. These results suggest that EMF exposure may cause profound changes in the boundary tissue of the seminiferous tubules. Therefore exposure to EMF may result in pathological changes that lead to subfertility and infertility (Carl et al., 2006).

Relationship between EMR, Oxidative Stress and the Male Reproductive System

Mitochondrial respiratory chain is the site for the generation of superoxide radicals [O^2 and H_2O_2] (Smith et al., 1996). EMF may affect the mitochondrial membranes to produce large amount of radical reactive oxygen species (ROS) (Desai et al., 2009; Pei et al., 2015). EMF may disturb ROS metabolism by enhancing the production of ROS or by decreasing the activity of antioxidant enzymes (Oksay et al., 2014). From the work of Oksay et al., (2014), it is obvious that such a change in testes that is highly dependent on oxygen to drive spermatogenesis and yet highly susceptible to the toxic effects of reactive oxygen metabolites, activities of anti-oxidant enzymes is sacrosanct for spermatogenesis. Reactive oxygen species (ROS) such as superoxide anions (O^{-}), hydroxyl radicals (OH^{-}) and hydrogen peroxide (H_2O_2) may influence the structural integrity and function of sperm, such as motility, capacitation, and sperm-oocyte fusion (Iwasaki and Gagon, 1992; Griveau et al 1994). Spermatozoa are particularly vulnerable to oxidative stress because their plasma membrane is rich in polyunsaturated fatty acids (PUFAS) and membrane bound NADPH oxidase (D'Autreaux and Toledano, 2007). Increased ROS production has been shown to correlate with reduced male fertility (Iwasaki and Gagnon 1992), to cause perioxidative damage to the sperm plasma membrane (Hughes et al 1996; Diem et al., 2005), In conclusion evidence abound that electromagnetic radiations have deleterious effects on the male reproductive system such as increased testicular temperature impeding the process of spermatogenesis, histological aberrations in the testes and sometimes reduction in weight of the testicular tissue. Efforts must be made to minimize contact with radiations and antioxidants must be administered regularly to counteract the effects brought about by radiations.

REFERENCES

1. Adey, W.R. 1981 Tissue interactions with non-ionizing electromagnetic fields. Physiol Rev, 61, 435–514.
2. Adey, W.R. 1996 Bioeffects of mobile communications fields: possible mechanisms for cumulative dose. In: Mobile Communication Safety; Kuster, Balzano, Lin, E; London:Chapman and Hall, 95–131.
3. Agarwal A, Prabakaran SA 2005. Mechanism, measurement amd prevention of oxidative stress in male reproductive physiology. Indian J Exp Biol. 43: 963-974.
4. Aitken RJ, L. E. Bennetts, Sawyer D. 2005 Impact of radio frequency electromagnetic radiation on DNA integrity in the male germline. International Journal of Andrology 28, 171–179
5. Al-Akhras, M., Darmani, H., Elbetieha, A. 2006. Influence of 50 Hz magnetic field on sex hormones and other fertility parameters of adult male rats. Bioelectromagnetics, 27(2):127-131.
6. Anderson V and Rowley J 2007 Measurements of skin surface temperature during mobile phone use. Bioelectromagnetics 28, 159–162
7. Ayrapetyan S., 2006, Cell Aqua Medium as a Primary Target for the Effect of Electromagnetic Fields, In: Bioelectromagnetics, Ayrapetyan, S.N. and Markov, M (Eds) Springer, Netherlands, pp.31-63.
8. Balmori, A. 2005. Possible Effects of Electromagnetic Fields from Phone Masts on a Population of White Stork (Ciconia ciconia). Electromagnetic Biology and Medicine, 24: 109–119.
9. Bushra H, Leila R, Amir A. K, Jafar S 2011. Histological study of testes and sperm parameters in adult mice exposed to 50 Hz electromagnetic field during developmental period. Annals of Biological Research, 2 (5): 455-462.
10. Carl, A. B., Ashwood, E. R., and Bruns, D. E. 2006. Tietz text book of clinical chemistry and molecular diagnostics (pp. 191–218). St. Louis, MO: Elsevier/Sanders.
11. Challis L. J. (2005) Mechanisms for interaction between RF fields and biological tissue. Bioelectromagnetics, 26: S98-106.
12. Cucullo L, Oby E, Hallenbeck JM, Aumayr B, Rapp E, Janigro D. 2005. Artificial blood-brain barrier. In DermietzelR, SprayDC, NedergaardM (Eds) Blood–brain interfaces: from ontogeny to artificial barriers. Wiley Press, Hoboken , NJ , pp. 375–402.
13. Cucurachi S, Tamis WL, Vijver MG, Peijnenburg WJ, Bolte JF, de Snoo GR 2013. A review of the ecological effects of radiofrequency electromagnetic fields (RF-EMF). Environ Int 51:116–140
14. D'Autreaux, B., and Toledano, M. B. 2007. ROS as signaling molecules: Mechanisms that generate specificity in ROS homeostasis. Nature Reviews Molecular Cell Biology, 8, 813–824.
15. Daniells, C., Duce, I., Thomas, D., Sewell, P., Tattersall, J. and De Pomerai, D. 1998.Transgenic nematodes as biomonitors of microwave-induced stress. Mutatation Research, 399: 55–64.

16. Dasdag S, Ketani MA, Akdag Z, Ersay AR, Sari I, Demirtas OC, Celik MS 1999. Whole-body microwave exposure emitted by cellular phones and testicular function of rats. Urological Research, 27 (3): 219 – 223
17. Dasdag S, Zulkuf Akdag M, Aksen F 2003 Whole body exposure of rats to microwaves emitted from a cell phone does not affect the testes. Bioelectromagnetics 24, 182–188.
18. De Seze R, Ayoub J, Peray P. 1999 Evaluation in humans of the effects of radiocellular telephones on the circadian patterns of melatonin secretion, a chronobiological rhythm marker. Journal of Pineal Research 27, 237–242.
19. Deepinder, F., Makker, K and Agarwal, A 2007. Cell phones and male infertility: dissecting the relationship. Reproductive BioMedicine, 15(3) 266-270
20. Desai, N. Sharma, R. Makker, K. Sabanegh, E and Agarwal, A. 2009. Physiologic and pathologic levels of reactive oxygen species in neat semen of infertile men. Fertillty and Sterility, 92(5): 1626-31
21. Diem E, Schwarz C, Adlkofer F Jahn O, Rüdiger H . 2005 Non-thermal DNA breakage by mobile-phone radiation (1800 MHz) in human fibroblasts and in transformed GFSH-R17 rat granulosa cells in vitro. Mutation Research 583, 178–183.
22. Doherty, P.F. and Grubb, T.C. 1996. Effects of high-voltage power lines on birds breeding within the power lines' electromagnetic fields. Sialia, 18, 129–134.
23. Drozdov KA, Khlistun O A, Drozdov AL. 2008. The influence of ultrasound and constant magnetic field on gametes, zygotes, and embryos of the sea urchin. Biofizika., 53(3): 513-518.
24. Dutta, S.K.; Ghosh, B.; Blackman, C.F.1998. Radiofrequency radiation-induced calcium ion efflux enhancement from human and other neuroblastoma cells in culture. Bioelectromagnetics, 10: 197–202.
25. Erogul O, Oztas E, Yildirim I, Kir T, Aydur E, Komesli G, Irkilata HC, Irmak MK, Peker AF 2015. Effects of electromagnetic radiation from a cellular phone on human sperm motility: an in vitro study. Archives of Medical Research, 37(7): 840-3
26. Faeghi, P., Narimani-Rad M.M and Pour, E.R. 201). Electromagnetic Fields and its effect on Chicken Embryo. Biological Forum,7(1) 559-563
27. Farrel, J.M., Litovitz, T.L. and Penafiel, M. 1997. The effect of pulsed and sinusoidal magnetic fields on the morphology of developing chick embryos. Bioelectromagnetics, 18: 431–438.
28. Fernie, K.J., Bird, D.M., Dawson, R.D., Lague, P.C. 2000. Effects of electromagnetic fields on the reproductive success of American Kestrels. Physiological and Biochemical Zoology, 73 (1): 60–65.
29. Fritze, K., Sommer, C., Schmitz, B., Mies, G., Hossman, K. and Kiessling, M. Effect of global system for mobile communication (GSM) microwave exposure on blood-brain barrier permeability in rat. Acta Neuropathol. 1997, 94, 465–470.
30. Giwereman A, Carlson E, Keiding N 1993. Evidence for increasing incidence of abnormalities of the human testis: a review. Environmental Health Perspective 101(supplement): 65-97.
31. Grigoriew Ju (1996). G. Role of modulation in biological effects of electromagnetic radiation. Radiat. Biol. Radioecol., 36, 659–670
32. Grigoriew, Ju. G.; Luk'ianova, S.N.; Makarov, V.P.; Rynskov, V.V. 1995. Total bioelectric activity of various structures of the brain in low-intensity microwave irradiation.Radiat. Biol. Radioecol., 35, 57–65.
33. Griveau JF, Renard P, Le Lannou D. 1994. An in vitro promoting role for hydrogen peroxide in human sperm capacitation. Int J Androl.17: 300–307.
34. Hackney, A. C., Moore, A. W., and Brownlee, K. K. 2005. Testosterone and endurance exercise hypogonadal male condition. Acta Physiological Hungarica, 92, 121–137.

35. Hughes CM, Lewis SE, Mckelvey-Martin VJ, 1996. Thompson W. A comparison of baseline and induced DNA damage in human spermatozoa from fertile and infertile men, using a modified comet assay. Molecular Human Reprodroduction.; 13, 1240-1247.
36. Hyland, G.J. 2000 Physics and biology of mobile telephony. Lancet, 356: 1–8.
37. Iwasaki A, Gagon C. Formation of reactive oxygen species in spermatozoa of infertile patients. Fertility Sterility. 1992; 57:409-416.
38. Jung, A. and Schill, WB 2000. Male infertility. Current life style could be responsible for infertility MMW Fortschritte der Medizin, 142(37): 31-33.
39. Kandeel FR, Swerdloff RS 1988 Role of temperature in regulation of spermatogenesis and the use of heating as a method for contraception. Fertil Steril 49, 1–23.
40. Kandeel, F. R. and Swerdloff, R .S. 1988. Role of Temperature in regulation of spermatogenesisnand use of heating as a method for contraception. Fertil Steril. 49(1), 1-23
41. Kartashev AH. 1992. Biological mechanism of long-term effect of alternating electric field on the development of mice. Fiziololgy Zhonghua 38(3):0 81-85.
42. Kartikeya Makker, Ashok Agarwal and Rakesh Sharma 2009. Oxidative stress and male infertility. Indian J Med Res 129, April, pp 357-367
43. Kesari, K.K., Kumar. S., Nirala, J., Siddiqui, M.H., Behari, J. 2013. Biophysical Evaluation of Radiofrequency Electromagnetic Field Effects on Male Reproductive Pattern. Cell Biochemistry and Biophysics. 65(2): 85-96
44. Khaki. A.A., Tubbs, R.S., Shoja, N.M., Rad, J.S., Khaki, A., Farahani, R.M. and Zarrintan, S. 2006. The Effects of an electromagnetic field on the boundary tissue of the seminiferrous tubules of the rat: a light and transmission microscope study. Folia Morphol, 65(3): 188-194.
45. Kodama H, Yamaguchi R, Fukada J, Kasai H, Tanaka T. 1997. Increased oxidative deoxyribonucleic acid damage in the spermatozoa of infertile male patients. Fertil Steril.68, 519-524.
46. Kurzynski, M. and Tuszynski, J. 2003, Introduction to Molecular Biophysics. CRC Press LLC, 2000 N.W. Corporate Blvd., Boca Raton, Florida 33431
47. Lai H and Singh NP. 1996. Single- and double-strand DNA breaks in rat brain cells after acute exposure to radiofrequency electromagnetic radiation. International Journal of Radiational Biology 69,513–521.
48. Lishko PV, Botchkina IL, Fedorenko A, Kirichok Y 2010. Acid Extrusion from Human Spermatozoa is mediated by Flagellar Voltage-Gated Proton Channel. Cell 140(3):327-337
49. Liu, Y Liu, W Liu, K.J. Ao, L. Zhong,J.L. Cao,J and Liu J.Y 2015. Effect of 50Hz Extremely Low-Frequency Electromagnetic Fields on the DNA Methylation and DNA Methyltransferases in Mouse Spermatocyte-Derived Cell Line GC-2 BioMed Research International Article ID 237183
50. Loscher, W., Kas, G 1998 Conspicuous behavioural abnormalities in a dairy cow herd near TV and Radio Transmitting Antenna. Pract. Vet. Surg. 1998, 29, 437–444
51. Makker, K., Varghese, A. Desai, N.R. Mouradi, R. and Agarwal, A. 2009. Cell Phones Modern Man's Nemesis Reproductive BioMedicine Online, 18(1): 148-157.
52. Mann, K. and Roschkle, J. (1996) Effects of pulsed high-frequency electromagnetic fields on human sleep. Neuropsychobiology, 33: 41–47.
53. Marino, A.A., Nilsen, E. and Frilot, C. 2003. Nonlinear changes in brain electrical activity due to cell phone radiation. Bioelectromagnetics, 24: 339–346.
54. Marjanovic, A.M., Pavicić I. and Trosic, I. 2012. Biological indicators in response to radiofrequency/microwave exposure. Arhiv za Higijenu Rada I Toksikologiju. 63:407-41

55. Marks, T.A., Ratke, C.C., English, W.O. 1995 Stray Voltage and developmental, reproductive and other toxicology problems in dogs, cats and cows: a discussion. Veterinary and Human Toxicology, 37:163–172.
56. Mohammadnejad, D., Abedelahi, A., Soleimani-rad, J., Mohammadi-roshandeh, A Rashtbar, J., and Azami, A. 2012. Degenerative Effect of Cisplatin on Testicular Germinal Epithelium Advanced Pharmaceutical Bulletein. 2(2): 173–177
57. Mollerlokken OJ, Moen BE. 2008. Is fertility reduced among men exposed to radiofrequency fields in the Norwegian Navy? Bioelectromagnetics 29:345–352.
58. Moses M, Janigro D. 2005. Very low intensity alternating current decreases cell proliferation. GLIA 51(1):65-72.
59. Nylund R, Leszczynski D 2004. Proteomics analysis of human endothelial cell line EA.hy926 after exposure to GSM 900 radiation. Proteomics, 4, 1359–1365
60. Nylund R, Leszczynski D 2006. Mobile phone radiation causes changes in gene and protein expression in human endothelial cell lines and the response seems to be genome- and proteome- dependent. Proteomics 6, 4769–4780.
61. Obukhan, K.I. 1998 The effect of ultrahigh-frequency radiation on adaptation thresholds and the damages to blood system cells. Lik Sprava, 7: 71–73.
62. Oksay, T., Naziroğlu, M., Doğan, S., Güzel, A., Gümral, N., and Koşar, P. A. 2014. Protective effects of melatonin against oxidative injury in rat testis induced by wireless (2.45 GHz) devices. Andrologia, 46, 65–72.
63. Ozguner, M., Koyu, A., Cesur, G., Ural, M., Ozguner, F., Gokcimen, A. and Delibas, N. 2005. Biological and morphological effects on the reproductive organ of rats after exposure to electromagnetic field. Saudi Medical Journal, 26:(3): 405-410.
64. Panagopoulos DJ, Chavdoula ED , Nezis IP, Margaritis LH 2007. Cell death induced by GSM 900-MHz and DCS 1800-MHz mobile telephony radiation. Mutation Research 626, 69–78.
65. Pei, X Gu, Q Ye, D Wang, Y Zou, X He, L., Jin, Y and Yao, Y . 2015. Effect of computer radiation on weight and oxidant-antioxidant status of mice Nutricion Hospitalaria. 31(3):1183-1186
66. Petrides, M. 2000. Exposure to electromagnetic fields by using cellular telephones and its influence on the brain. Neuroreport, 15, 15-25.
67. Ramezani V F., Majd A., Nejadsattari T. and Arbabian P.S. 2012. Study of Effects of Extremely Low Frequency Electromagnetic Radiation on Biochemical Changes in Satureja Bachtiarica L. International Journal of Scientific and Technology Research 1(7). 77-86
68. Ribeiro EP, Rhoden EL, Horn MM 2007. Effects of subchronic exposure to radio frequency from a conventional cellular telephone on testicular function in adult rats. Journal of Urology 177, 395–399.
69. Sarkar, S., Ali, S. and Behari, J. 1994 Effect of low power microwave on the mouse genome: a direct DNA analysis. Mutatation Research, 320: 141–147.
70. Sepehrimanesh M, Saeb M, Nazifi S, Kazemipour N, Jelodar G, Saeb S. 2014. Impact of 900 MHz electromagnetic field exposure on main male reproductive hormone levels: a Rattus norvegicus model. Intrnational Journal of Biometeorology 58:1657–1663
71. Simko, M. and Mattson, M. 2004. Extremely Low Frequency Electromagnetic Fields as Effectors of Cellular Responses In Vitro: Possible Immune Cell Activation. Journal of Cellular Biochemistry 93:83–92
72. Smith R, Vantman D, Ponce J, Escobar J, Lissi E. 1996. Total antioxidant capacity of human seminal plasma. Hum Reprod .11:1655–60.
73. Susa M and Pavicic I. 2007. Effects of radiofrequency electromagnetic fields on mammalian spermatogenesis.. Arhiv za higijenu rada i toksikologiju, 58(4):449-59.

74. Szmigielski, S., Bortkiewicz, A., Gadzicka, E., Zmyslony, M. and Kubacki, R. (1998). Alteration of diurnal rhythms of blood pressure and heart rate to workers exposed to radiofrequency electromagnetic fields. Blood Pressure Monitor, 3: 323–330.
75. Valberg PA. 2005 Modulated RF energy: mechanistic viewpoint on the health implications. In: Repacholi M, van Deventer E, Ravazzani P, editors. Proceedings International Workshop on Base Stations and Wireless Networks: Exposures and Health Consequences; 15-16 June 2005; Geneva, Switzerland. Geneva: WHO; 2005. p. 33-46.
76. Vishki, R., Majd, F. A., Nejadsat tari, T. and Arbabian, S. (2012). Effects of electromagnetic field radiation on inducing physiological and biochemical changes in Satureja bachtiarica L. Iranian Journal of Plant Physiology, 2(4):509 - 516.
77. Wang, S. M., Wang, D. W., Peng, R. Y., Gao, Y. B., Yang, Y., Hu, W. H. 2003a Effect of electromagnetic pulse irradiation on structure and function of Leydig cells in mice. National ,Journal of Andrology 9, 327–330.
78. Wang SM, Wang DW, Peng RY. 2003b Effect of electromagnetic pulse irradiation on structure and function of Leydig cells in mice. pathologic levels of reactive oxygen species in neat semen of infertile men. Fertility and Sterility, 92(5), 1626–1631.
79. Wang XW, Ding GR, Shi CH, Zeng LH, Liu JY, Li J, Zhao T, Chen YB, Guo GZ. 2010. Mechanisms involved in the blood-testis barrier increased permeability induced by EMP. Toxicology 276:58 – 63.
80. Wdowiak A, Wdowiak L, Wiktor H. 2007. Evaluation of the effect of using mobile phones on male fertility Ann Agric Environ Med 14(1):169-172
81. Wdowiak, A Paweł A. Mazurek, A Wdowiak I B. 2017. Effect of electromagnetiwaves on human reproduction. Annals of Agricultural and Environmental Medicine, 24(1): 13–18
82. World Health Organization (WHO) 1993. Electromagnetic Fields (300 Hz to 300 GHz). Environmental Health Criteria 137. WHO, Geneva.
83. Yellon SM. 1994. Acute 60 Hz magnetic field exposure effects on the melatonin rhythm in the pineal gland and circulation of the adult Djungarian hamster. J Pineal Res 16:136–114.