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## IMPACTS OF MOBILE TOWER RADIATION ON BIODIVERSITY

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**Abstract:** Electromagnetic radiation, can travel through empty space as well as sometimes passing through air, water and solid matter. The electromagnetic radiation pervading the environment, this is now increasingly realized that it has added to the list of another pollutant in the environment i.e. electro-pollution. By 2013, it is estimated that more than one billion people will be having cell phone connection in India. Various studies have shown that 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. Electromagnetic radiation and their negative impacts on biological systems and environment have already been reported by several studies. 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. Exposure to electromagnetic fields has shown to be in connection with Alzheimer's disease, motor neuron disease and Parkinson's disease. More severe reactions include seizures, paralysis, psychosis and stroke. Trees, algae, and other vegetation may also be affected by RF-EMF. It was observed that experimental tadpoles developed more slowly, less synchronously than control tadpoles. Many species of frogs have disappeared all over the world in the last 3–5 years. 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. 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. Bats use electromagnetic sensors in different frequencies, decrease in number of bats were noted. There were abundant signs of wildlife, migrating and resident birds, bats, small and large mammals, and insects including bees which are affected by EMR.



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## INTRODUCTION

Radiation is energy in motion, in the form of waves or streams of particles. Radiation has always been present and is all around us in many forms. When people hear the word radiation, they often think of atomic energy, nuclear power and radioactivity. Radiation has many different forms like non-ionizing radiation and Ionizing radiation. Examples of non-ionizing radiation are Sound, visible light, ultraviolet radiation (that produces a suntan), infrared radiation (a form of heat energy), and radio and television signals. Radiation can be thought of as energy, travelling from one place to another. Like all forms of energy, it can be both useful and harmful to human beings.

### Types of Radiation

#### 1) Ionizing Radiation

#### 2) Non-ionising Radiation

##### Ionizing Radiation

Ionizing (or ionising) radiation is composed of subatomic particles, ions or atoms moving at relativistic speeds, or electromagnetic waves on the short wavelength end of the electromagnetic spectrum that carry enough energy to liberate electrons from atoms or molecules, thereby ionizing them. Gamma rays, X-rays, and the upper vacuum ultraviolet part of the ultraviolet spectrum are ionizing, whereas the lower ultraviolet, visible light (including laser light), infrared, microwaves, and radio waves are considered non-ionizing radiation (although lower ultraviolet can still create some ionization) **(1)**

##### Non-ionizing electromagnetic radiation

The electromagnetic spectrum is the range of all possible electromagnetic radiation frequencies. The electromagnetic spectrum (usually just spectrum) of an object is the characteristic distribution of electromagnetic radiation emitted by, or absorbed by, that particular object. The non-ionizing portion of electromagnetic radiation consists of electromagnetic waves that (as individual quanta or particles, see photon) are not energetic enough to detach electrons from atoms or molecules and hence cause their ionization. These include radio waves, microwaves, infrared, and (sometimes) visible light. The lower frequencies of ultraviolet light may cause chemical changes and molecular damage similar to ionization, but is technically not ionizing. The highest frequencies of ultraviolet light, as well as all X-rays and gamma-rays are ionizing. The occurrence of ionization depends on the energy of the individual particles or waves, and not on their number. An intense flood of particles or waves will not cause ionization if these particles or waves do not carry enough energy to be ionizing, unless

they raise the temperature of a body to a point high enough to ionize small fractions of atoms or molecules by the process of thermal-ionization **(2)**.

### **Radiation by Mobiles**

A mobile phone (also known as a cellular phone, cell phone, and a hand phone) is a phone that can make and receive telephone calls over a radio link while moving around a wide geographic area. It does so by connecting to a cellular network provided by a mobile phone operator, allowing access to the public telephone network. By contrast, a cordless telephone is used only within the short range of a single, private base station. In addition to telephony, modern mobile phones also support a wide variety of other services such as text messaging, MMS, email, Internet access, short-range wireless communications (Infrared, Bluetooth), business applications, gaming and photography. Mobile phones that offer these and more general computing capabilities are referred to as smart phones. The first hand-held cell phone was demonstrated by John F. Mitchell and Dr. Martin Cooper of Motorola in 1973, using a handset weighing around 2.2 pounds (1 kg)**(3)**. In 1983, the Dyna TAC 8000x was the first to be commercially available. From 1990 to 2011, worldwide mobile phone subscriptions grew from 12.4 million to over 6 billion, penetrating about 87% of the global population and reaching the bottom of the economic pyramid **(4)**. **Geneva, 5 May 2014** – New figures released by ITU indicate that, by end 2014, there will be almost 3 billion Internet users, two-thirds of them coming from the developing world, and that the number of mobile-broadband subscriptions will reach 2.3 billion globally. Fifty-five per cent of these subscriptions are expected to be in the developing world.

Scientific studies have investigated the possible health effects of mobile phone and its tower radiations. These studies are occasionally reviewed by some scientific committees to assess overall risks **(5,6)**. A cell phone is low power radio frequency device that transmit radio frequency radiation in the microwave region of 900-1800 MHz through an antenna used close to users head. Radio frequency radiation from cell phone is expressed in terms of SAR (Specific Absorption Rate) value. In USA, SAR limit for cell phones is 1.6 W/Kg, which is actually for 6 minutes per day use. It has a safety margin of 3 to 4, so a person should not use cell phone for more than 18 to 24 minutes per day. It has been reported that after use cell phones for more than 20 minutes, ear lobes get warmed due to heating of blood by microwave energy of cell phones. The problem begins with a pain in the ear that gradually develops into tinnitus or a ringing sensation which finally leads to hearing loss and ear tumour. Also, over use of cell phones leads to drying of the skin and fluid in the eyes, sleep disorder, lack of concentration, memory loss, and even induction of cancer **(7,8,9)**.

The radiation given out by mobile phones and mobile phone towers is non-ionizing radiation. Unlike ionizing radiation (as emitted by X-ray machines), RF energy from cell phones and other wireless devices cannot break chemical bonds in the human body. Cell phones emit low-level radiofrequency (RF) energy, some of which is absorbed into the human body. The amount of energy absorbed depends on many factors, such as how close you hold cell phone to the body and the strength of the signal. The transmitting power of a cell phone varies, depending on the type of network and its distance from the cell phone tower. **(10).**

### Cell Phones and Cell Tower Standards in India

India has adopted ICNIRP guidelines as the standard for safety limits of exposure to radiofrequency 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/m<sup>2</sup>, and general public is 4.5 W/m<sup>2</sup> 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, Wi MAX 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).

**Table 1: Radio-frequency sources in India**

RF source	Operating frequency	Transmission powers	Numbers
AM towers	540–1600 kHz	100KW	197 towers
FM towers	88–108 MHz	10KW	503 towers
TV towers	180–220 MHz	40KW	1201 towers
Cell towers	800, 900, 1800 MHz	20KW	5.4 laks towers
Mobile phones	GSM-1800/CDMA	1KW	800+ millions

	GSM-900	2KW	
Wi-Fi	2.4–2.5 GHz	10–100 mW	Wi-Fi hot spots

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 (11), 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 (12).

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

### ELECTROMAGNETIC POLLUTION AND HEALTH HAZARDS

Our workspaces, homes and public places are filled with electromagnetic radiations resulting in tremendous contribution towards electromagnetic pollution. Since some electromagnetic radiations can penetrate 12 inch concrete walls, they are definitely dangerous to human health as well. Towers may contribute 40% of the total exposure by electromagnetic radiations. Hence we are becoming victims of electromagnetic pollution.

## Impacts on Human

Since its beginning, there have been concerns about the adverse effects of the mobile towers and mobile phones. Electromagnetic radiation and their negative impacts on biological systems and environment have already been reported in several studies **(13,14,15)**. Radiation from cell phone towers causes larger increase in brain tumor. This is due to the damage in the blood brain barrier and the brain cell. Studies by Blackman **(16)** have indicated that weak electromagnetic fields release calcium ions from cell membranes. Loss of calcium ions causes leaks in the membranes of lysosomes releasing DNAase that causes DNA damage. As human body contains 70% of liquid, it absorbs radiation when body is exposed to the EMR. The human height is much greater than the wavelength of the cell tower transmitting frequencies, so there will be multiple resonances in the body. This creates localized heating inside the body causing boiling, drying up of the fluids around eyes, brain, joints, heart, and abdomen, etc. **(17)**.

It has been reported that for some people, short term effects from cell tower radiation exposure is observed. This includes headaches, sleep disorders, poor memory, mental excitation, confusion, anxiety, depression and appetite disturbance. The response to similar levels of electromagnetic radiation differs individually. A study by doctors from Naila city (Germany) monitored 1000 people residing in an area around two cell phone towers for 10 years. They found that those living within 400 meters of tower had a newly-diagnosed cancer rate three times higher than those who lived further away. In the observed cases breast cancer topped in the list, but cancers of the prostate, pancreas, skin melanoma, lung and blood were also increased **(18)**. Some investigators had observed effect of GSM phone radiation on human pulse rate (Heartbeat Rate). It was found that pulse rate do not change significantly when subjects were exposed to phone radiation. However, the percentage decreases in people of age 40 years and above **(19)**. Even a cell phone in the pocket or on belt may damage sperm DNA and impair fertility in men **(20)**.

## BIOLOGICAL EFFECTS

The current international standards (based on ICNIRP recommendations) are purely based on the thermal effects of radiation where as various epidemiological and experimental studies have shown to have significant biological effects far below these standards. Non-thermal effects of Radio frequency radiation accumulate over time and the risks are more pronounced after 8 to 10 years of exposure **(21)**. The effects are not observed in the initial years of exposure as the body has certain defence mechanisms and the pressure is on the stress proteins of the body, namely the heat shock proteins **(22)**. This means that the body recognizes these electromagnetic radiations as a potential harm. An additional concern is that if the stress goes

on too long, there is a reduced response, and the cells are less protected against the damage. This is why prolonged or chronic exposures may be quite harmful, even at very low intensities.

Radiation from cell phone towers has been associated with greater increase in brain tumour **(21)**. Irreversible infertility has been reported in mice **(23)** and continuous exposure has been associated with reduction in sperm viability and mobility by around 25% in men **(24)** Children are more vulnerable to radio frequency radiation emissions as their skulls are thinner, their nervous system still developing and myelin sheath is yet not developed. The RF Exposure can adversely affect the heart pace maker, implantable cardiovascular defibrillators and impulse generators **(25)**. These radiations may stop Pace Maker from delivering pulses in a regular way or may generate some kind of external controlling pulse putting the patient to death. Another study reveals that workers who are in the highest 10% category for EMF exposure are twice as likely to die of prostate cancer as those exposed at lower levels **(26)**. Exposure to electromagnetic fields has shown to be in connection with Alzheimer's disease, motor neuron disease and Parkinson's disease **(27)**. All these diseases are involved with the death of specific neurons and are classified as neurodegenerative diseases. Inhabitants living near mobile phone base stations are also at risk for developing neuropsychiatric problems as headache, memory loss, nausea, dizziness, tremors, muscle spasms, numbness, tingling, altered reflexes, muscle and joint pain, leg/foot-pain, depression, and sleep disturbance **(28)**. More severe reactions include seizures, paralysis, psychosis and stroke. All point to the fact that the current exposure standards for microwaves are not safe for long-term exposure.

A pregnant woman and the fetus both are vulnerable because of the fact that these RF radiations continuously react with the developing embryo and increasing cells. Microwave radiation can damage the placental barrier; the membrane which prevents the passage of some materials between the maternal and fetal blood, protecting the fetus, implying that pregnant woman should avoid cell phone or use during emergency **(29)**. In a recent finding, an association was found between a mother's cell phone use during pregnancy and greater likelihood for spontaneous abortion, congenital malformations and behavioural problems in their children. It is believed that the eggs, which form the embryo, are affected and the damage will become apparent after the child reaches puberty**(29)**.The Russian National Committee on Non- Ionizing Radiation Protection says that use of the phones by both pregnant women and children should be "limited". It concludes that children who talk on the handsets are likely to suffer from "disruption of memory, decline of attention, diminishing learning and cognitive abilities, increased irritability" The short term, and that long-term hazards include "depressive syndrome" and "degeneration of the nervous structures of the brain"**(30)**.

### ***Effect on Skin***

Radiation from cell towers and mobile phones affects human skin. People who talk often on cell phones have a higher concentration of the *transthyretin* protein than those who do not. *Transthyretin* is formed in the liver; it helps transport 'vitamin A' in the body and plays an important role in nervous diseases such as Alzheimers **(31)**. The symptoms of *Morgellons* disease include those of electromagnetic hypersensitivity (EHS); may be based on how body uses electric currents to repair wounds of the skin. People who suffer from this condition report a range of skin symptoms including crawling, biting and stinging sensations; granules, threads or black speck-like materials on or beneath the skin and/or lesions (e.g., rashes or sores). EMFs degrade the immune system and stimulate various allergic and inflammatory responses. The high radiation from cell towers can result in an increase in mast cells, which explains the clinical symptoms of itch, pain, edema and erythema **(32,33)**.

### ***Tinnitus and Ear Damage***

Tinnitus, popularly known as "Ringxiety"- is the psychological disease of hearing phantom sound and sensation of cell phone ring and it has been reported among millions of cell phone users in the world. People with severe tinnitus may have trouble hearing, working or even sleeping. The radiation emitted by mobile phones may damage the delicate workings of the inner ear, and long-term and intensive mobile phone use for more than four years and for longer periods than 30 minutes in a day are at a higher risk of developing hearing loss, which cannot be reversed **(34)**. This auditory perception has been shown to occur when a person's head is illuminated with microwave energy. The microwave pulse upon absorption in the head, launches a thermo-elastic wave of acoustic pressure that travels by bone conduction to the inner ear. There it activates the cochlear receptors via the same process involved for normal hearing, which explains the "clicks" heard by people exposed to microwave radiation **(35)**. Today, more and more young people between 18 and 25 years of age are suffering from hearing loss, which doctors say is due to excessive use of mobile phones and other gadgets. Good hearing depends on the health of some 16,000 hair cells present in each inner ear. Anyone who spends two to three hours on the cell-phone every day runs the risk of partial deafness over three to five years. Most of the marketing and tele-consulting professionals are in their 20s, and their jobs demand long conversations on cell phones. The problem starts with a pain in the ear that gradually develops into tinnitus or a ringing sensation which finally leads to hearing loss **(36)**.

### ***Effect on Eye/ Uveal Melanoma***

Frequent use of mobile phones can also damage the visual system in many ways and cause uveal melanoma i.e. tumor of the eye. Tumors involve the choroid (98%), iris (1%) and unknown

parts of the uveal tract (1%). Computational modelling and experiments with several laboratory animals show that microwave radiation similar to mobile phone frequencies (900, 1800 MHz and 2450MHz) can induce chromosomal breaks in the corneal epithelial cells and increase the intraocular temperature of the eye with prolonged exposure **(37)**. Increase in temperature close to the eye lens (as low as 30°C) can result in lens opacities and increase the risk of developing cataracts in humans, a condition characterized by clouding in the natural lens of the eye and lens opacities. When Bovine eye lenses were exposed to microwave radiation, it caused macroscopic damage and affected the optical function of the lens. The damage increased as the irradiation continued and reached a maximum level after a number of days **(38)**. Prolonged exposure to microwave radiation similar to that used by cellular phones can lead to both macroscopic and microscopic damage to the lens and part of this damage seems to accumulate over time and does not heal **(39)**.

### ***Cell phone emission weaken bones***

Researchers have measured bone density at the upper rims of the pelvis (iliac wings) in men who were mobile users and carried their phones on their belts. The iliac wings are widely used source of bone for bone grafting, so any reduction in bone density may be of special importance to reconstructive surgery. The results showed reduction in iliac wing bone density on the side where men carried their phones. In general, it is better to keep mobile phones as far as possible from our body during our daily lives **(40)**.

### ***Sleep Disorders***

Electromagnetic fields have been shown to affect the brain physiology. Use of mobile phones disturbs 4 stage sleep, the stage important for full recuperation of brain and body. Use of the handsets before bed, delays and reduces sleep, and causes headaches, confusion and depression **(41)**. The findings are especially alarming for children and teenagers as they use cell phones at night and also keep the phone next to their head; which may lead to mood and personality changes, depression, lack of concentration and poor academic performance **(42)**.

### ***Neurodegenerative Diseases***

Exposure to electromagnetic fields has shown to be in connection with Alzheimer's disease, motor neuron disease and Parkinson's disease. All these diseases are involved with the death of specific neurons and are classified as neurodegenerative diseases **(43)**. People living near mobile phone base stations are also at risk for developing neuro- psychiatric problems as headache, memory loss, nausea, dizziness, muscle spasms, numbness, tingling, altered reflexes, muscle and joint pain, leg/foot pain, depression, and sleep disturbance. More severe reactions include seizures, paralysis, psychosis and stroke **(44)**.

### Effects 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 **(45)**. They also have a gloomy and unhealthy appearance, possible growth delays, and a higher tendency to contract plagues and illnesses. 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 **(46)**. The tree tops are known as RF wave guides. 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 **(17)**.

### Effects 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 antennas are adept at electrical transmission and found to respond to frequencies as low as 9 MHz. Flying ants are very sensitive to electromagnetic fields **(47)**. 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 **(48)**. 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 **(49)**. 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 **(50)**. 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, they may fly in the wrong direction when attempting to return to the hive **(51)**. Bee colonies irradiated with digital enhanced cordless communications (DECT) phones and mobile handsets had a dramatic impact on the behaviour of the bees, namely by inducing the worker piping signal. In natural conditions, worker piping either announces the swarming process of the bee colony or is a signal of a disturbed bee colony **(52)**.

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 **(53)**. Likewise in 2007, in both 900 and 1800 MHz, similar changes in reproductive capacity with no significant difference

between the two frequencies were observed (54). 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 (55).

### Effects 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 (56). Toads when exposed to 1425 MHz at a power density of 0.6 mW/cm<sup>2</sup> developed arrhythmia (57). Increased mortality and induced deformities were noted in frog tadpoles (*Ranatemporaria*) (55). 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 (58). 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 (59). In the eggs and embryos of *Ranasylvatica* 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 sub-epidermal blistering and edema. Effects were noted in reproduction, circulatory, and central nervous system, general health and well-being (60,61).

### Effects 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 (62). Observed changes included reproductive and coordination problems and aggressiveness. Tower-emitted microwave radiation affected bird breeding, nesting, and roosting in Valladolid, Spain (63). 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. 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 **(64)**. 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. In a study in Spain, the effects of mobile phone mast has been noted in house sparrow (*Passer domesticus*), white stork (*Ciconiaciconia*), reporting problems with reproduction, circulatory, and central nervous system, general health and well-being (which is collectively called microwave syndrome) **(59)**.

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 **(63)**. Neural responses of Zebra Finches to 900 MHz radiation under laboratory conditions showed that 76% of the neurons responded by 3.5 times more firings **(65)**. Eye, beak, and brain tissues of birds are loaded with magnetite, sensitive to magnetic fields, interferes with navigation **(66)**.

#### Effects on Mammals

In a survey of two berry farms in similar habitats in Western Massachusetts, 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 9.3 GHz for 20 minutes revealed statistically significant changes in cardiac activity **(67)**. Brady-cardia 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 **(68)**.

It was found that at a GSM signal of 915 MHz, all standard modulations included, output power level in pulses 2 W, specific absorption rate (SAR) 0.4 mW/g exposure for 2 hours, 11 genes were up-regulated and one down-regulated, hence affected expression of genes in rat brain cells **(69)**. 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 0.21 mW/cm<sup>2</sup> power density SAR (0.038 W/kg), a significant decrease in melatonin and increase in both creatine kinase and caspase 3 was found **(70)**. This

shows that chronic exposure to these radiations may be an indication of possible tumour promotion.

A study on pregnant rats and brains of fatal 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), malon-di-aldehyde (MDA), nor-adrenaline (NE), dopamine (DA), and 5-hydroxyindoleacetic acid (5-HIAA) in the brain were assayed. The significant content differences of nor-adrenaline and dopamine were found in fatal rat brains (71). A study in rabbits exposed to continuous wave and pulsed power at 5.5 GHz found acute effects in the eyes, where lens opacities developed within 4 days (72). Behavioural 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 900 MHz) on various frequencies and SAR values (73). 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 behaviour and hippocampal morphology in rats (74). 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 2450 MHz radiation for 2 hours at an average power density of 2 mW/cm<sup>2</sup> and their brain cells were subsequently examined for DNA breaks by comet assay. The authors found a dose-dependent (0.6 and 1.2 W/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.

Death in domestic animals like hamsters and guinea pigs were noted (75). 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 80 m from the colony. A dead specimen of *Myotis myotis* was found near a small antenna in the city centre (59). 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 (76).

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