

eISSN: 09748369

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Biology and Medicine

Review Article

Impacts of radio-frequency electromagnetic field (RF-EMF) from cell phone towers and wireless devices on biosystem and ecosystem – a review

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Accepted: 3rd Dec 2012, Published: 6th Jan 2013

Abstract

This paper summarizes the effect of radio-frequency electromagnetic field (RF-EMF) from cell towers and wireless devices on the biosphere. Based on current available literature, it is justified to conclude that RF-EMF radiation exposure can change neurotransmitter functions, blood-brain barrier, morphology, electrophysiology, cellular metabolism, calcium efflux, and gene and protein expression in certain types of cells even at lower intensities. The biological consequences of such changes remain unclear. Short-term studies on the impacts of RF-EMF on frogs, honey bees, house sparrows, bats, and even humans are scarce and long-term studies are non-existent in India. Identification of the frequency, intensity, and duration of non-ionizing electromagnetic fields causing damage to the biosystem and ecosystem would evolve strategies for mitigation and would enable the proper use of wireless technologies to enjoy its immense benefits, while ensuring one's health and that of the environment.

Keywords: Radio-frequency electromagnetic field; cell phone tower; power density; SAR; non-ionizing radiation; non-thermal.

Introduction

There has been an unprecedented growth in the global communication industry in recent years which has resulted in a dramatic increase in the number of wireless devices. Mobile services were launched in India in 1995 and it is one of the fastest growing mobile telephony industries in the world. According to the Telecom Regulatory Authority of India (TRAI, 2012), the composition of telephone subscribers using wireless form of communication in urban area is 63.27% and rural area is 33.20%. By 2013, it is estimated that more than one billion people will be having cell phone connection in India. This has led to the mushrooming of supporting infrastructure in the form of cell towers which provide the link to and from the mobile phone. With no regulation on the placement of cell towers, they are being placed haphazardly closer to schools, creches, public playgrounds, on commercial buildings, hospitals, college campuses, and terraces of densely populated urban residential areas. Hence, the public is being exposed to continuous, low intensity radiations from these towers. Since the

electromagnetic radiations, also known as electrosmog cannot be seen, smelt or felt, one would not realize their potential harm over long periods of exposure until they manifest in the form of biological disorders. Various studies have shown the ill-effects of radio-frequency electromagnetic field (RF-EMF) on bees, fruit flies, frogs, birds, bats, and humans, but the long-term studies of such exposures are inconclusive and scarce, and almost non-existent in India (MOEF, 2010; DoT, 2010). In 2011, International Agency for Research on Cancer (IARC), part of WHO, designated RF-EMF from cell phones as a “possible human carcinogen” Class 2B (WHO, 2011). Cancer, diabetes, asthma, infectious diseases, infertility, neurodegenerative disorders, and even suicides are on the rise in India. This invisible health hazard pollution (IHHP) is a relatively new environmental threat.

Electromagnetic radiation, in the form of waves of electric and magnetic energy, have been circulating together through space. The electromagnetic spectrum includes radio waves, microwaves, infrared rays, light rays, ultraviolet rays, X-rays, and gamma rays (ARPANSA, 2011;

FCC, 1999). The electromagnetic radiations are of two types, one being ionizing radiations such as X-rays and gamma rays, and the other being non-ionizing radiations such as electric and magnetic fields, radio waves, radio-frequency band which includes microwaves, infrared, ultraviolet, and visible radiation (Figure 1). The biological effects of RF-EMF at molecular level induce thermal and non-thermal damage, which may be due to dielectric heating leading to protein denaturation, polar molecular agitation, cellular response through molecular cascades and heat shock proteins, and changes in enzyme kinetics in cells (Instituto Edumed, 2010). The three major physical parameters of RF-EMF radiations is frequency, intensity, and exposure duration. Although the non-ionizing radiations are considered less dangerous than ionizing radiation, over-exposure can cause health hazards (FCC, 1999).

Electromagnetic Spectrum and RF-EMF Radiation

The RF-EMF radiations fall in the range of 10MHz–300GHz. Cell phone technology uses frequencies mainly between 800MHz and 3GHz and cell tower antenna uses a frequency of 900 or 1800MHz, pulsed at low frequencies, generally known as microwaves (300 MHz–300 GHz).

Power Density and Specific Absorption Rate (SAR)

Variables used in the measurement of these radiations are power density, measured in watts per meter squared (W/m^2) and specific absorption Rate (SAR). The term used to describe the absorption of RF-EMF radiation in the body is SAR, which is the rate of energy that is actually absorbed by a unit of tissue, expressed in watts per kilogram (W/kg) of tissue. The SAR measurements are averaged either over the whole body or over a small volume of tissue, typically between 1 and 10g of tissue. SAR was set with the help of a phantom, known as specific anthropomorphic mannequin (SAM) derived from the size and dimensions of the 90th percentile large adult male reported in a 1988 US Army study who is 6 feet 2 inches and weighed 200 pounds (Davis, 2010). SAR is set at 1.6W/kg averaged over 1g of body tissue in the US and Canada and 2W/kg averaged over 10g of body tissue in countries adopting the ICNIRP guidelines. The SAR is used to quantify energy absorption to fields typically between 100 kHz and 10GHz and encompasses radio-frequency radiation from devices such as cellular phones up through diagnostic magnetic resonance imaging (MRI). The biological effects depend on how much of the energy

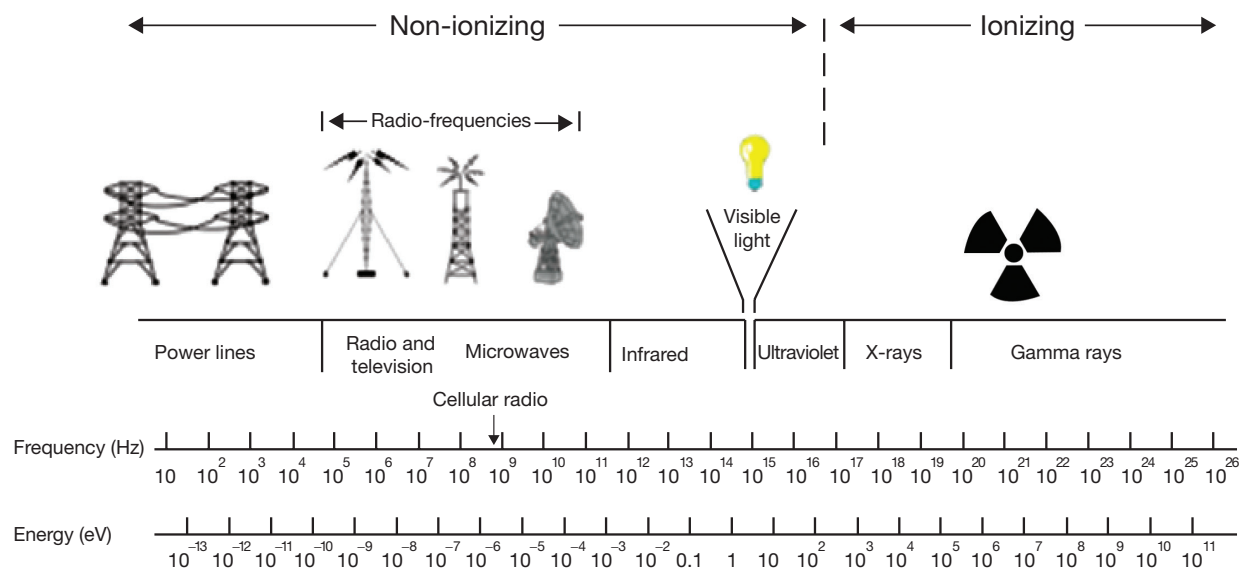


Figure 1: Electromagnetic spectrum from the Federal Communications Commission (FCC), OET Bulletin 56, 1999.

is absorbed in the body of a living organism, not just what exists in space. Absorption of RF-EMF radiations depend on frequency of transmission, power density, distance from the radiating source and the organism's size, shape, mineral, and water content. Exposure will be lower from towers under most circumstances than from cell phones because the transmitter is placed directly against the head during cell phone use whereas proximity to a cell tower will be an ambient exposure at a distance (Levitt and Lai, 2010). Exposure guidelines for RF protection had adopted the value of 4 W/kg averaged over the whole body (SARWB) as the threshold for the induction of adverse thermal effects associated with an increase of the body core temperature of about 1°C in animal experiments. This standard is set by International Commission on Non-ionizing Radiation Protection (ICNIRP), national Radiological Protection Board (NRPB), and Institute of Electrical and Electronics Engineers (IEEE) (Barnes and Greenebaum, 2007).

Cell Phones and Cell Tower Standards in India

India has adopted ICNIRP guidelines as the standard for safety limits of exposure to radio-frequency energy produced by mobile handsets for general public as follows: whole-body average SAR of 0.08 W/kg, localized SAR for head and trunk of 2 W/kg, and localized SAR for limbs 4 W/kg. The basic restrictions/proper limits for power density specified in ICNIRP guidelines for safe frequencies between 400 and 2000 MHz, adopted in India, for occupational exposure is 22.5 W/m², and general public is 4.5 W/m² for 900 MHz (ICNIRP, 1998).

Antennas of cell tower transmit in the frequency range of 869–890 MHz for CDMA, 935–960 MHz for GSM-900, 1805–1880 MHz for

GSM-1800, and 2110–2170 MHz for 3G. Wi-Fi frequency range is 2.4 GHz, WiMAX is 2.5–3.3 GHz, and 4G LTE is 2.99 GHz. The antennas for cellular transmissions are typically located on towers mounted on terraces of houses, apartments or other elevated structures including rooftops and the sides of buildings, and also as a freestanding tower. Typical heights for cell towers are 50–200 feet. Sector antennas for 2G and 3G transmission, broader sector antennas for 4G transmission, and parabolic microwave antennas for point-to-point communications are used in urban and suburban areas (Table 1). There are different types of base stations used by operators in India and they include the macro cell, micro cell, or pico cell. Categorization is based on the purpose of the site rather than in terms of technical constraints such as radiated power or antenna height. In India, macro cellular base station provide the main infrastructure for a mobile phone network and their antennas are mounted at sufficient height to give them a clear view over the surrounding geographical area. The maximum power for individual macro cellular base station transmitter is 20 W. According to FCC (1999), depending on the cell tower height, the majority of cellular base stations in urban and suburban areas operate at an effective radiated power (ERP) of 100 W per channel or less. ERP is a quantity that takes into consideration transmitter power and antenna directivity. An ERP of 100 W corresponds to an actual radiated power of about 5–10 W, depending on the type of antenna used. In urban areas, an ERP of 10 W per channel (corresponding to a radiated power of 0.5–1 W) or less is commonly used. In India, cell tower sites transmit hundreds of watts of power with antenna gain of 50, so ERP sometimes equals 5000 W (Kumar, 2010).

For installation of mobile towers, the standing advisory committee on radio frequency

Table 1: Radio-frequency sources in India.

RF source	Operating frequency	Transmission powers	Numbers
AM towers	540–1600 kHz	100 KW	197 towers
FM towers	88–108 MHz	10 KW	503 towers
TV towers	180–220 MHz	40 KW	1201 towers
Cell towers	800, 900, 1800 MHz	20 W	5.4 lakh towers
Mobile phones	GSM-1800/CDMA GSM-900	1 W 2 W	800+ million
Wi-Fi	2.4–2.5 GHz	10–100 mW	Wi-Fi hot spots

allocations (SACFA) clearances are issued by the wireless monitoring organization, Department of Telecommunications (DoT), after getting no objection from defence and airport authority considering aviation hazards, obstruction to line of sight of existing/planned networks and interferences. In many metros in India, there is no restriction on the location of the towers leading to a situation of overlapping of towers, where even more than 30 cell towers can be seen within 1 km².

As mobile technology progresses, the data demands on mobile network increases, coupled with lower costs, their use has increased dramatically and the overall levels of exposure of the population as a whole had increased drastically. Table 2 gives the reference levels for general public exposure adopted by various countries and organizations.

Impacts on Biosystem and Ecosystem

Every living being is tuned into the earth's electromagnetism and uses it for various purposes. A natural mineral magnetite, which is found in living tissues, seems to play an important role. These magnetite crystals are found in

bacteria, protozoa, teeth of sea mollusks, fish and sea mammals, eye and beak of birds, and in humans. They are also found in the ethmoid bone above the eye and sinuses and blood-brain barrier (Warnke, 2007). Migratory birds rarely get lost, but sometimes there are disruptions due to storms and magnetic disturbances caused by man (Kirschvink *et al.*, 2001). The traditional and most effective approach to study cause-effect relationships in biological sciences is by experimentation with cells and organisms. The areas of enquiry and experimentation of in vitro studies include genotoxicity, cancer-related gene and protein expression, cell proliferation and differentiation, and apoptosis and in vivo studies include thermal effects, animal behavior, brain biochemistry, neuropathology, teratogenicity, reproduction and development, immune function, blood-brain barrier, visual auditory systems and effects on genetic material, cell function, and biochemistry (Repacholi and Cardis, 2002). In human health studies, concerns have been expressed about the possible interactions of RF-EMF with several human organ systems such as nervous, circulatory, reproductive, and endocrine systems. In order to reveal the global effects of RF-EMF on gene and protein expression, transcriptomics,

Table 2: Reference levels for the general public.

Country/organization Standards	Power density (W/m ²)	
	900 MHz	1800 MHz
ICNIRP, 1998, adopted by India	4.5	9
FCC, 1999	6	10
IEEE, USA, 1999	6	12
Australia	2	2
Belgium	1.1	2.4
Italy	1	1
Israel	x	1
New Zealand	x	0.5
China	x	0.4
Russia	x	0.2
Hungary	0.1	0.1
Toronto Board of Health, Canada, 1999	0.06	0.1
Switzerland	0.04	0.1
France	x	0.1
Germany, ECOLOG, 1998	x	0.09
Austria's precautionary limit	0.001	0.001

and proteomics as high-throughput screening techniques (HTSTs), were eventually employed in EMF research with an intention to screen potential EMF responsive genes and/or proteins without any bias (Nylund and Leszczynski, 2004). The safety standards set by ICNIRP, adopted by India, has only taken into account the short-term effects and not against the biological effects from long-term, non-thermal, low-level microwave exposure from mobile phones, cell phone towers, and many other wireless devices.

Current Research

Various studies have shown that even at low levels of this radiation, there is evidence of damage to cell tissue and DNA, and it has been linked to brain tumors, cancer, suppressed immune function, neuroendocrine disruption, chronic fatigue syndrome, and depression (Rogers, 2002; Milham, 2010). Oncogenesis studies at molecular and cellular levels due to RF-EMF radiations are considered particularly important (Marino and Carrubba, 2009). Orientation, navigation, and homing are critical traits expressed by organisms ranging from bacteria through higher vertebrates. Across many species and groups of organisms, compelling evidence exists that the physical basis of this response is tiny crystals of single-domain magnetite (Fe_3O_4) (Kirschvink *et al.*, 2001). All magnetic field sensitivity in living organisms, including elasmobranch fishes, is the result of a highly evolved, finely-tuned sensory system based on single-domain, ferromagnetic crystals. Animals that depend on the natural electrical, magnetic, and electromagnetic fields for their orientation and navigation through earth's atmosphere are confused by the much stronger and constantly changing artificial fields created by technology and fail to navigate back to their home environments (Warnke, 2007).

Studies on Plants

Tops of trees tend to dry up when they directly face the cell tower antennas and they seem to be most vulnerable if they have their roots close to the water (Belyavskaya, 2004). They also have a gloomy and unhealthy appearance, possible growth delays, and a higher tendency to contract plagues and illnesses. According to Levitt (2010), trees, algae, and other vegetation may

also be affected by RF-EMF. Some studies have found both growth stimulation and dieback. The browning of tree tops is often observed near cell towers, especially when water is near their root base. The tree tops are known as RF waveguides. In fact, military applications utilize this capability in trees for low-flying weapon systems. In an observational study, it was found that the output of most fruit-bearing trees reduced drastically from 100% to <5% after 2.5 years of cell tower installation in a farm facing four cell towers in Gurgaon–Delhi Toll Naka (Kumar and Kumar, 2009).

Studies on Insects

Monarch butterflies and locusts migrate great distances using their antennae to sense air currents and earth's electromagnetic fields. Moths are drawn to light frequencies. Ants, with the help of their antennae are adept at electrical transmission and found to respond to frequencies as low as 9 MHz. Flying ants are very sensitive to electromagnetic fields (Warnke, 2007).

Bees have clusters of magnetite in the abdominal areas. Colony collapse disorder (CCD) was observed in beehives exposed to 900 MHz for 10 minutes, with sudden disappearance of a hive's inhabitants, leaving only queen, eggs, and a few immature workers behind. With navigational skills affected, worker bees stopped coming to the hives after 10 days and egg production in queen bees dropped drastically to 100 eggs/day compared to 350 eggs (Sharma and Kumar, 2010). Radiation affects the pollinators, honeybees, whose numbers have recently been declining due to CCD by 60% at US West Coast apiaries and 70% along the East Coast (Cane and Tepedino, 2001). CCD is being documented in Greece, Italy, Germany, Portugal, Spain, and Switzerland. Studies performed in Europe documented navigational disorientation, lower honey production, and decreased bee survivorship (Kimmel *et al.*, 2007). EMFs from telecommunication infrastructure interfere with bees' biological clocks that enable them to compensate properly for the sun's movements, as a result of which, may fly in the wrong direction when attempting to return to the hive (Rubin *et al.*, 2006). Bee colonies irradiated with digital enhanced cordless communications (DECT) phones and mobile handsets had a dramatic impact on the behavior of the bees, namely by inducing the worker

pip-ing signal. In natural conditions, worker piping either announces the swarming process of the bee colony or is a signal of a disturbed bee colony (Favre, 2011).

A study by the University of Athens on fruit flies exposed to 6 minutes of 900 MHz pulsed radiation for 5 days showed reduction in reproductive capacity (Panagopoulos *et al.*, 2004). Likewise in 2007, in both 900 and 1800 MHz, similar changes in reproductive capacity with no significant difference between the two frequencies were observed (Panagopoulos *et al.*, 2007). In a third study, it was found it was due degeneration of large numbers of egg chambers after DNA fragmentation (Panagopoulos *et al.*, 2010). When *Drosophila melanogaster* adult insects were exposed to the radiation of a GSM 900/1800 mobile phone antenna at different distances ranging from 0 to 100 cm, these radiations decreased the reproductive capacity by cell death induction at all distances tested (Levengood, 1969).

Studies on Amphibians and Reptiles

Salamanders and turtles have navigational abilities based on magnetic sensing as well as smell. Many species of frogs have disappeared all over the world in the last 3–5 years. Amphibians can be especially sensitive because their skin is always moist, and they live close to, or in water, which conducts electricity easily (Hotary and Robinson, 1994). Toads when exposed to 1425 MHz at a power density of 0.6 mW/cm² developed arrhythmia (Levitina, 1966). Increased mortality and induced deformities were noted in frog tadpoles (*Rana temporaria*) (Levengood, 1969). It was observed that experimental tadpoles developed more slowly, less synchronously than control tadpoles, remain at the early stages for a longer time, developed allergies and that EMF causes changes in the blood counts (Grefner *et al.*, 1998). In a two-month study in Spain in common frog tadpoles on the effects of mobile phone mast located at a distance of 140 m noted low coordination of movements, an asynchronous growth, resulting in both big and small tadpoles, and a high mortality (90%) in exposed group. For the unexposed group in Faraday cage, the coordination of movements was normal, the development was synchronous, and a mortality of 4.2% was obtained (Balmori, 2009). In the eggs and embryos of *Rana sylvatica* and *Ambystoma maculatum* abnormalities at

several developmental stages were noted such as microcephalia, scoliosis, edema, and retarded growth. Tadpoles developed severe leg malformations and extra legs, as well as a pronounced alteration of histogenesis which took the form of subepidermal blistering and edema. Effects were noted in reproduction, circulatory, and central nervous system, general health and well being (Balmori, 2010; Balmori, 2005).

Studies on Birds

A study by the Centre for Environment and Vocational Studies of Punjab University noted that embryos of 50 eggs of house sparrows were damaged after being exposed to mobile tower radiation for 5–30 minutes (MOEF, 2010). Observed changes included reproductive and coordination problems and aggressiveness. Tower-emitted microwave radiation affected bird breeding, nesting, and roosting in Valladolid, Spain (US Fish & Wildlife Service, 2009). House sparrows, white storks, rock doves, magpies, collared doves exhibited nest and site abandonment, plumage deterioration (lack of shine, beardless rachis, etc.), locomotion problems, and even death among some birds. No symptoms were observed prior to construction of the cell phone towers. According to Balmori, plumage deterioration and damaged feather are the first signs of weakening, illnesses, or stress in birds. The disappearance of insects, leading to lack of food, could have an influence on bird's weakening, especially at the first stages in young bird's life. In chick embryos exposed to ELF pulsed EMR, a potent teratogenic effect was observed, leading to microphthalmia, abnormal trunkal torsion, and malformations on the neural tube (Lahijani and Ghafoori, 2000).

White storks were heavily impacted by the tower radiation during the 2002–2004 nesting season in Spain. Evidence of a connection between sparrow decline in UK and the introduction of phone mast GSM was established (Balmori, 2009). In a study in Spain, the effects of mobile phone mast has been noted in house sparrow (*Passer domesticus*), white stork (*Ciconia ciconia*), reporting problems with reproduction, circulatory, and central nervous system, general health and well-being (microwave syndrome) (Balmori, 2009). Deformities and deaths were noted in the domestic chicken embryos subjected to low-level, non-thermal radiation from the standard 915 MHz cell phone

frequency under laboratory conditions (US Fish & Wildlife Service, 2009). Neural responses of Zebra Finches to 900MHz radiation under laboratory conditions showed that 76% of the neurons responded by 3.5 times more firings (Beason and Semm, 2002). Eye, beak, and brain tissues of birds are loaded with magnetite, sensitive to magnetic fields, interferes with navigation (Mouritsen and Ritz, 2005).

Studies on Mammals

In a survey of two berry farms in similar habitats in Western Massachusetts (Doyon, 2008), one with no cell phone towers, there were abundant signs of wildlife, migrating and resident birds, bats, small and large mammals, and insects including bees and the other farm with a cell-phone tower located adjacent to the berry patch, virtually no signs of wildlife, tracks, scat, or feathers were noted. The berries on bushes were uneaten by birds and insects and the berries that fell to the ground were uneaten by animals. Whole body irradiation of 20 rats and 15 rabbits at 9.3GHz for 20 minutes revealed statistically significant changes in cardiac activity (Repacholi *et al.*, 1998). Bradycardia developed in 30% of the cases. Separate ventricular extra systoles also developed. In a study on cows and calves on the effects of exposure from mobile phone base stations, it was noted that 32% of calves developed nuclear cataracts, 3.6% severely. Oxidative stress was increased in the eyes with cataracts, and there was an association between oxidative stress and the distance to the nearest mast (Hässig *et al.*, 2009). It was found that at a GSM signal of 915MHz, all standard modulations included, output power level in pulses 2W, specific absorption rate (SAR) 0.4mW/g exposure for 2 hours, 11 genes were up-regulated and one down-regulated, hence affected expression of genes in rat brain cells (Belyaev *et al.*, 2006). The induced genes encode proteins with diverse functions including neurotransmitter regulation, blood-brain barrier (BBB), and melatonin production.

When rats were exposed for 2 hours a day for 45 days at 0.21mW/cm² power density SAR (0.038W/kg), a significant decrease in melatonin and increase in both creatine kinase and caspase 3 was found (Kesari *et al.*, 2011). This shows that chronic exposure to these radiations may be an indication of possible

tumor promotion. A study on pregnant rats and brains of fetal rats was carried out after irradiating them with different intensities of microwave radiation from cellular phones for 20 days three times a day. Superoxide dismutase (SOD), glutathione peroxidase (GSH-Px), malondialdehyde (MDA), noradrenaline (NE), dopamine (DA), and 5-hydroxyindoleacetic acid (5-HIAA) in the brain were assayed. The significant content differences of noradrenaline and dopamine were found in fetal rat brains (Jing *et al.*, 2012). A study in rabbits exposed to continuous wave and pulsed power at 5.5GHz found acute effects in the eyes, where lens opacities developed within 4 days (Birenbaum *et al.*, 1969).

Behavioral tasks, including the morris water maze (MWM), radial arm maze, and object recognition task have been extensively used to test cognitive impairment following exposure of rodents to mobile phone radiation (GSM 900MHz) on various frequencies and SAR values (Fragopoulou *et al.*, 2010). Exposed animals in most of the cases revealed defects in their working memory possibly due to cholinergic pathway distraction. Mobile phone RF-EMF exposure significantly altered the passive avoidance behavior and hippocampal morphology in rats (Narayanan *et al.*, 2010).

With regards to DNA damage or cell death induction due to microwave exposure, in a series of early experiments, rats were exposed to pulsed and continuous-wave 2450MHz radiation for 2 hours at an average power density of 2mW/cm² and their brain cells were subsequently examined for DNA breaks by comet assay. The authors found a dose-dependent (0.6 and 1.2W/kg whole body SAR) increase in DNA single-strand and double-strand breaks, 4 hours after the exposure to either the pulsed or the continuous-wave radiation. The same authors found that melatonin and PBN (N-tert-butyl-alpha-phenylnitrone) both known free radical scavengers, block the above effect of DNA damage by the microwave radiation (Lai and Singh, 1995, 1996, 1997). Death in domestic animals like hamsters and guinea pigs were noted (Balmori, 2003). Bats use electromagnetic sensors in different frequencies. Since 1998, a study on a free-tailed bat colony, having *Tadarida teniotis* and *Pipistrellus pipistrellus* has been carried out in Spain and a decrease in number of bats were noted with several phone masts 80m from the colony. A dead specimen of *Myotis myotis* was found near a small antenna in the city centre (Balmori, 2009).

The most affected of the species are bees, birds, and bats and without these pollinators visiting flowers, 33% of fruits and vegetables would not exist, and as the number of pollinators decline, the agricultural crops will fall short and the price of groceries will go up (Kevan and Phillips, 2001).

Studies on Humans

The exposure to continuous RF-EMF radiation poses a greater risk to children, particularly due to their thinner skulls and rapid rate of growth. Also at risk are the elderly, the frail, and pregnant women (Cherry, 2001). DNA damage via free radical formation inside cells has also been recorded (Lai and Singh, 1996). Free radicals kill cells by damaging macromolecules such as DNA, protein, and membrane are carcinogenic. In fact, EMR enhances free radical activity. Single- and double-strand DNA breaks are seen in rat brain cells after acute exposure to radio-frequency electromagnetic radiation. Kane (2001) denotes that RF-EMF radiations lead to tissue damage, DNA damage, or chromosome mutations. In 2008, the Austrian Department of Health found a higher risk of cancer among people living within 200 m of a mobile phone base station and that cancer risk rose with increasing exposure, reaching 8.5 times the norm for people most exposed. From a study on in vitro cell response to mobile phone radiation (900 MHz GSM signal) using two variants of human endothelial cell line, it was suggested that the cell response to mobile phone radiation might be genome- and proteome-dependent. Therefore, it is likely that different types of cells and from different species might respond differently to mobile phone radiation or might have different sensitivity to this weak stimulus (Nylund and Leszczynski, 2006).

The results of the interphone, an international case-control study to assess the brain tumor risk in relation to mobile telephone use, reveals no overall increase in risk of glioma or meningioma but there were suggestions of an increased risk of glioma at the highest exposure levels (30 minutes per day of cell phone use for 8–10 years) and ipsilateral exposures (ICNIRP, 2011). Children and young adults were excluded from the study and a separate study called Mobi-Kids is underway. According to Santini *et al.* (2002), comparisons of complaints in relation with distance from base station show significant

increase as compared to people living greater than 300m or not exposed to base station, till 300m for tiredness, 200m for headache, sleep disturbance, and discomfort, and 100m for irritability, depression, loss of memory, dizziness, and libido decrease. Women significantly more often than men complained of headache, nausea, loss of appetite, sleep disturbance, depression, discomfort, and visual perturbations (Santini *et al.*, 2002). According to Oberfeld *et al.* (2004) in Spain, a follow-up study found that the most exposed people had a higher incidence of fatigue, irritability, headaches, nausea, loss of appetite, sleeping disorders, depression, discomfort, difficulties concentrating, memory loss, visual disorders, dizziness, and cardiovascular problems. Women are more at risk as they tend to spend more time at home and are exposed to radiation continuously. The authors recommended a maximum exposure of 0.0001 W/cm² or 0.000001 W/m². There was prevalence of neuropsychiatric complaints among people living near base stations (Abdel-Rassoul *et al.*, 2007). Urban electromagnetic contamination (electrosmog) 900 and 1800 MHz pulsed waves interfere in the nervous system of living beings (Hyland, 2000). Growing amounts of published research show adverse effects on both humans and wildlife far below a thermal threshold, usually referred to as “non-thermal effects”, especially under conditions of long-term, low-level exposure (Levitt and Lai, 2010).

Australian research conducted by De luliis *et al.* (2009) by subjecting in vitro samples of human spermatozoa to radio-frequency radiation at 1.8 GHz and SAR of 0.4–27.5 W/kg showed a correlation between increasing SAR and decreased motility and vitality in sperm, increased oxidative stress and 8-Oxo-2'-deoxyguanosine markers, stimulating DNA base adduct formation and increased DNA fragmentation. GSM mobile phone exposure can activate cellular stress response in both humans and animal cells and cause the cells to produce heat shock proteins (HSP27 and HSP70) (Leszczynski, 2002). HSPs inhibit natural programmed cell death (apoptosis), whereby cells that should have committed suicide continue to live. Recent studies have shown that these HSPs inhibit apoptosis in cancer cells. In several cases, melatonin hormone which controls the daily biological cycle and has an oncostatic action, produced by the epiphysis (pineal gland) in mammals, mainly during the night, is found to reduce the action of EMR exposure, but the synthesis of melatonin itself seems to be reduced

by EMR (Panagopoulos *et al.*, 2008). In a study to observe the effects of melatonin in hormone balance in a diabetic, it was found that melatonin caused reduction in serum insulin, serum cortisol, serum ACTH, and serum TSH levels while increase in serum gastrin level. Of the biochemical parameters, melatonin caused reductions in TLC, LDLC, and FBS while increase in HDLC. It also caused reduction in neutrophil and increase in lymphocyte count in a diabetic with increase in faecal fat excretion (Mitra and Bhattacharya, 2008).

RF-EMR produces DNA damage via free radical formation inside cells. Free radicals kill cells by damaging macromolecules such as DNA, protein, and membrane, also shown to be carcinogenic. EMR enhances free radical activity. EMR interferes with navigational equipments, life-line electronic gadgets in hospitals, and affects patients with pacemakers. A short-term exposure (15 and 30 minutes) to RFR (900 MHz) from a mobile phone caused a significant increase in DNA single strand breaks in human hair root cells located around the ear which is used for the phone calls (Çam and Seyhan, 2012). Various in vitro studies have shown that 1800 MHz RF-EMF radiation could cause oxidative damage to mtDNA in primary cultured neurons. Oxidative damage to mtDNA may account for the neurotoxicity of RF radiation in the brain (Xu *et al.*, 2010).

Studies carried out on the RF levels in North India, particularly at the mobile tower sites at Delhi have shown that people in Indian cities are exposed to dangerously high levels of EMF pollution (Tanwar, 2006). An independent study was commissioned by the Cellular Operators Association of India (COAI) and Association of Unified Telecom Service Providers of India (AUSPI) as a proactive measure stemming from the concern for the public health and safety issues on electromagnetic radiation measurement at New Delhi showed compliance with ICNIRP standards. 180 areas were studied across the capital to understand the extent of RF-EMF radiations emitting from the mobile towers, revealed that the readings were 100 times below international safety guidelines. The study measured cumulative emissions within the 800–2000 MHz band of frequency (which includes both GSM and CDMA technologies) across in the nation's capital using carefully calibrated equipment, as per the DoT prescribed procedure in line with the ICNIRP specifications. In a similar, but independent case study in Mumbai, it was found that people living within 50–300 m radius are in

the high radiation zone and are more prone to ill-effects of electromagnetic radiation. Four cases of cancer were found in three consecutive floors (6th, 7th, 8th) directly facing and at similar height as four mobile phone towers placed at the roof of the opposite building (Kumar, 2010). According to the Seletun Scientific Statement (2011), low-intensity (non-thermal) bioeffects and adverse health effects are demonstrated at levels significantly below existing exposure standards. ICNIRP/WHO and IEEE/FCC public safety limits are inadequate and obsolete with respect to prolonged, low-intensity exposures (New International EMF Alliance, 2011). New, biologically-based public exposure standards are urgently needed to protect public health world-wide. EMR exposures should be reduced now rather than waiting for proof of harm before acting (Fragopoulou *et al.*, 2010).

Electrohypersensitivity (EHS) and Electromagnetic Field Intolerance (EFI) Syndrome

Electrosensitivity of people is now recognized as a physical impairment by government health authorities in the United Kingdom and Sweden. The UK Health Protection Agency (HPA) recognized that people can suffer nausea, headaches, and muscle pains when exposed to electromagnetic fields from mobile phones, electricity pylons, and computer screens. A case study in Sweden, one of the first countries where mobile technology was introduced approximately 15 years ago, shows that 250,000 Swedes are allergic to mobile phone radiation. Sweden has now recognized EHS as a physical degradation and EHS sufferers are entitled to have metal shielding installed in their homes free of charge from the local government (Kumar, 2010; Johansson, 2010).

Belpomme (2011) in his presentation at the 8th National Congress on Electromog in Berne in 2011 elaborates on the dangers of wireless technology and the diagnostics and treatment of the electromagnetic field intolerance (EFI) Syndrome. In his study from 2008 to 2011, the patients with EHS were investigated with a pulse equilibrium brain scan, dosage of histamine in the blood, dosage of the heat shock proteins HSP70 and HSP27, and appearance and disappearance of symptoms on exposure to an electromagnetic field source. Diagnosis of fatigue and depression were noted. The physiological changes such as vitamin D deficiency, decrease in heat

shock proteins, increase in histamines, increase in biomarker of the opening of blood-brain barrier, protein S100P, decrease in urinary melatonin, and increase in blood anti-myelin proteins were noted in the electrosensitives. Around 50% of the patients in the study had used a mobile phone for more than one hour per day during several years and his findings were similar to the figures published by Hardell's study (2007) dealing with the cancer occurrences and electromagnetic fields.

Future Challenges and Solutions

Research into the advantages of radio-frequency energies seen in tissue heating in benign prostatic hyperplasia (BPH), electrical therapy for cardiac arrhythmia, radio-frequency ablation, use of 41.5–44.5°C temperature to kill tumors, shortwave and microwave diathermy for musculoskeletal injuries, and microwave oven used in food preparation are all carried out under controlled conditions. But effects, if any, from RF-EMF radiations released into the environment over a long period of time in densely populated areas where people are continuously exposed to them will show in years to come. According to Osepchuk (1983), frequencies used in industrial, scientific, and medical heating processes are 27.12, 40.68, 433, 915, 2450, and 5800 MHz. Out of which, for diathermy, frequencies used are 27.12, 915, and 2450 MHz in US and 433 MHz is authorized in Europe. According to Kasevich (2000), “the physics of electromagnetic waves and their interactions with material and biological systems is based on the concept that the electromagnetic wave is a force field which exerts a mechanical torque, pressure or force on electrically changed molecules. All living things contain these dielectric properties. The thermal effects produced by absorption of electromagnetic energy are the direct result of water molecules acted upon by the oscillating electric field, rubbing against each other to produce electric heat (thermal effects)”. Research work on electromagnetic bioeffects in humans and animals in the non-thermal range is continuing where effects are noted even at intensities lower than 1 mW/m² (0.001 W/m² or 1000 W/m², 0.0001 mW/cm² or 0.1 W/cm²).

According to Levitt (2007), adverse outcomes of pregnancy can be mutagenic, teratogenic, oncogenic or carcinogenic, and ionizing radiations can cause all three. In animal studies, non-ionizing radiation was also found to be teratogenic and oncogenic, and likely mutagenic, but

it is unclear if these observations were due to heating affect, non-thermal affects or both. Trees, plants, soil, grass, and shrubs have the ability to absorb electromagnetic wave energy over a very broad range of wavelengths. According to the resonance concept, human beings can act as receiving antennas for some frequencies, where the absorbed energy is maximized in some areas of the body, like the brain (Levitt, 2007).

In the Bioinitiative Report, a document prepared by 14 international experts in a nine-month project, in which over 2000 scientific studies were reviewed, Sage (2007) came to a conclusion that there may be no lower limit that may be safe, and there was a need for biologically-based limits (1 mW/m² or 0.001 W/m²) and children are at most risk. Safety limits suggested are 0.001 W/m² for outdoor cumulative radio-frequency exposure and 0.0001 W/m² for indoor, cumulative radio-frequency exposure. According to Blank (2012), there is a need for a realistic biological standard to replace the thermal (SAR) standard. The precautionary approaches includes prudence avoidance for public and ALARA, which stands for “as low as reasonably attainable” for regulatory agencies.

According to Havas (2006), several disorders, including asthma, ADD/ADHD, diabetes, multiple sclerosis, chronic fatigue, fibromyalgia, are increasing at an alarming rate, as is electromagnetic pollution in the form of dirty electricity, ground current, and radio-frequency radiation from wireless devices and the connection between electromagnetic pollution and these disorders needs to be investigated and the percentage of people sensitive to this form of energy needs to be determined. According to Milham (2010), 20th century epidemic of the so-called diseases of civilization, including cardiovascular disease, cancer, diabetes, and also suicides, was caused by electrification and the unique biological responses we have to it and that our evolutionary balance, developed over the millennia has been severely disturbed and disrupted by man-made EMFs.

Conclusion

The Department of Telecommunication (DoT) in India has set new norms for cell phone towers with effect from September 1, 2012 (The Hindu, 2012). Exposure standards for RF-EMF radiation has been reduced to one-tenth of the existing level and SAR from 2 to 1.6 W/kg. This came after the ministry of environment and forest

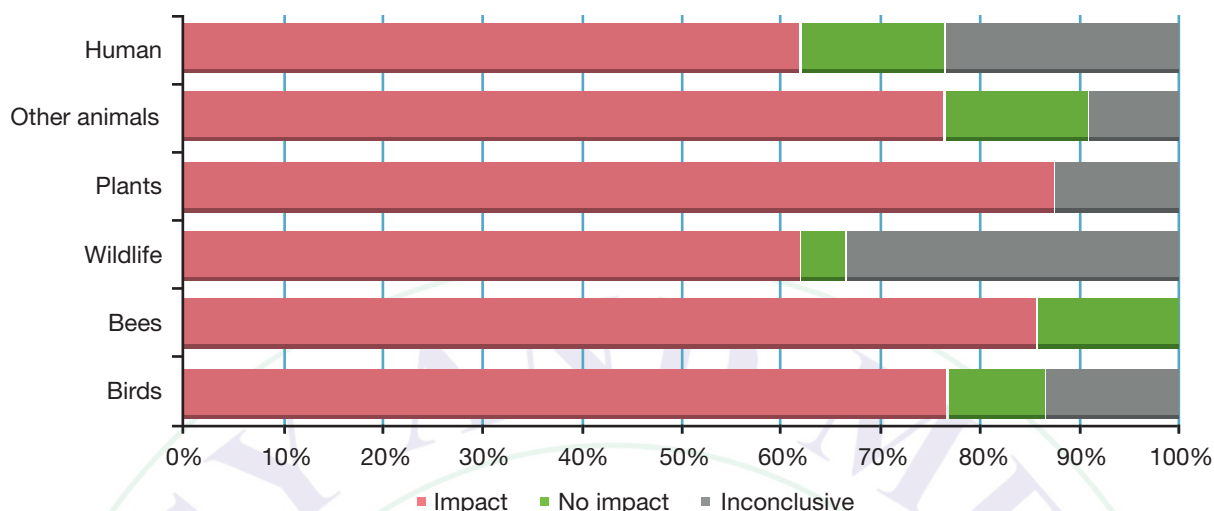


Figure 2: Percentage of studies that reported harmful effect of EMR in various groups of organisms ($n = 919$), MOEF Report (2010).

(MOEF) set up an Inter-ministerial Committee (IMC) to study the effects of RF-EMF radiations on wildlife (Figure 2) and concluded that out of the 919 research papers collected on birds, bees, plants, other animals, and humans, 593 showed impacts, 180 showed no impacts, and 196 were inconclusive studies. They conclude that there are no long-term data available on the environmental impacts of RF-EMF radiations in India. The population of India is increasing as well as the cell phone subscribers and the cell towers as supporting infrastructure. Hence, there is an urgent need to fill the gaps and do further research in this field with emphasis on the effects of early life and prenatal RF-EMF radiation exposure in animals, dosimetry studies, cellular studies using more sensitive methods, and human epidemiological studies, especially on children and young adults on behavioral and neurological disorders and cancer. Meanwhile, one can take the precautionary principle approach and reduce RF-EMF radiation effects of cell phone towers by relocating towers away from densely populated areas, increasing height of towers or changing the direction of the antenna.

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