6.0 DISCUSSION

There is an ongoing debate worldwide about the bioeffects of the radiofrequency electromagnetic field (RF-EMF) radiation transmitted from cell phone towers, particularly in India. The World Health Organization’s International Agency for Research on Cancer (WHO-IARC) in 2011, had termed that electromagnetic radiation from mobile phones as a “possible human carcinogen”, group 2B. This radiation spreads in a surrounding area and creates an electromagnetic field (EMF). Every antenna on cell phone tower radiates electromagnetic power and the power intensity or Power Density (PD) in milliwatt per square meter (mW/sq.m) in a nearby area depends on the number of antennae on the tower. The intensity of EMF is strongest at the source, which is the cell tower and becomes weaker as distance increases. Hence, the distance plays a key role. Time is also an important factor in how much exposure a person receives. The RF-EMF exposure from cell phone towers are far-field, involuntary, whole body and for 24 hours a day, while that of the cell phones are localized and intermittent, under the voluntary control of the user. Both the sources may involve the same carrier frequency but differ in power output. According to the Department of Telecommunication (DoT), (2012), the intensity of radiofrequency electromagnetic waves from cell phone towers is generally found to be much below the safety guidelines set by International Commission on Non-lionizing Radiation Protection (ICNIRP), adopted by India. In this age of toxicity, one is already exposed to increasing electrosmog through medical intervention and environmental background radiation, in addition to the tremendous increase in mobile telephony. The long-term RF-EMF radiation exposure from cell phone towers may have possible non-thermal effects.

6.1 DOSIMETRY

At many places in India, Chennai in particular, the cell phone towers are mounted on rooftops of the hospitals, schools, residential and commercial buildings. Typical locations where the public is exposed are at ground level, in buildings beneath antennae and in buildings facing antennae mounted on towers or other buildings. Even though the antennae mounted on these towers radiate less power vertically down, the distance between the antennae and the top floor of the adjacent building is usually a few meters, so the radiation level in the top two floors of nearby buildings remains high (Kwan-Hoong Ng, 2003; Kumar, 2013). Some antennae are mounted in balconies of residences and windows of apartments and commercial establishments. As a result of
which, people are found living and working merely 10 m, and sometimes, even 5 m from the antennae, as seen in Figure 6.1. The aim of the dosimetry study was to measure RF-EMF radiation in Chennai city, particularly from cell phone towers located near schools, colleges, hospitals, children’s playground, residential apartments and commercial/industrial establishments.

![Cell tower antennae on balconies and rooftop of buildings](image)

*Figure 6.1: Cell tower antennae on balconies and rooftop of buildings (Sivani S et al., 2014).*

According to dosimetry study I, using the cumulative cell phone tower radiation detector, out of the 106 spots measured, column percentage of RF-EMF radiation above 26.19 mW/sq.m, considered to be in danger levels (red), was recorded in Central Chennai at 57.1%, South Chennai at 25% and West Chennai at 17.9% and none in North Chennai (0%); RF-EMF radiation between 0.07 to 26.19 mW/sq.m or the caution levels (yellow) was recorded in Central Chennai at 41.1%, West Chennai at 28.8%, South Chennai at 16.4% and North Chennai at 13.7%; RF-EMF radiation below 0.07 mW/sq.m or safe levels (green) was recorded in West Chennai at 60% and South Chennai at 40%, but none in North or Central Chennai. According to row percentage, Central Chennai was the highest among all zones in danger levels (red) at 34.78%, North Chennai was the highest among all zones in caution levels (yellow) at 100% and West Chennai was the highest among all zones in safe levels (green) at 10.34% among the locations measured.

There was a significant difference at 1% level (p<0.001) between Indian RF-EMF Radiation Standard at 450 mW/sq.m and upper limits of Biological Standard for RF-EMF radiation at 0.5 mW/sq.m and RF-EMF radiation in all four zones of Chennai. There was a significant difference at 1% level (p<0.001) between Indian RF-EMF Radiation Standard and RF-EMF radiation in North and West Zones of Chennai, whereas it was not significant when compared to the upper limits of
Biological Standard for RF-EMF radiation for both zones. There was a significant difference at 1% level (p<0.001) between Indian RF-EMF Radiation Standard and the upper limits of Biological Standard for RF-EMF radiation and the RF-EMF radiation in Central and South Zones of Chennai.

In case of power density measurements obtained using the triaxial digital RF-EMF strength meter, West Zone of Chennai had the highest power density mean at 31.39 mW/sq.m, followed by Central zone at 30.02 mW/sq.m, South Zone at 23.32 mW/sq.m and North Zone at 4.31 mW/sq.m. In this survey, out of 106 readings across four zones of Chennai, namely North, Central, West and South, 51 readings were found to be above 5 mW/sq.m. The upper limit of biological standard is 0.5 mW/sq.m. Among the locations surveyed, 50% were found to be more than 10 times the upper biological limit of 0.5 mW/sq.m. According to Indian standard of 450 mW/sq.m, 99% of the locations are less than half (225 mW/sq.m) of Indian standard. Once particular location showed a power density of 450 mW/sq.m when surveyed. Overall mean for all four zones was 55.33 mW/sq.m.

Central Chennai being the commercial hub, with considerably less green cover and numerous cell phone towers, had increased electrosmog, followed by South Chennai which is the Information Technology (IT) hub and does have considerable green cover. North Chennai is a thriving trade and commerce centre, with many industrial establishments and less green cover. West Chennai has well-planned townships, less congestion and increased green cover, although commercial activities are on the rise currently. Vegetation often reduced the cell tower signals, but buildings do not appreciably diminish signal transmission (Sage, 2000).

In dosimetry study II, an investigation of RF-EMF radiation in 15 zones of Chennai Corporation (Fig. 6.2), at 50 spot locations near commercial/industrial establishments were measured. The zones showing danger levels (red or >26.19 mW/sq.m) were found in Manali, Ambattur, Anna Nagar, Teynampet, Kodambakkam, and Adyar, with a mean power density of 66.72 mW/sq.m. Manali Zone in the Northern suburb of Chennai has numerous industrial establishments. Ambattur Zone has industrial estates and Information Technology (IT) parks. Anna Nagar Zone although a residential area with substantial green cover, has a recent spurt in commercial establishments. Teynampet Zone is one of the busiest commercial localities and has a mixed residential upscale neighbourhood. Kodambakkam Zone has one of India’s principal shopping districts and is where all the Tamil movie studies are located. Adyar Zone has many prominent educational and research institutions, costliest real estate, although with vast green cover. Zones
showing safe levels (green or <0.07 mW/sq.m) were found in Anna Nagar, Teynampet, Adyar and Shozhinganallur, with a mean power density of 0.006 mW/sq.m. Shozhinganallur, although an IT corridor with many global financial establishments, has a large green cover and is at a close proximity to the beaches. The zones indicating yellow or caution levels (between 0.07 to 26.19 mW/sq.m) were Thiruvottiyur, Manali, Madhavaram, Tondiarpet, Royapuram, Thiru-vi-ka Nagar, Anna Nagar, Teynampet, Kodambakkam, Valsaravakkam, Alandur, Adyar, Perungudi, and Shozhinganallur, with a mean power density of 7.31 mW/sq.m.

Figure 6.2: 15 Zones of Corporation of Chennai
(Image Source: http://www.chennaicorporation.gov.in/)
An independent cellular tower study in 2010 to assess the cumulative emissions within the 800 to 2000 MHz band of frequency, which included both GSM and CDMA technologies, at 180 areas in New Delhi, using carefully calibrated equipment, as per the DoT prescribed procedure in line with the ICNIRP specifications were carried out by leading experts from the Indian Institute of Technology-Madras (IIT-M), Chennai, Thiagarajar College of Engineering (TCE), Madurai and Centre of Excellence in Wireless Technology (CEWiT), Chennai. It revealed that cumulative measurement levels of radiation from cell phone towers in Delhi were 100 times below international safety guidelines and in compliance with the limit set by ICNIRP (1998). The 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 to address public health and safety issues (COAI, 2010). According to the Bioinitiative Report (2012), the power density at which bioeffects were seen was in the range of 0.5 to 0.01 mW/sq.m. Safe radiation levels for long-term continuous exposure were postulated as in Table 6.1.

### Table 6.1: RF-EMF Radiation Standards and spot location power density readings

<table>
<thead>
<tr>
<th>Standards</th>
<th>Power Density in mW/sq.m</th>
<th>Comments</th>
</tr>
</thead>
</table>
| New Indian Guidelines 1 September 2012         | 450 for 900 MHz  
920 for 1800 MHz        | Reduced to one-tenth of ICNIRP guidelines      |
| Safe Radiation density level for long-term continuous exposure | For 100 years - < 0.1  
For 10 years - < 1  
For 1 year - < 10         | Guha SK and Kumar G, (2011)                    |

### Table 6.2: Power Density measurements and Standards according to DoT, (2012)

<table>
<thead>
<tr>
<th>Standard Power Density of cell phone towers adopted by India (mW/sq.m)</th>
<th>Standard Power Density Measurements at various distances from the direction of main beam of cell phone towers as per DoT (mW/sq.m)</th>
<th>Power Density Measurements at which bioeffects are noted (mW/sq.m)</th>
</tr>
</thead>
</table>
| For GSM900 - 450  
For GSM1800 - 900                                                      | At 150 m - 7  
At 100 m - 1.6  
At 50 m - 6.5  
At 30 m - 18                                                          | Bioinitiative Report 2012 - 0.01 to 0.5  
Bioinitiative Report 2007 - 0.5 to 1                                  |
According to DoT (2012), at 150 m from the cell phone tower, the power density in the antenna main beam direction must be 7 mW/sq.m, 1.6 mW/sq.m at 100 m, 6.5 mW/sq.m at 50 m, and 18 mW/sq.m at 30 m (Table 6.2). The RF-EMF measurement, as shown in Figure 6.3, atop a three-story apartment building in West Chennai, facing the antennae of two cell phone towers, at a distance of 100 m, showed power density of 1.202 μW/sq.cm = 12.02 mW/sq.m.

![Figure 6.3: Power Density measurement using an RF Meter](image)

A study by Dhami AK. et al., (2011), to estimate the microwave/RF pollution by measuring radiation power densities near schools and hospitals of Chandigarh city in India, where the highest measured power density was 11.48 mW/sq.m. The results indicated that the exposure levels in the city were below the ICNIRP limit, but much above the biological limit. An investigation by Haumann T. et al., (2002), showed that the GSM cellular phone tower radiation was the dominating high-frequency source in residential areas in Germany. The power density was found in the range of 0.2 mW/sq.m with the maximum value exceeding 100 mW/sq.m. No location reached or exceeded the official standard values for the USA or Germany.

A study by Kumar and Kumar, (2009), indicated that continuous exposure to RF-EMF from cell phone towers caused serious health problems over the years and the effects could be either thermal or non-thermal. The current safety standard for exposures was mainly based on thermal effects, which was inadequate. Measurements were carried out at various places near the cell phone towers in Mumbai and the radiation levels were found to be very high. Case studies done by Kumar, (2010), from the measurements at various locations in Mumbai, it was found that if the radiation level was more than 26 mW/sq.m (> -15 dBm), health problems occurred within one to two years. If the radiation level was between 0.07 and 26 mW/sq.m (-30 to -15 dBm), then health problems occur in five to ten years. If radiation level is less than 0.07 mW/sq.m (< -30 dBm), no health problems were recorded. The risk depended on the proximity to a tower and the power.
transmitted by each antenna. The greater the power and the number of antennae, the higher the radiation impact. Maximum RF-EMF radiation was in the direction of the building facing the antennae.

A study was conducted to evaluate RF-EMF radiation levels near several cell phone towers in two major cities in Malaysia. The measured values at public locations were then compared with the recommended international maximum permissible exposure limit and they were found to be less than 1% of the maximum permissible exposure. The amount of RF-EMF radiation from the selected cell phone tower locations were adhering to the international limits, although the cell phone tower infrastructures spawning out everywhere in these areas gave the reverse impression (Ismail A. et al., 2010). Mahfouz Z. et al., (2011), investigated the general public daily exposure to mobile telephony from GSM900 and other 2G cell phone towers. The study focussed on the assessment of the maximal real electric field received over the day from an instantaneous measurement performed any time during the day. Real-life exposure to 3G base stations of the general public in environment during a period of one day were investigated. The field variations were found to be higher during daytime than at night due to the traffic demand.

There have been several dosimetry studies to measure the RF-EMF radiation around cell phone towers in the world from early 2000. An investigation by Hamnerius, (2000), in Sweden where four different environments like city, town, rural and indoor locations were chosen for RF spectral measurements in the range of 30 MHz-2000 MHz in 1999-2000 in 26 sites to decipher the public exposure to living environment, where the highest mean contribution in all environments was found to be from GSM900. A similar study was carried out by Neubauer G, (2000), in Austria where 100 sites in cities and towns and 102 sites in rural areas were chosen for RF spectral measurements around base stations in Salzburg area from 1997 to 1999. There were dosimetry studies from Australia (Line, 2000), United Kingdom (Mann, 2000) and Canada (Gajda and Thansandote, 1998) where measurements were taken in public places, especially near schools. It was concluded that although within the standards of exposure, were much above the biological limit at which bioeffects are seen. According to Shandala and Vinogradov, (1983), the electromagnetic radiation near a re-emitting element such metal-coated structures like wires, pipes, cranes, power transmission lines, and metal fences will be higher.

European Union member states and some industrialised nations follow different approaches with great diversity in RF-EMF exposure limits (Table 6.3). Some member states follow their
national recommendation, some follow recommendation by ICNIRP, some have more lenient limits and still some others no regulation. In countries like Germany and Slovakia, the reference levels have become the exposure limits. In some places, the basic restrictions are stricter, where reference levels are based on precautionary principal or due to public pressure created from widespread awareness or based on the principle 'as low as reasonably achievable without endangering service’. For instance, in Belgium, precautionary limits were declared unconstitutional and regulation was left to regional government, with maximum exposure per location being 50% of the reference level for 10 MHz to 10 GHz. In Greece, mobile phone towers are not allowed within the property boundaries of schools, kindergartens, hospitals and senior homes. Russia, which has been into decades long research in RF-EMF radiation, has much stricter exposure limits, named hygienic epidemiological requirements, to prevent biological effects that are not generally seen as health risk in Western countries. In United States, basic restrictions are only for portable devices and not for non-potable devices like cell phone towers, where the reference levels are applied as de facto exposure limits (Stam R, 2011).

Table 6.3: General public and occupational exposure limits of RF-EMF radiation

<table>
<thead>
<tr>
<th>Exposure limits of electromagnetic fields for general public</th>
<th>900 MHz (GSM) power density (mW/sq.m)</th>
<th>1800 MHz (GSM) power density (mW/sq.m)</th>
<th>Occupational exposure limits of electromagnetic fields</th>
<th>900 MHz (GSM) power density (mW/sq.m)</th>
<th>1800 MHz (GSM) power density (mW/sq.m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recommendation 1999/519/EC</td>
<td>4,500</td>
<td>9,000</td>
<td>Directive 2004/40/EC</td>
<td>22,500</td>
<td>45,000</td>
</tr>
<tr>
<td>Austria</td>
<td>4,500</td>
<td>9,000</td>
<td>Austria</td>
<td>22,500</td>
<td>45,000</td>
</tr>
<tr>
<td>Belgium</td>
<td>-</td>
<td>-</td>
<td>Belgium</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Bulgaria</td>
<td>100</td>
<td>100</td>
<td>Bulgaria</td>
<td>10,000</td>
<td>10,000</td>
</tr>
<tr>
<td>Cyprus</td>
<td>4,500</td>
<td>9,000</td>
<td>Cyprus</td>
<td>22,500</td>
<td>45,000</td>
</tr>
<tr>
<td>Czech Republic</td>
<td>4,500</td>
<td>9,000</td>
<td>Czech Republic</td>
<td>22,500</td>
<td>45,000</td>
</tr>
<tr>
<td>Denmark</td>
<td>-</td>
<td>-</td>
<td>Denmark</td>
<td>22,500</td>
<td>45,000</td>
</tr>
<tr>
<td>Estonia</td>
<td>4,500</td>
<td>9,000</td>
<td>Estonia</td>
<td>6,000</td>
<td>12,000</td>
</tr>
<tr>
<td>Finland</td>
<td>4,500</td>
<td>9,000</td>
<td>Finland</td>
<td>22,500</td>
<td>45,000</td>
</tr>
<tr>
<td>France</td>
<td>4,500</td>
<td>9,000</td>
<td>France</td>
<td>22,500</td>
<td>45,000</td>
</tr>
</tbody>
</table>
Wiart J et al., (2011), have done a review to analyse the progress in building child and foetus models to assess the Specific Absorption Rate (SAR) for numerical dosimetry purpose. The results show that compliance methods used nowadays to certify phones are valid for children. The analysis revealed the finding that specific tissues such as peripheral brain tissues have higher exposure in children than in adults, the whole body SAR of children were higher than the whole body SAR of adults and that compliance to ICNIRP reference levels did not guarantee the compliance to ICNIRP basic restrictions. Dealing with the fetus models and dielectric properties,
the results showed that the fetus exposure was lower than the mother’s exposure, with an important influencing parameter being the position of the fetus in the uterus.

There is an ongoing dosimetry study from 2013 by Hong in Korea, to evaluate the exposure of radiofrequency electromagnetic fields among 11- to 15-year-olds in large cities of Korea, where the age of starting to use cellular phones is relatively early. The level of individual exposure is being measured for 24 hours. Kim HB et al., (2013), indicated from their study on the exposure level analysis of RF-EMF radiation on people living around base stations in Korea that most of the measurement levels were much lower than ICNIRP guidelines for human exposure, but also noted that RF-EMF exposure levels were found to rise every year.

6.2 EPIDEMIOLOGY

If one uses the cell phone continuously for more than two hours a day and does not live in the vicinity of a cell phone tower, then the exposure from the cell phone radiation is higher. If one does not use a cell phone and live within 50-100 m of a cell phone tower(s), the RF-EMF exposure from the tower(s) is higher. This scenario in a metro like Chennai is very common as clusters of cell phone towers are found within 300 m and cell phones are used extensively by people, as confirmed by the urban teledensity. Lifestyle, general health and welfare of people living in an environment of RF-EMF exposure, considered to be an invisible health hazard radiation, were assessed. People in the Information Technology (IT) field, in companies in Tidel Park in the IT Corridor, Tharamani, South Chennai, where there was high RF-EMF radiation, were deliberately chosen for the epidemiology survey I. In epidemiology survey II, people living around the cell phone towers in an urban locality in Central Chennai and a rural locality in Tamil Nadu, were chosen for the survey.

From the epidemiology survey I, IT professionals who were females, unmarried and non-vegetarians, those in the age group of below 25 years, and those who worked for 9 hours/day and slept for 6 hours/day were highly susceptible to RF-EMF radiation effects. The frequency of symptoms often experienced included hair loss (32.02%), difficulty sleeping (12.36%), poor short-term memory and pain in teeth and deteriorated fillings (10.11%), headache (8.99%), fatigue and dryness of lips, tongue, mouth, eyes (5.06%) and depression (2.81%). In severity, the symptoms often experienced include hair loss (22.47%), poor short-term memory (10.11%), pain in teeth and deteriorated fillings (10.11%), difficulty sleeping (7.30%), irritability (7.30%), difficulty
concentrating (7.30%), headache (6.18%), fatigue (5.06%), and dryness of lips, tongue, mouth and eyes (5.06%). All IT professionals possessed a cell phone, 80.34% of them used a wired computer, while 73.60% of them used a wireless computer; 20.22% used a microwave and 19.66% used a cordless phone. Only 2.25% of them use the landline.

In Pearson Correlation Coefficient between frequency of non-specific symptoms, cell phone use and hours of work and sleep in the IT Professionals, the following symptoms were significant (p<0.01): poor short-term memory, difficulty sleeping, difficulty concentrating, dizziness, pain in teeth and deteriorated filling, dryness of lips, tongue, mouth and eyes; (p<0.05): headache, depression, blurred vision, irritability, fatigue, ringing in the ears, hair loss, impaired sense of smell, nosebleeds, and loss of libido. Similarly, in severity, the following symptoms were significant (p<0.01): headache, poor short-term memory, dizziness, depression, blurred vision, difficulty sleeping, difficulty concentrating, hair loss, pain in teeth and deteriorated fillings and dryness of lips, tongue, mouth and eyes; (p<0.05): irritability, fatigue, ringing in the ears, impaired sense of smell, nosebleeds and loss of libido.

In Chi-square test for association between gender and non-specific symptoms among the IT professionals, significant symptoms in females: (p<0.01) - headaches, tremors (frequent), dizziness; depression, blurred vision, difficulty sleeping, irritability, difficulty concentrating, chronic pain, pain in teeth and deteriorated fillings, dryness of lips, tongue, mouth and eyes (sometimes frequent and severe); (p<0.05) - blurred vision (sometimes frequent) and fatigue (sometimes frequent and severe). In Chi-square test for association between gender and non-specific symptoms among the IT professionals, significant symptoms in males: (p<0.01) - poor short-term memory (severe); depression (frequent and severe); difficulty sleeping, irritability, pain in teeth and deteriorated fillings, dryness of lips, tongue, mouth and eyes (often frequent and severe); difficulty concentrating (often severe); (p<0.05) - blurred vision (often severe) and fatigue (often frequent and severe). In Chi-square test for association between gender and medical conditions among IT professionals, significant at 1% level (p<0.01) was allergies and asthma, found mostly in females (85%) than males; significant at 5% level (p<0.05) was skin problems, found mostly in females (70.6%) and eye problems, found mostly in males (65.5%).

In Chi-square test for association between gender and electronic/communication devices used by IT professionals, there was significant (p<0.05) use of landline by males (100%),
significant (p<0.01) use of wired computer network (more males at 54.5% than females),
significant (p<0.05) use of wireless computer network (more females at 56.5% than males), and
significant (p<0.05) use of microwave oven (more females at 69.4% than males). For association
between gender and use of Bluetooth device by IT professionals, it was found that more females
(71%) used a Bluetooth device than males.

T-test for association between gender and years and hours of use of electronic/communication
devices among the IT professionals, it was found that per year usage of cell phones in females is
significant (p<0.01) than males whereas per hour use is significant (p<0.01) in males than females. More males (p<0.05) use cordless phones per hour than females. As for the use of wireless computer network per year, more females (p<0.01) use it than males. Wireless computer network use per year and per hour is more in females (p<0.01) than in males. There is a positive relationship between cell phone use per year and number of hours of work per day at 43% and number of hours of sleep per day at 33%, significant at 1% (p<0.01); positive relationship between cell phone use per hour and sleep per day at 31%, significant at 1% (p<0.01). For cordless phone, it was a 53% positive relationship between use per year and number of hours at work per day, significant at 1% level (p<0.01). For wired computer network use, 60% positive relationship between use per year and number of hours of work per day and sleep per day at 49%, significant at 1% level (p<0.01). There was a positive relationship between wired computer network use per hour and number of hours of sleep per day at 29%, significant at 1% level (p<0.01). A similar positive relationship was seen between wireless computer network use per year and number of hours of sleep per day at 20%, significant at 5% level (p<0.05). There was a positive relationship between microwave oven use per year and number of hours of work per day at 76%, significant at 1% level.

From the epidemiology survey II, in the survey of people living around the cell phone
towers in urban and rural locality, it was found that more males (67.6%) lived around the cell phone
tower in the rural area (p<0.01) than the urban area, whereas more females (69.5%) lived around
the cell phone tower in the urban area (p<0.01) than the rural area. More single individuals (75%)
in the urban area lived around the cell phone tower (p<0.01) than in the rural area and more married
people (79.3%) in the rural area lived around the cell phone tower (p<0.01) than in the urban area.
The most people found around the cell phone tower in the urban area were in the age group of
below 25 years (89.6%), whereas in the rural, it is between 35-45 years (85%). Most people found
around the cell phone tower are students in the urban area (72%) and in the rural area, people who
are village officers, tailors, shopkeepers, photographers, teachers, carpenters, mechanic, housewives, postman, and building workers (39%) are found living around the cell phone tower followed by businessmen (36%).

People living around cell phone towers in the rural area are found to be significantly (p<0.01) higher in mean weight (64.85%) than the ones in the urban area. Most people who live around the cell phone tower in the urban area (p<0.05) were found to be non-smokers (52.8%), whereas most people who live around the cell phone tower in the rural area were significantly found to be smokers (72.7%). In the rural area, 75% of the people who live around the cell phone towers are found to be alcoholics whereas in the urban area 54.1% of the people who live around the cell phone tower were were found to be non-alcoholics (p<0.01). More vegetarians (81.5%) are found living around the cell phone tower in the urban area than in the rural area, whereas more non-vegetarians (54.9%) are found living around the cell phone tower in the rural area than in the urban area (p<0.01).

Most people in the urban area (49%) live around 6 cell phone towers or more, whereas in the rural area, most number of people (66%) live around less than 3 cell phone towers (p<0.01). Most people in the urban area lived within 100-300 m of the cell phone tower (35%), whereas 70% of the rural people lived within 50-100 m of the cell phone tower (p<0.01). Also of note, more people in the urban area lived within 10 m and 10-50 m of the cell phone tower than in rural area. Most of the urban people lived beside (35%) and facing (31%) the antenna (p<0.01). Most of the rural people lived beside (46%) and beneath (41%) the antenna (p<0.01). Most of the urban people lived near the cell phone tower for more than 5 years (64.3%), whereas the rural people lived between 1-5 years (60.3%). Among the people surveyed, 100% of the urban people used computer (>2 hrs/day) whereas none used in rural locality (p<0.01). 93.1% of the urban people who live around the cell phone tower used the cell phone for more than 20 minutes per day when compared to the rural people at 6.9% (p<0.01).

Most people in the urban area frequently had fatigue (69.2%), loss of appetite (54.5%), hearing disruption (52.9) and joint pain/problems (56.3%); symptoms frequent in the rural area were difficulty sleeping (64.5%), depression (71%), feelings of discomfort (62.5%) and dizziness (54.4%); all significant at 1% (p<0.01). Most frequent symptoms significant at 5% level in the urban area were irritability (59.3%), difficulty in concentration (66.7%), and memory loss short-
term (52%), and in the rural area, it was cardiovascular problems (75%) and loss of libido (3%). Visual disruption was present in both urban (50%) and rural (50%) areas, significant at 5% level (p<0.05).

Among medical conditions, heart ailment (palpitations, arrhythmias, chest pain or pressure, shortness or breath) at 100%, asthma, allergies, sinusitis, bronchitis, and pneumonia at 93.1%, stomach pain, ulcer, and gastro-esophageal reflux disease (GERD) at 97.7%, swollen lymph nodes, enlarged thyroid, testicular/ovarian pain at 90.9%, and eye pain or burning in the eyes, pressure in/behind the eyes, deteriorating vision, floaters, and cataracts at 87.5% are frequently found in the urban people living around the cell phone tower, significant at 1% level (p<0.01), when compared to the rural people. Symptom significant at 5% level (p<0.05) is high blood pressure, which is seen mostly in rural people (76.2%). There is association between overall medical conditions and locality of people around the cell phone tower, significant at 1% level (p<0.01). Most medical conditions are found in urban people living around the cell phone towers (89.5%) and the least are found among the rural people (69.4%).

Discriminant analysis is used to distinguish between rural and urban localities around cell phone towers based on 18 non-specific symptoms. Among symptoms significant at 1% level (p<0.01), feelings of discomfort is the most, followed by depression, difficulty sleeping, loss of appetite, joint pain problem, and hearing disruption. Dizziness, loss of libido, and visual disruption are found to be significant at 5% level (p<0.05). Of the cases used to create the Discriminant Analysis Classification model, 79% of the urban locality and 80% of the rural locality were classified correctly. Overall, 79.5% of the cases were classified correctly based on their locality.

There is a significant (p<0.01) association between number of years living near the cell phone tower with respect to the overall medical conditions in the urban locality surveyed. At least one medical condition is found to occur between 1-5 years of living near the cell phone tower, followed by three to five medical conditions above 5 years of living near the cell phone tower. Most low EMF-emitters found near the cell phone tower are electrical transformers (53.3%) and very high tension power lines (26.7%). Most people in the urban area lived around the cell phone tower with the antenna of the cell phone tower facing very high tension power lines (54.8%), while most electrical transformers were found beside the antenna (35.5%). Most people (35.4%) in the urban area lived between 1-5 years near the cell phone tower in the presence of electrical transformers and very high tension power lines.
There is a significant difference between numbers of years of living near the cell phone tower with respect to overall severity of non-specific symptoms in the rural locality surveyed at 1% level (p<0.01). Based on Duncan Multiple Range Test (DMRT), there is a significant difference between below 1 year with between 1-5 years and above 5 years, but there is no significant difference between 1-5 years and above 5 years of living near the cell phone tower and overall severity of non-specific symptoms in the rural locality. There is an association between number of years living near the cell phone tower and the presence of transformers, power lines and transmitters with respect to the rural locality surveyed at 1% level (p<0.01); 43.8% of the rural people lived between 1-5 years near the cell phone tower in the presence of electrical transformers and 45% above 5 years in the presence of very high tension power lines.

Experimental studies on short-term exposure to cell phone towers gave evidence that GSM signals reduced the wellbeing of people who were sensitive to this exposure. According to Kundi and Hutter (2009), two ecological studies of cancer in the vicinity of cell phone towers reported, both with a strong increase of incidence within a radius of 350 and 400 m respectively. It was suggested that power densities of around 0.5 to 1 mW/sq.m must be exceeded in order to observe an effect. Radiofrequency Radiation Sickness Syndrome is a systemic human response to chronic low-intensity RF exposure, identified in the 1950s by Soviet medical researchers who named it neurotic syndrome (Liakouris, 1998). The clinical manifestations accepted by Russian medicine include elevated lymphocyte counts, protozoan intestinal diseases, dermographism (psoriasis, eczema, inflammatory and allergic skin problems), neurological diseases of the peripheral nerves and ganglia among males, reproductive problems during pregnancy, childbirth, tumours (benign among men, malignant among women), hematological changes, mood alterations (irritability, depression, loss of appetite), functional deficits (concentration difficulties) and refractive eye problem.

According to Sage (2000), within the first 100 to 300 feet, power density levels were found to be 0.1 to 30 mW/sq.m. Elevated RF-EMF power density levels from a major wireless antenna site can often be detected at 1000 feet or more. Power density levels away from wireless antenna sites measure between 0.01 mW/sq.m to 0.00001 mW/sq.m. Cell phone towers incorporated into stealth designs, such as church steeples, water tanks, trees and flag poles called as stealth installations produced elevated RF-EMF levels in nearby areas where people lived and worked and children went to school, all of them being unaware of it.
According to Schreier N. *et al.* (2006), a survey carried out in 2004 confirmed the presence of electrohypersensitivity in Switzerland. According to Blettner M. *et al.* (2008), people living near cell phone towers had clear indications of adverse health effects, such as sleep problems, headaches, nervousness, fatigue, difficulty concentrating, hair loss and depression. Two-thirds of the respondents had taken measures to reduce their symptoms by avoiding exposure and only 13% had consulted their physicians (Roosli M. *et al.*, 2004). According to Pall, (2007), electrohypersensitivity syndrome should be counted among multi-system disorders such as Chronic Fatigue Syndrome (CFS), Multiple Chemical Sensitivity (MCS), fibromyalgia and Post Traumatic Stress Disorder (PTSD). As early as 1977, Brodeur in his book “Zapping of America” referred to an incident where a microwave technician working for a corporation, complaining of blurred vision, was diagnosed by his medical director to have bilateral cataracts and acute inflammation of the retina after investigations revealed that the technician routinely exposed his head to the antenna radiations when checking to see if it was generating properly. The power level was estimated to be as high as 10,00,000 mW/sq.m. It was concluded that utmost precaution must be taken while working with RF-EMF radiation at close quarters.

Carcinogenic potential of cell phone radiation is one of the most conflicting aspect in various studies conducted by several groups. Following public concern that cell phone exposure may lead to cancer, Hardell L. *et al.* (2007) conducted an epidemiological questionnaire-based study and concluded that astrocytoma (grade III–IV) and acoustic neuroma did show a positive correlation with cell phone usage, and the odds ratio increased with latency (10 years). The results of the INTERPHONE, an international case-control study to assess the brain tumor risk in relation to mobile telephone use, revealed 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 (Cardis E. *et al.* 2011a, 2011b, 2011c). Children and young adults were excluded from the study and a separate study called Mobi-Kids is underway.

According to Santini R. *et al.*, (2002), comparisons of complaints in relation with distance from cell phone towers show a significant increase as compared to people living greater than 300 m or not exposed to base station, till 300 m for tiredness, 200 m for headache, sleep disturbance, and discomfort, and 100 m for irritability, depression, loss of memory, dizziness and libido decrease.
was significant in women more than men, with complaints of headache, nausea, loss of appetite, sleep disturbance, depression, discomfort and visual perturbations. According to Oberfeld G. 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 were more at risk as they tend to spend more time at home and were exposed to radiation continuously. The authors recommended a maximum exposure of 0.001 mW/sq.m. There was prevalence of neuropsychiatric complaints among people living near cell phone towers (Abdel-Rassoul G. et al., 2007).

Urban electromagnetic contamination, known as electrosmog, from 900 and 1800 MHz pulsed waves interfered in the nervous system of living beings (Hyland GJ, 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 B, 2010). Studies carried out on the RF levels in North India, particularly at the mobile tower sites in Delhi have shown that people in Indian cities were exposed to dangerously high levels of EMF pollution (Tanwar VS, 2006). In an independent case study in Mumbai, it was found that people living within 50 to 300 m radius were in the high radiation zone and were 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 G, 2010). According Fragopoulou, (2010), the Seletun Scientific Statement was drawn to highlight the low-intensity (non-thermal) bioeffects and adverse health effects, demonstrated at levels significantly below existing exposure standards. Public safety limits set by WHO/ICNIRP along with the Institute of Electrical and Electronics Engineers (IEEE) and Federal Communications Commission (FCC), are inadequate and obsolete with respect to prolonged, low-intensity exposures. New, biologically-based public exposure standards were urgently needed to protect public health worldwide. EMR exposures should be reduced now rather than waiting for proof of harm before acting.

Research reports headaches, concentration difficulties and behavioral problems in children and adolescents, and sleep disturbances, headaches and concentration problems in adults. Mobile phone use after lights out may be associated with poor mental health, suicidal feelings, and self-injury in both early and late adolescents (Oshima N. et al., 2012). Extensive research by Cherry N,
(2001), states that there is strong evidence that microwaves are associated with accelerated aging from enhanced cell death, headaches from microwave-induced leakage of harmful molecules through the blood-brain barrier, mood alteration, depression, suicide, anger, rage and violence, primarily through cellular calcium ion alteration and the melatonin/serotonin imbalance. The exposure to continuous RF-EMF radiation posed 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.

In 2008, the Austrian Department of Health found a higher risk of cancer among people living within 200 m of a cell phone tower and that cancer risk rose with increasing exposure, reaching 8.5 times the norm for people most exposed. Sandstrom M. et al. (2001), in a questionnaire-based study involving some 17,000 respondents, showed that cell phone usage led to complaints such as warmth on and behind the ear (31%), fatigue (28%), headache (21.4%), decreased concentration (15%), dizziness (10%), memory loss (9%), and tingling and numbness (6.7%). They also concluded that a statistically significant positive trend was shown by warmth and neurasthenic symptoms (headache, fatigue) with calling time and number of calls per day. They proposed that these changes were due to either radiofrequency exposure or thermal effects of electromagnetic radiation. Of all the people who attributed these symptoms to cell phone usage, 45% of them took steps such as using a reducing kit or a landline phone to reduce cell phone exposure (Oftedal G. et al., 2007).

In a cross-sectional study of randomly selected inhabitants living in urban and rural areas for more than one year at the vicinity of 10 selected cell phone towers, 365 subjects were investigated by Hutter HP. et al., (2006). Parameters assessed were cognition, wellbeing and sleep quality. Field strengths were measured in the bedrooms of 336 households. The results showed a maximum power density of 4.1 mW/sq.m. Distance from antennae was 24 to 600 m in the rural area and 20 to 250 m in the urban area. Average power density was slightly higher in the rural area (0.05 mW/sq.m) than in the urban area (0.02 mW/sq.m). There was a significant relation of some symptoms to measured power density, among which the highest was for headaches. There was an increase in perceptual speed, while accuracy decreased insignificantly with increasing exposure levels. Sleep quality remained unaffected. It was concluded from this study that despite very low exposures, the effects on wellbeing and performance could not be ruled out and the mechanism of action remained unknown. All studies support that in all examined positions, RF-EMF radiation
exposure at locations accessible to public were many times below the exposure limits of guidelines, but well above the biological limit. Due to the proliferation of cell phone towers, the contribution of RF-EMF radiation exposure due to GSM technology is increasing, with rising ambient electrosmog.

6.3  **IN VIVO PURSUIT USING ANIMAL MODEL (GUINEA PIG)**

Global studies on the bioeffects of RF-EMF radiation on guinea pigs are rare and this is the first investigation to date that deals with the bioeffects from cell phone tower exposure on guinea pigs in India.

6.3.1  **RF-RMF EXPOSURE SOURCE AND DESIGN OF ANIMAL CAGES**

The Duncan-Hartley strain of guinea pigs were maintained for a period of six months at two distances from the cell phone tower (RF-EMF source) in Cage C1 at 5 m and Cage C2 at 100 m. The third cage was the sham-exposure Cage C, which contained the control group used to simulate the environmental conditions of RF-EMF-exposed animals, but in absence of RF-EMF exposure. At the end of the six month period, the animals were 253 days old (8.3 months). The difference in weight was significant at 5% level for the guinea pigs in Cage C2 at 100 m exposure distance. The mean weight of female guinea pigs was more than male guinea pigs. The six-month average day and night temperature (26 ± 3.6°C) and relative humidity (69± 13%) were noted at Cage C, Cage C1 and Cage C2. The six-month average RF-EMF radiation (Power Density in mW/sq.m) readings at Cage C was 0 mW/sq.m, Cage C1 was 0.533 mW/sq.m and Cage C2 was 0.880 mW/sq.m.

6.3.2  **BIOCHEMICAL PARAMETERS**

The biochemical parameters included blood cell count, antioxidant assay and lipid peroxidation.

6.3.2.1  **BLOOD CELL COUNT**

The blood parameters haemoglobin (Hb), packed cell volume (PCV), red blood cells (RBC), white blood cells (WBC), Neutrophils, Lymphocytes, Monocytes and Eosinophils were investigated.
After two months of RF-EMF exposure, in male guinea pigs, there was a significant difference (p<0.05) in haemoglobin content and white blood cell count. The mean haemoglobin content in Cage C1 was the lowest and Cage C2 was the highest when compared to Cage C. As for female guinea pigs, there was a significant difference (p<0.05) only in haemoglobin content. The mean haemoglobin content in Cage C1 was the highest and C2 cage was the lowest when compared to Cage C.

After two months, in Cage C, there was no significant difference in blood parameters of male and female guinea pigs. In Cage C1, there was a significant difference (p<0.05) in haemoglobin content and packed cell volume in guinea pigs, with males having the lowest mean and females highest mean. In Cage C2, there was a significant difference (p<0.05) in haemoglobin content, red blood cell count and white blood cell count of guinea pigs, with the females having the lowest mean.

After four months of RF-EMF exposure, in male guinea pigs, there was a significant difference (p<0.01) in haemoglobin content, packed cell volume, red blood cell count and white blood cell count and neutrophils (p<0.05), with the mean in Cage C1 being the lowest for all and highest for neutrophils. Packed cell volume, red blood cell count and white blood cell count were significantly different in C1 when compared to both C and C2, while there was no difference between C and C2 for the same. As for female guinea pigs, there was a significant difference in the white blood cell count (p<0.01), haemoglobin content (p<0.05), packed cell volume, (p<0.05) and red blood cell count (p<0.05), with the mean being the lowest in Cage C2.

After four months, in Cage C, there was no significant difference in blood parameters of male and female guinea pigs. In Cage C1, there was a significant difference in haemoglobin content (p<0.01), packed cell volume (p<0.01), red blood cell count (p<0.05) and white blood cell count (p<0.05) of guinea pigs, with the highest mean in females. In Cage C2, there was a significant difference in haemoglobin content (p<0.01), red blood cell count (p<0.01) and white blood cell count (p<0.01), with the mean being the lowest in females.

After six months of RF-EMF exposure, in male guinea pigs, there was a significant difference in packed cell volume (p<0.01), haemoglobin (p<0.05), white blood cell count (p<0.05), neutrophils (p<0.05) and lymphocytes (p<0.05), with the mean in C1 being the lowest for all and highest for neutrophils. As for female guinea pigs, there was a significant difference in the white
blood cell count (p<0.01) and haemoglobin content (p<0.05), with the mean being the lowest in Cage C2.

After six months, in Cage C, there was no significant difference in blood parameters of male and female guinea pigs. In Cage C1, there was a significant difference in haemoglobin content (p<0.01) and packed cell volume (p<0.01) of guinea pigs, with the highest mean in females. In Cage C2, there was a significant difference in haemoglobin content (p<0.01), packed cell volume (p<0.01), red blood cell count (p<0.01) and white blood cell count (p<0.01), with the mean being the lowest in females.

In an experimental research by Adang D. et al., (2009), to assess the possible biological effects of electromagnetic radiation, four-month-old Wistar albino rats were exposed to low-level microwaves for 21 months to two different microwave frequencies and exposure modes, 2 hours a day for seven days a week. Statistically significant difference (20%) in monocytes were found between the exposed (970 MHz continuous wave group) and sham-exposed group after three and eight months. There was a significant increase in white blood cells (15%) and neutrophils (25%) after 14 and 18 months of exposure. After 18 months of exposure, there was decrease of lymphocytes (15%).

In a study by Shahin S. et al., (2013), female mice were exposed to 2.45 GHz low-level microwaves, to investigate irradiation-induced stress response and it was observed that the irradiated mice were affected compared to control. There was a significant increase in haemoglobin (p<0.001), RBC and WBC counts (p<0.001) and Neutrophil/Lymphocyte ratio (p<0.01). There was a significant increase in ROS, DNA damage (p<0.001) in brain cells, and plasma estradiol concentration (p<0.05). A significant decrease in NO level (p<0.05) and antioxidant enzyme activities of MW-exposed mice was observed. It was concluded that there was increased oxidative stress due to microwave exposure leading to increased DNA strand breakage in the brain cells in mice.

Otitoloju AA. et al., (2012), investigated the haematological effects of radiofrequency (RF) radiation from Global Systems for Mobile Communication (GSM) base stations on four successive generations of albino mice, Mus musculus, and found a pattern of pancytosis and significant increase in packed cell volume (PCV), white blood cell (WBC) count, red blood cell (RBC) count. Such increase in the haemopoetic process caused significant effects on bone marrow stem cell
proliferation and differentiation. In a study by Grefner NM. et al., (1998), on frog tadpoles (*Rana temporaria L.*) to investigate the effects of electromagnetic field (EMF) exposure, it was found that over the period of exposure, the tadpoles developed allergies and EMF caused changes in their blood counts. Balode (1996) demonstrated altered blood cells from cows from a farm close and in front of radar showing significantly higher level of severe genetic damage. The effects of chronic exposure to RF-EMF on blood parameters was found to be sufficient to apply the precautionary principle to discourage the indiscriminate installation of GSM cell phone towers in areas where prolonged exposure to RF-EMF radiations were likely to occur.

6.3.2.2 ANTIOXIDANT ASSAYS AND LIPID PEROXIDATION

In this study, there was a significant difference ($p>0.01$) between antioxidant enzyme, Catalase (CAT) and non-enzymatic antioxidant, Glutathione (GSH) in blood samples of guinea pigs exposed to RF-EMF radiation. As for antioxidant enzyme, Superoxide Dismutase (SOD), there was no significant difference. CAT and GSH in blood samples of guinea pigs were elevated in Cage C1 and C2 when compared to sham-exposure Cage C. The mean levels of CAT and GSH in blood samples were the highest in Cage C2. There was a significant difference ($p>0.01$) between antioxidant enzymes, Catalase (CAT) and Superoxide Dismutase (SOD), and non-enzymatic antioxidant, Glutathione (GSH) in brain samples of guinea pigs and the RF-EMF radiation exposure sites in Cage C2 and sham-exposure Cage C. The levels of CAT, SOD, and GSH were higher in Cage C2 when compared to sham-exposure Cage C.

According to IARC (2002), oxidative stress caused by biological, chemical and physical factors have been associated with increased risk of cancer. Cells activate several oxidant-generating enzymes that produce high concentrations of diverse free radicals and oxidants. These reactive species can damage DNA, RNA, lipids and proteins, leading to increased mutations and altered function of enzymes and protein, which contributes to the multistage carcinogenesis process. Metabolic processes that generate oxidants and antioxidants can be influenced by increased RF-EMF exposure, which can modify the activity of the organism by reactive oxygen species (ROS) leading to oxidative stress. The biological system has the ability to readily neutralize the ROS molecular components and repair the resulting damage. Their levels are kept low by the antioxidant enzyme systems; if not, they begin to attack lipids, nucleic acids and proteins, resulting in various degrees of oxidative damage.
The process by which reactive oxygen species (ROS) cause oxidation in lipids is referred to as lipid peroxidation. Polyunsaturated fatty acids in the cell membrane are particularly susceptible to it, resulting in structural and functional changes to its membrane (Esterbauer H. et al., 1992). In this study, there was a significant difference (p>0.01) between biomarker of lipid peroxidation, Malondialdehyde (MDA) in blood samples of guinea pigs and the RF-EMF radiation exposure sites. MDA in blood samples of guinea pigs was elevated in Cage C1 and C2 when compared to sham-exposure Cage C. The mean level of MDA in blood samples was the highest in Cage C2. There was a significant difference (p>0.01) between MDA in brain samples of guinea pigs and the RF-EMF radiation exposure sites in Cage C2 and sham-exposure Cage C. The level of MDA was higher in Cage C2 when compared to sham-exposure Cage C.

Achudume AC et al., (2009), assessed the potential health risk of electromagnetic field from GSM base stations, with a peak power of 2 Watts, and linked the biological effects to biochemical activity. Male Wistar rats were placed at the vicinity (<10 m) of cell phone tower and the control animals were placed in another location (>300 m). The exposure were of three types namely, continuous waves modulated at 900MHz, modulated GSM-nonDTX and the 1800 MHz, specific absorption radiation (SAR) was 0.95-2W/kg for 40 and/or 60 days continuously. At 40 days, the results were insignificant. At 60 days, a decreased activity of Glutathione Reductase (GR), MDA as a biomarker of lipid peroxidation, and total cholesterol was demonstrated in rat brain tissues. It was concluded that two months of exposure would bring about lesser bioeffects and that there would be greater health risks for longer periods of constant exposure, such as from living near a cell phone tower.

A study was designed to demonstrate the effects of 900-MHz electromagnetic field (EMF) emitted from cellular phone (12 hours a day for 30 days, SAR 0.95 w/kg) on brain tissue and also blood malondialdehyde (MDA), glutathione (GSH), retinol (vitamin A), vitamin D(3) and tocopherol (vitamin E) levels, and catalase (CAT) enzyme activity of guinea pigs. It was found that in the brain tissues of EMF-exposed guinea pigs, MDA level increased (p<0.05), GSH level and CAT enzyme activity decreased (p<0.05), and vitamins A, E and D(3) levels did not change (p>0.05). In the blood of EMF-exposed guinea pigs, MDA, vitamins A, D(3) and E levels, and CAT enzyme activity increased (p<0.05), and GSH level decreased (p<0.05). It was concluded that
RF-EMF radiation might produce oxidative stress in brain tissue of guinea pigs (Meral I. et al., 2007).

In an Indian study by Kesari KK. et al., (2011), on the effects of free radical formation due to RF electromagnetic wave exposure from cellular phones, male Wistar rats were exposed and sham-exposed for 2 hours a day for 35 days, the specific absorption rate (SAR) being 0.9 W/kg. There was a decrease in antioxidant enzymes, glutathione peroxidase ($p<0.001$) and superoxide dismutase ($p<0.007$) and an increase in catalase ($p<0.005$). Malondialdehyde ($p<0.003$) showed an increase. Free radical generation was significantly increased due to an overproduction of reactive oxygen species (ROS). It was concluded that their results were a clear indication of effects of RF-EMF radiation. In another study by the same team, to investigate the effects of RF-EMF radiation from mobile phones on rat brain, Wistar rats were exposed for 45 days for 2 hours a day at SAR of 0.9 W/kg. A significant decrease ($p<0.05$) in the level of glutathione peroxidase, superoxide dismutase, and an increase in catalase activity was observed in the brain samples. A significant increase in ROS (reactive oxygen species) ($p<0.05$) was also recorded. The team concluded that any imbalance, whether increase or decrease in antioxidative enzyme activities was related to an overproduction of reactive oxygen species (ROS) in animals due to RF-EMF radiation exposure and that these are prominent biomarkers, which are clear indicators of possible health implications. Hence, microwave exposure can be affective at genetic level, indicating tumor promotion through the overproduction of ROS.

In a study abroad to analyse oxidative stress from RF-EMF exposure from a GSM cell phone tower by Yurekli A et al., (2006), male Wistar albino rats were exposed to whole-body GSM945 MHz signal at a power density of 3670 mW/sq.m (below the current exposure limit of the country where study was carried out), 7 hours a day for 8 days or sham-exposed in a gigahertz transverse electromagnetic (GTEM) cell, which simulated a far-field base station exposure. Malondialdehyde (MDA) level was found to increase, reduced glutathione (GSH) concentration was found to decrease significantly ($p<0.0001$) and there was a less significant increase in superoxide dismutase (SOD) activity under RF-EMF exposure. Similarly, when earthworms, (*Eisenia fetida*) were exposed to RF-EMF radiation (900 MHz) at certain exposure conditions, increased levels of MDA and protein carbonyls were observed and demonstrated oxidative damage of lipids and proteins (Tkalec M. et al., 2013). Another study by Oktem F. et al., (2005), demonstrated the potential of 900 MHz RF-EMF to causes an increase in MDA and a decrease in
antioxidant biomarkers such as superoxide dismutase (SOD), catalase (CAT), and glutathione peroxidase (GSH-Px) in rats. When melatonin was administered, these effects were prevented due to its capacity to neutralise free radicals by changing electric charges (Frentzel-Beyme, 2002).

Jelodar G. et al., (2013), investigated the prophylactic effect of vitamin C on oxidative stress indexes in rat eyes following exposure to radiofrequency wave generated by a cell phone tower antenna model. The results demonstrated a decreased antioxidant enzyme activity and increased MDA compared with the control groups (p<0.05). When vitamin C was administered, it improved antioxidant enzyme activity and reduced MDA compared to the test group (p<0.05). It was concluded that RF-EMF radiation caused oxidative stress in the eyes of rats and that vitamin C improved the antioxidant enzymes activity and decreases MDA. Enhanced activity of CAT and Glutathione Reductase indicated the induction of antioxidant stress response upon exposure to RF-EMF. However, different behaviour of the two antioxidative enzymes was observed. Whereas CAT activity was enhanced only at certain exposure conditions, GR activity was increased at all investigated treatments, presumably to maintain the cellular redox balance. It has been shown that activities of CAT in RF-EMF exposed animals can vary substantially between different systems, from no difference (Dasdag S. et al., 2008), to increased (Koyu A. et al., 2009) or decreased CAT activities (Guney M. et al., 2007).

The involvement of glutathione antioxidant system and the depletion of glutathione have also been previously reported in rats exposed to RF-EMF (Mailankot M. et al., 2009), and up-regulated Glutathione Reductase activity has been observed upon 900 MHz EMF exposures in some plants (Sharma VP. et al., 2009). In an animal study, Ozguner F. et al., (2005), reported increase in oxidative stress in rat myocardium on exposure to 900 MHz RF-EMW (30 min/day, for 10 days). Irmak MK et al., (2002) analyzed MDA, SOD, CAT, and GSH-Px levels among others in both brain and sera of RF-EMF exposed rabbits (900MHz GSM signal, 2 W peak power, average power density 200 mW/sq.m, for 30 minutes per day). An elevated activity of only SOD was observed in the sera of exposed animals, but no change was noted in any brain parameters of rabbits.

Hassan NS. et al., (2010) conducted a study to investigate the oxidative stress and erythrocyte hemolysis induced by exposure to RF-EMF radiation (2450 MHz continuous wave) and to evaluate the possible protective role of grape seed extract in rats. Malondialdehyde was significantly elevated, antioxidative enzymes significantly decreased, and the erythrocyte hemolysis
rate was increased in the exposed group when compared to the control group. On oral administration of grape seed extract (GSE), a marked amelioration of LPO, antioxidative enzymes, and normalised rate of hemolysis were noted. It was concluded that GSE had a potent antioxidant effect against RF-EMF-induced oxidative changes in the blood tissue by strengthening the antioxidant defense system. Waste products such as hydroxyl radicals, generated during lipid peroxidation can cause damage to DNA (Hruszkewycz, 1992). Increased ROS can lead to DNA damage as well. Severe lipid peroxidation leads to the loss of mitochondrial transmembrane potential (Quillet MA. *et al.*, 1997). In addition, if apoptogenic factors such as cytochrome c and AIF are released (Liu X. *et al.*, 1996), it leads to the opening of permeability transition pores (PTP) of other mitochondria, which lead to more ROS and apoptogenic factors being released. AIFs induce DNA fragmentation in the cell nucleus (Susin SA. *et al.*, 1999). This shows how lipid peroxidation and the resulting release of ROS as well as AIFs can cause DNA damage.

In a study by Abu KM. *et al.*, (2014), to evaluate the biochemical status in the saliva of 12 males before/after using mobile phones, RF-EMF radiation frequency signals of 1800 MHz (continuous wave transmission, 217 Hz modulate and Global System for Mobile Communications), specific absorption rate (SAR) of 1.09 W/kg for 15 and 30 minutes. A significant increase of superoxide dismutase (SOD) after 15 minutes was noted and as talking time increased, the SOD activity started to drop. In contrast to this, there was no statistically significant effect of talking time on the level of salivary albumin, cytochrome c, catalase or uric acid. The results suggested that exposure to RF-EMF radiation exerted an oxidative stress on human cells as evidenced by the increase in the concentration of the superoxide radical anion released in the saliva of cell phone users.

### 6.3.3 MOLECULAR PROFILING

There is a disagreement among the scientific community that RF-EMF radiation from cell phone towers and cell phones, belonging to the non-ionising band in the electromagnetic spectrum, does have sufficient energy to break chemical bonds and cause damage to the DNA, unlike ultraviolet radiation or X-rays. According to Hyland HJ (2003), although RF-EMF radiation in publicly accessible locations near cell phone towers, fall well within the current safety guidelines set by the International Commission for Non-Ionising Radiation Protection (ICNIRP), these limits are based only on thermal effects of RF-EMF radiation, to ensure that the amount of tissue heating
caused by absorption of this radiation in the body is not in excess of what the body’s thermoregulatory mechanism can cope with. If heating intensities were the only criteria of the radiation, then the existing guidelines are sufficient to protect the public against this emission. Unfortunately, RF-EMF radiation has properties other than intensity alone to deal with. The pulsed microwave radiation used in the GSM telecommunication, for instance, is coherent, meaning that it is characterised by well-defined frequencies, which range from very high to very low, which have the capability to interfere with the biochemical mechanism of the body, as opposed to the incoherent heat radiation that is emitted by the body, depending on its physiological temperature.

Various studies have demonstrated that low-level, non-thermal, RF-EMF exposures from can result in genotoxic effects in the form of increased single- and double-strand DNA breaks (Aitken RJ. et al. 2005; Diem E. et al., 2005; Lai and Singh 2005; Schwarz C. et al., 2008) and chromosome aberrations (Fucic A. et al., 1992; Trosic et al., 2002; Busljeta I. et al., 2004). It is now well known that if the rate of DNA damage exceeds the rate of repair, imbalance of antioxidants or impaired genetic regulation process or protein expression can lead to diverse pathological ramifications, including carcinogenesis, which can be initiated and promoted by DNA damage mediated by reactive oxygen species (ROS) (Totter JR, 1980; Janssen Y. et al., 1993; Halliwel B, 1998; Takabe W. et al., 2001).

6.3.3.1 DNA FRAGMENTATION

The RF-EMF radiations from cell phone towers although non-ionizing, do have the ability to interfere with the mechanisms involved in the natural repair of DNA breakage and DNA replication. They have the capability to subtly alter molecular architecture through chromosomal aberrations (Vijayalaxmi, 1997, 2000), micronuclei formation (Tice RR. et al., 2002), and DNA fragmentation (Lai and Singh, 1996).

In this study, DNA fragmentation was noted in blood samples of guinea pigs after six months of RF-EMF exposure from Cage C1 and C2 and from brain samples from Cage C2, when compared to the sham-exposed Cage C. Hence, in the animals at distance of 5 meters (Cage C1) from the cell phone tower, positioned beneath the antennae, under constant, whole-body RF-EMF exposure, with a mean power density of 0.5 mW/sq.m, average day and night temperature of 26°C and relative humidity 69% for 6 months demonstrated DNA fragmentation in blood samples. Under similar exposure conditions, animals at a distance of 100 meters (Cage C2) from the cell phone tower, positioned on the pathway of propagation of the main beam of the cell tower antenna,
with a mean power density of 0.880 mW/sq.m demonstrated DNA fragmentation in brain samples, as well.

To date, there are more than 100 scientific publications from early 1990s on genotoxicity of RF-EMF radiation from mobile phone frequencies out of which nearly a half show genotoxic effects and less than half shows no effects (Stewart Report, 2000). In a study by Garaj-Vrhovac V. et al., (1991), one hour exposure to 7.7 GHz RF-EMF radiation at 1000 mW/sq.m caused higher incidence of chromosome aberrations in Chinese Hamster fibroblasts. Maes A. et al., (1993), reported that on acute exposure to 2450 MHz RF-EMF radiation under constant temperature, dicentric chromosome and acentric chromosomal fragments were observed in human lymphocytes. An increase in the number of single- and double-strand DNA breaks was reported in the brain cells of rats exposed for two hours to continuous-wave 2.45 GHz RF-EMF radiation at power density of 2000 mW/sq.m and that free-radical scavenger, melatonin, blocked this effect when administered before and after the RF-EMF exposure (Lai and Singh, 1997).

In a study by Rotkovska D. et al., (1993), DNA synthesis in cells from irradiated corneas reduced by 25%, but not statically significantly, when mice were exposed to 35 GHz (Police radar) for 17 hours/day for 5 days/week for 2 weeks at a power density of 200 mW/sq.m. Sarkar S. et al., (1994), observed increased DNA rearrangement in samples from testes and brain of Swiss albino mice exposed to 2450 MHz RF-EMF radiation for 2 hours/day for 120, 150 and 200 days (6+ months) at a power density of 10,000 mW/sq.m. In an in vitro study by Campisi A. et al., (2010), on rat primary cortical astrocytes, exposed to RF-EMF radiation at 900 MHz continuous wave or amplitude-modulated at power flux density of 26 mW/sq.m for 5, 10, and 20 minutes, revealed increased ROS levels and DNA fragmentation after a 20-minute exposure to amplitude-modulated RF-EMF radiation. No effects were noted with continuous wave radiation and there was no temperature control for this experiment.

In a series of studies by Panagopoulos DJ. et al., (2002, 2007, 2010, and 2012) adverse effects were reported on the reproduction of Drosophila melanogaster after exposure to RF-EMF radiation at non-thermal frequencies (900 or 1800 MHz) at a power flux density of 37 mW/sq.m. Commercially available cell phones were used as exposure devices in these experiments. The exposures, of duration from 1 to 20 minutes per day for six days, starting with the day of eclosion with the temperatures monitored, were carried out with the antenna of the instrument in contact outside the glass vials containing the fruit flies. The results indicated a decrease in reproduction
due RF-EMF-induced DNA fragmentation. It was concluded that RF-EMF radiation, especially GSM mobile phone exposure at 900 MHz, is highly bioactive and could cause significant alterations in the physiological function of living organisms.

De Iuliis GN. et al., (2009), studied purified human spermatozoa exposed to RF-EMF radiation at 1800 MHz at a SAR of 0.4–27.5 W/kg for 16 hours at 21 °C. With increasing SAR values, motility and vitality of the sperm cells were significantly reduced, while mitochondrial production of reactive oxygen species was significantly increased (p<0.001). There was also a significant increase (p<0.05) in formation of 8-OHdG adducts (measured immunochemically) and DNA fragmentation at SARs of 2.8 W/kg and higher. The temperature during these experiments was kept at 21 °C and the highest observed exposure-induced temperature increase was +0.4 °C at a SAR of 27.5 W/kg. It was concluded that RF-EMR in both the power density and frequency range of mobile phones enhanced the generation of mitochondrial reactive oxygen species, leading to decreased vitality and motility of human spermatozoa, while stimulating DNA base adduct formation leading to DNA fragmentation. These findings have clear implications for the safety of extensive mobile phone use by males of reproductive age, potentially affecting both their fertility and the health and wellbeing of their offsprings.

A study by Buttiglione M. et al., (2007), showed a statistically significant increase in apoptosis after 30 hours of exposure to GSM900 at SAR of 1 W/kg for 24 hours. Franzellitti S. et al., (2010) showed increased DNA strand breaks in trophoblasts after exposure to a 217-Hz modulated 1.8 GHz RF-EMF. Luukkonen J. et al., (2009) reported a continuous-wave 872-MHz RFR increased chemically-induced DNA strand breaks and free radicals in human neuroblastoma cells. A short-term exposure of 15 and 30 minutes to RF-EMF radiation (900-MHz) from a mobile phone caused a significant increase in DNA single-strand breaks in human hair root cells located around the ear where cell phone are held while attending a call (Cam and Seyhan, 2012). Paulraj and Behari, (2006), reported increased single strand breaks in brain cells of rats after 35 days of exposure to 2.45 and 16.5 GHz fields. Zhang DY. et al., (2006), reported that 1800-MHz field at 3.0 W/kg induced DNA damage in Chinese hamster lung cells after 24 hours of exposure.

Avendaño C. et al., (2012), have demonstrated, in a first ever study that ex vivo non-thermal exposure of human spermatozoa to a wireless internet-connected laptop decreased motility and induced DNA fragmentation. Diem et al., (2005) have demonstrated an increase in DNA fragmentation in a variety of human and animal cells following cell phone exposures. According to
a study, RF-EMF radiation at levels equivalent to the vicinity of cell phone towers is genotoxic and could cause DNA damage (Phillips JL. et al., 1998). A recent study by Gandhi G. et al., (2014), was conducted in India to investigate the genetic damage of individuals residing at the vicinity of a mobile phone base station and parameters assessed were DNA migration length, damage frequency and damage index in peripheral blood leukocytes by the comet assay. Genetic damage parameters (DNA migration length, damage frequency and damage index) were significantly elevated in the exposed groups (from 50 m to 300 m of the base station, mean power density 11,490 mW/sq.m) compared to the unexposed group (away from the base station, mean power density 4.5 mW/sq.m). The female residents of the exposed group had significantly elevated damage frequency compared to the male residents, but no differences were found for DNA migration length and damage index.

It was proposed from these studies that all biological responses to RF-EMF radiation depended on the parameters of the radiation and that it could be due to either direct RF-EMF-mediated effects or a defect in DNA repair mechanisms (Lai and Singh, 2004).

6.3.3.2 KARYOTYPING ANALYSIS

Studies on karyotyping in relation to RF-EMF radiation from cell phone towers, especially in guinea pigs (Cavia porcellus) are close to none. In this study, karyotyping in guinea pigs was done to identify chromosomal aberrations if any, caused due to RF-EMF radiation from cell towers. There are no proven experimental data on karyotyping analysis on guinea pigs to support. However, optimization was aimed to characterize the chromosomes of guinea pig to support the same. A standard protocol was followed in surgical collection, storage and karyotyping as shown in the materials and methods section. The result of the bone marrow karyotyping analysis was obtained from the exposed animals from Cage C2 at 100 m distance from the RF-EMF source at power density of 0.880 mW/sq.m. The guinea pig is rarely used for chromosomal investigations currently due to its high diploid number of 64.

The 64 chromosomes in the Giemsa-stained karyotype were arranged in 31 autosome pairs in the decreasing order of chromosome size or arm length and the sex chromosomes were placed separately. The sex chromosomes consisted of a large metacentric X-chromosome which was second in size. Y chromosome was one of the largest acrocentric chromosomes. The first pair had the largest acrocentric chromosome, the second and the third pair were medium in size and were submetacentric. The remaining autosomes had a subterminal or terminal kinetochore position and
formed a continuous series, which decreased in size without noticeable gaps, making their identification tentative. It was similar to the karyotype obtained by Hsu and Benirschke, (1976) and Todehdeghghan F. et al., (2013) (Fig 6.4). Environmental or chemical carcinogen-induced neoplastic transformation of guinea pig cells in culture need not be accompanied by numerically or morphologically visible chromosomal alterations, according to a study on chromosome patterns of *in vitro* chemical carcinogen-transformed guinea pig cells by Popescu NC. et al., (1974).

![Karyotype of female and male hairless guinea pig](image)

### Figure 6.4: (a) Female and (b) Male guinea pig karyotype (Todehdeghghan F. et al., 2013)

There was no doubt that most chemical or environmental carcinogens cause chromosome damage, but these damaged cells become inviable and in some circumstances, the damaged chromosomes may be involved in the formation of abnormal chromosomes. There are instances where transformed cell lines and *in vivo*-induced tumor may have a normal diploid constitution (Hsu and Benirschke, 1968; Popescu NC. et al., 1974; Levan, 1974). In a study by Bourthoumieu S. et al., (2010), karyotyping was performed on exposed and sham-exposed human cells to detect single- or double-strand breaks, chromosome rearrangements (deletions, duplications, translocations, inversions), and numerical aberrations (aneuploidies). Although, it is a reliable method for evaluating clastogenic and aneuploidogenic effects of RF-EMF radiation and for the identification of chromosomes involved in rearrangements, it is rarely performed to detect
genotoxic effects because of the expertise required to interpret the results. This cytogenetic study result showed that less than 20% of exposed or sham-exposed metaphase cells displayed chromosomal aberrations as usually observed in a routine constitutional cytogenetic laboratory. No significant difference was observed between the RF-radiation-exposed and the sham-exposed groups at either 0 or 24 hours after exposure. Hence, this study did not provide evidence of a genotoxic effect of GSM900 RF-EMF radiation alone after 24-hour exposure using R-banded karyotyping. No difference in the rate of chromosomal aberrations was found between exposed and sham-exposed cells 0 or 24 hours after exposure. The numbers of exposed or sham-exposed cells with structural chromosomal aberrations decreased after 24 hours in culture.

Skykes PJ. et al., (2001), studied the somatic intra-chromosomal recombination in the spleen of transgenic pKZ1 mice exposed to pulsed-wave RF-EMF radiation at 900 MHz (SAR 4 W/kg) for 30 minutes per day for 1, 5, or 25 days. There was a significant reduction in inversions below the spontaneous frequency in the group exposed for 25 days, whereas no effect was found in mice exposed for 1 or 5 days. These facts lead to the conclusions that visibly recognisable chromosomal changes are not essential for the malignant state and that the chromosomal aberrations induced either cell cycle arrest to repair DNA or cell death through apoptosis when aberrations were too extensive to be repaired (Bourthoumieu S. et al., 2010).

6.3.3.3 REAL-TIME PCR (RT-PCR)

Research over the last two decades on the effect of RF-EMF radiation has yielded controversial results. It is said that even an extensive epidemiological and biochemical studies might not be sufficient to elucidate the bioeffects of RF-EMF because of the low sensitivity of these approaches. Hence, to validate the mixed results from the above studies, further data from in vivo animal studies needed to be analysed. Several lines of evidences suggest that the novel methodologies such as genomics, transcriptomics, proteomics and metabolomics could help in the search for clues to decipher the negative impacts of RF-EMF radiation on human health (Leszczynski, 2002; Nylund and Leszczynski, 2004). High-throughput screening techniques, although expensive, could be used to pick up minute variations like those caused by RF-EMF radiation on gene expression that might be of insufficient magnitude to give any phenotypic alteration, but can alter cell physiology. Hence, a modern gene-testing technique like RT-PCR was chosen to investigate if RF-EMF radiation can cause any change in gene expression. The study of
EMFs and their effects on genes and proteins are still in its infancy, however, by having some confirmation at the gene level that weak RF-EMF exposures do register changes may be an important step in establishing what risks to health can occur. Hence, an investigation into the effects of RF-EMF radiation from cell phone towers on six genes of interest in guinea pigs is pursued.

In this experiment, the effects of exposure of RF-EMF radiation on gene expression of six genes of interest in guinea pigs and their fold differences were studied using Real-Time PCR (RT-PCR). The genes of interest were Fos, TNF-alpha, GFAP, TGF-beta, HSB1, and VEGF with the housekeeping gene (HKG) being GAPDH. RT-PCR is a method where an RNA strand was reverse-transcribed into its complementary DNA (cDNA) using the enzyme reverse transcriptase, with the resulting cDNA being amplified using RT-PCR. The RNA was extracted from the brain samples of female guinea pigs from Cage C2 at 100 meter distance from the RF-EMF source (power density of 0.880 mW/sq.m) and from Cage C or sham-exposed, power density being zero. The results were analyzed as gene expression relative to the housekeeping gene expression. Fold change analysis was calculated to identify genes with expression differences between the exposed and sham-exposed which was beyond a given cut-off or threshold. Under the exposure conditions investigated in this study, it was found that all the genes from the brain samples of female guinea pigs at 100 meters distance from the cell phone tower, were up-regulated on exposure to RF-EMF radiation and no down-regulation was noted. Their fold differences were as follows: TGF-beta +12.08, GFAP +9.64, HSB1 +8.87, Fos +6.68, TNF-alpha +5.13 and VEGF +1.38.

TGF-beta: According to Derynck R. et al., (2001), TGF-beta is both a tumor suppressor and a promoter of tumor progression and invasion. According to Gold, (1999), there is a marked increase in the expression of TGF-beta in in vivo studies in cancers, including those of the pancreas, colon, stomach, lung, endometrium, prostate, breast, brain, and bone. The increased expression of TGF-beta is usually accompanied by a loss in the growth inhibitory response to TGF-beta. Certain tumor cells in culture (colon carcinoma and glioblastoma multiforme) demonstrated a progressive loss of the growth inhibitory response to TGF-beta that varied directly with the malignant stage of the original tumor. Once malignant cells lose their growth inhibitory response to TGF-beta and produce massive amounts of these proteins, the increased expression of TGF-beta provides a selective advantage for tumor cell survival as TGF-betas are also angiogenic and have potent immunosuppressive effects, including specifically inhibiting tumoricidal natural and lymphocyte-
activated killer cells. Changes in cell cycle proteins, receptors, signal transduction, and gene activation related to TGF-beta have all been implicated in the oncogenesis of many cancers (Gold, 1999; Padua and Massagué, 2009).

**GFAP (Gfap):** Glial fibrillary acidic protein (GFAP) gene encodes the GFAP protein which is a member of the cytoskeletal protein family. It is widely expressed in astroglial cells and in neural stem cells (Eng LF. et al., 1971; Doetsch, 2003). GFAP up-regulation is an adequate reaction to different pathological states in the nervous system and is expressed in astroglial tumours, such as astrocytoma and GBM (Jacque CM. et al., 1978; Hamaya K. et al., 1985; Abaza MS. et al., 1998). According to Jung CS. et al., (2007), serum GFAP is a diagnostic biomarker for glioblastoma (GBM). In an in vivo study by Hebert and O'Callaghan (2000), to delineate the relative contribution of MAPK- and JAK-signaling components to reactive gliosis as measured by induction of glial-fibrillary acidic protein (GFAP), following chemical-induced neural damage in female mice, GFAP up-regulation occurred. It was concluded that these pathways could be obligatory for the triggering and/or persistence of reactive gliosis, which was the most prominent response to diverse forms of central nervous system injury and modulated glial response to neural damage (O’Callaghan, 1994). GFAP along with vimentin maintain the structural plasticity of astrocytes and that proliferation and differentiation of astrocytes are related in part to the modulation of GFAP expression during central nervous system development (Gomes FCA. et al., 1999). Several animal studies report increased GFAP expression, also a marker of neuroinflammation, that is related to neurodegenerative damage after acute and/or repeated RF-EMF exposures (Maskey D. et al., 2012; Roosli, 2014). A null mutation in GFAP gene disrupted the integrity of CNS white matter and caused abnormal myelination (Liedtke W. et al., 1996) as well as inefficient blood-brain barrier formation (Pekny M. et al., 1998). Modulators of GFAP expression include several hormones such as thyroid hormone, glucocorticoids and several growth factors such as TGF-beta, among others. In a study by Goncalves, (1994), in the brain of guinea pig, mouse and rat, it was noted that GFAP presented small differences in two-dimensional electrophoretic mobility and the phosphorylation of GFAP was dependent on Ca2+ in the incubation medium in adult animals of all three species.

**HSB1 (Hspb1):** Heat shock proteins (HSP), which act as intracellular chaperones for other proteins, are frequently used in toxicological studies as biomarkers of cell damage (Didelot C. et al., 2007). Also known as stress proteins, the heat-shock proteins have been reported to be affected by RF-EMF radiation. Studies involving experimental exposure to electromagnetic fields have revealed numerous modifications in expression of heat shock proteins in vivo. An increase in heat
shock proteins in neuronal subpopulations and/or its activation in new non-neuronal glial and microglial cell populations indicated participation by this protein in neuroprotective mechanisms, oxidative stress and anti-apoptotic activity (Ohtsuka and Suzuki, 2000; Lanneau D. et al., 2007). HSPs increased heat tolerance and performed functions essential to cell survival under these conditions. Some HSPs served to stabilize proteins in abnormal configurations, while others played a role in the folding and unfolding of proteins, acting as molecular chaperones. Because HSPs and their associated factors are induced by a variety of stressors, they have been proposed as possible biomarkers of RF-field exposure (Morimoto, 1993; Lis and Wu, 1993). According to French PW. et al., (2001), repeated exposure to RF-EMF radiation may act as a repetitive stressor, leading to continuous over-expression of HSPs in exposed cells and tissues.

**Fos (c-fos)** - Proto-oncogenes are normal cellular genes whose alteration have been implicated in cancerous proliferation and transformation (Bishop, 1987). These genes play a key role in biochemical pathways controlling normal cell proliferation. One among them is c-fos, which encodes nuclear proteins (Juvenot M. et al., 1990). It was first discovered in rat fibroblasts that had the transforming gene of the FBJ MSV (Finkel–Biskis–Jinkins murine osteogenic sarcoma virus). They are part of a bigger Fos family of transcription factors. C-fos encodes a 62 k Da protein, which forms heterodimer with c-jun (part of Jun family of transcription factors), resulting in the formation of AP-1 (Activator Protein-1) complex which binds DNA at AP-1 specific sites at the promoter and enhancer regions of target genes and converts extracellular signals into changes of gene expression. It plays a predominant role in many cellular functions which has been found to be over-expressed in a variety of cancers (Ivorra C. et al., 2006).

**TNF-alpha:** Tumor necrosis factor-alpha (TNF-alpha) is a pro-inflammatory cytokine that rapidly up-regulates in the brain after injury (Barone FC. et al., 1997). TNF-alpha can up-regulate and down-regulate some key pro-inflammatory cytokines (IFN-gamma, IL-12p40) and directly change the blood brain barrier permeability and structure (Mayhan, 2002). Recent evidence suggests that TNF-alpha is a central regulator of multiple inflammatory signaling cascades, leading to activation of MAPK and the transcription factor NF-κB (Wajant H. et al., 2003). Low levels of this cytokine may aid in maintaining homeostasis by regulating the body's circadian rhythm. The cytokine possesses both growth stimulating properties and growth inhibitory processes, and it appears to have self-regulatory properties as well. Prolonged overproduction of TNF-alpha also resulted in a condition known as cachexia, which is characterized by anorexia, net catabolism, weight loss and anemia and which occurs in illnesses such as cancer (Beutler B. et al., 1985). TNF-alpha causes necrosis of some types of tumours and promotes the growth of other types of tumor cells (Merrill
and Benveniste, 1996). TNF-alpha gene is up-regulated in the brain in disease such as Alzheimer’s (Sheng JG. et al., 1996), Parkinson’s (Mogi M. et al., 1994), multiple sclerosis (Barone FC. et al., 1997), and amyotrophic lateral sclerosis (ALS) (Poloni M. et al., 2000).

**VEGF:** Vascular endothelial growth factor (VEGF) is an endothelial cell-specific mitogen and an angiogenesis inducer released by a variety of tumour cells. The development of new blood vessels (angiogenesis) is required for many physiological processes including embryogenesis, wound healing and corpus luteum formation. Blood vessel neoformation is also important in the pathogenesis of many disorders, particularly rapid growth and metastasis of solid tumours. VEGF is one of several potential mediators of tumour angiogenesis (Kim KJ. et al., 1993). It has several biological activities and serve a variety of functions in vivo. It is both a permeability and growth factor and is responsible for initiating and promoting tumor angiogenesis and stroma generation (Nagy JA. et al., 1988). It is known for increasing free cytosolic Ca(2+) in endothelial cells (Brock TA. et al., 1991). Hence, it has a diverse role spanning neoplastic growth, wound healing and inflammation (Berse B. et al., 1992). VEGF induces an increase in hydraulic conductivity of isolated microvessels and this effect is mediated by increase calcium influx (Bates and Curry, 1997). VEGF up-regulation has been implicated in the development of brain edema, and in a study on rats, levels were enhanced after induction of focal cerebral ischemia; VEGF is often over-expressed in glioblastoma multiforme (GBM) (Plate, 1999; Zagzag D. et al., 2006, Keunen O. et al., 2011). Angiogenesis, as reflected by microvessel density counts, was significantly increased in tumors from stressed compared with control mice. VEGF mRNA and protein levels were significantly elevated in the tumor samples from mice exposed to daily stress (Lutgendorf SK. et al., 2003; Thaker PH. et al., 2006). *In vitro* and *in vivo* studies have confirmed a correlation between tumor grade and VEGF expression in gliomas. Besides, studies in animal models have shown that inhibiting VEGF function inhibits growth of glioma cells *in vivo* and causes regression of blood vessels (Maity A. et al., 2000). According to Oka N. et al., (2007), VEGF signaling pathway played an important role in gliomagenesis, its activation being closely related with brain tumor development via vascular formation, and concluded that VEGF promoted tumor angiogenesis resulting in rapid growth of glioblastoma. The results of their study revealed that VEGF induced the proliferation of vascular endothelial cells (VEC) in the vascular-rich tumor environment of the stem cell niche.

In a study by Yan JG. et al., (2008), on adult Sprague-Dawley rats being exposed to regular cell phones for 6 hours per day for 18 weeks and following RT-PCR analysis, there was a
significant m-RNA up-regulation of injury-associated proteins, such as Calcium ATPase, Neural Cell Adhesion Molecule, Neural Growth Factor, and Vascular Endothelial Growth Factor. These results indicated that relative chronic exposure to RF-EMF radiation from mobile phones may result in cumulative injuries that could eventually lead to clinically significant neurological damage.

Chen C et. al., (2014) exposed embryonic neural stem cells (eNSCs) to 1800 MHz RF-EMF at specific absorption rate (SAR) values of 1, 2, and 4 W/kg for 1, 2, and 3 days. Real-Time PCR with GAPDH as HKG was one of the methods used in this study for validation. They found that neurite outgrowth of eNSC differentiated neurons was inhibited after 4 W/kg RF-EMF exposure for 3 days. Additionally, the mRNA and protein expression of the proneural genes Ngn1 and NeuroD, which are crucial for neurite outgrowth, were decreased after RF-EMF exposure. The expression of their inhibitor Hes1 was up-regulated by RF-EMF exposure. These results together suggested that 1800 MHz RF-EMF exposure impairs neurite outgrowth of eNSCs and hence, brain development could be adversely affected by RF-EMF exposure.

Goswami PC. et al., (1999), used an RT-PCR assay to explore the possible effects of analog (835.62 MHz FMCW) or digital (847.74 MHz CDMA) cellular telephone signals on proto-oncogene expression. They found no effect of RF-EMF exposure on the expression of c-jun or c-myc proto-oncogenes, while very small increases of c-fos expression were observed during one specific phase of the cell cycle. Fritze K. et al., (1997), exposed rats to RF-EMF radiation at 900 MHz (GSM; SAR 1.5 W/kg) or to continuous-wave RF radiation at 900 MHz (SAR 7.5 W/kg), for 4 hours. To mimic actual life exposure as closely as possible, the signal was generated with a commercial mobile GSM phone. Enhanced expression of Hsp70 mRNA and a significant increase in c-Fos expression in the brain was seen (Fritze et al., 1997).

Salford LG, et al., (2003), have shown that weak pulsed microwaves give rise to significant leakage of albumin through the blood-brain barrier (BBB) and that pathologic leakage across BBB brought about by exposure to GSM mobile phone RF-EMFs of different strengths lead to neuronal damage in the cortex, hippocampus and basal ganglia in the brains of exposed rats. Zhao TY. et al., (2007), investigated whether expression of genes related to cell death pathways are dysregulated in primary cultured neurons and astrocytes by exposure to a working GSM cell phone rated at a frequency of 1900 MHz for two hours. Following, RT-PCR analysis, the results indicated an up-regulation of caspase-2, caspase-6 and Asc (apoptosis associated speck-like protein) gene
expression in neurons and astrocytes. In neurons, there was up-regulation observed when the cell phones were in on and in standby modes, whereas in astrocytes, it was observed only in on mode. Astrocytes showed up-regulation of the Bax gene and the effects were specific since up-regulation was not seen for other genes associated with apoptosis, such as caspase-9 in either neurons or astrocytes or Bax in neurons. The results show that even relatively short-term exposure to cell phone radiofrequency emissions can up-regulate elements of apoptotic pathways in cells derived from the brain, and that neurons appear to be more sensitive to this effect than astrocytes.

The changes of gene expression in rat neuron induced by 1.8 GHz RF-EMF radiation to screen for RF-EMF-responsive genes and the effect of different exposure times and modes on the gene expression in neurone were studied using the microarray and RT-PCR. Differentially expressed genes were found to be Egr-1, Mbp and Plp). The expression levels of Egr-1, Mbp and Plp were observed at different exposure times (6 hours, 24 hours) and modes (intermittent and continuous exposure). Among 1200 candidate genes, 24 up-regulated and 10 down-regulated genes and these genes were associated with multiple cellular functions such as cytoskeleton, signal transduction pathway, and metabolism. It was concluded that 1.8 GHz RF-EMF radiation brought about changes in many gene expression of rat neurons. Down-regulation of Egr-1 and up-regulation of Mbp, Plp indicated the negative effects of RF-EMF on neurons. The effect of RF-EMF intermittent exposure on gene expression was more obvious than that of continuous exposure and the effect of 24-hour intermittent and continuous RF-EMF exposure on gene expression was more obvious than that of the same for 6 hours (Zhang SZ. et al., 2008).

In a study by Paparini A. et al., (2008), to analyze possible effects of microwaves on gene expression, mice were exposed to global system for mobile communication (GSM) 1800 MHz signal for one hour at a whole body SAR of 1.1 W/kg. Gene expression was studied in the whole brain, where the average SAR was 0.2 W/kg, by expression microarrays containing over 22,600 probe sets. Comparison of data from sham and exposed animals showed no significant difference in gene expression modulation. However, when less stringent constraints were adopted to analyze microarray results, 75 genes were found to be modulated following exposure. Forty-two probes showed fold changes ranging from 1.5 to 2.8, whereas 33 were down-regulated from 0.67- to 0.29-fold changes, but these differences in gene expression were not confirmed by RT-PCR. A study using matrix-assisted laser desorption/ionization-mass spectrometry found statistically significant altered expression levels of 38 various proteins in human endothelial cell lines following GSM900
MHz irradiation (Nylund and Leszczynski, 2004). Two of the affected proteins were determined to be isoforms of cytoskeletal vimentin and might have an effect on the physiological functions that are regulated by the cytoskeleton. Results from a study by the same team using human lens epithelial cells (HLEC) exposed to non-thermal dosages of RF-EMF from wireless communications showed repairable DNA damage and increased Hsp70 protein expression. The over-expression of Hsp70 also involved mitogen-activated phosphokinase (MAPK) cell response cascades, which consisted of regulator enzymes that serially activated one another to control the expression of specific sets of genes in response to growth factors, cytokines, tumour promoters and other major biological stimuli. The authors suggested that non-thermal stress response of Hsp70 protein increased on RF-EMF exposure might be involved in protecting HLEC from DNA damage and maintaining the cellular capacity for proliferation. Similar results were also obtained by Lixia S. et al., (2006).

A landmark study was undertaken to examine whether non-thermal exposures of cultures of the human endothelial cell line EA.hy926 to 900 MHz GSM mobile phone microwave radiation could activate stress response. Results obtained demonstrate that one-hour non-thermal exposure of EA.hy926 cells changes the phosphorylation status of numerous proteins, heat shock protein-27 (hsp27) being one of them. All these changes were non-thermal effects because, as determined using temperature probes, irradiation did not alter the temperature of cell cultures, which remained throughout the irradiation period at 37±0.3°C. Changes in the overall pattern of protein phosphorylation suggested that mobile phone radiation activated a variety of cellular signal transduction pathways, among them the hsp27/p38MAPK stress response pathway. Based on the known functions of hsp27, it was concluded that mobile phone radiation-induced activation of hsp27 may facilitate the development of brain cancer by inhibiting the cytochrome c/caspase-3 apoptotic pathway and cause an increase in blood-brain barrier permeability through stabilization of endothelial cell stress fibers. It was postulated that these events, when occurring repeatedly over a long period of time, might become a health hazard because of the possible accumulation of brain tissue damage (Leszczynski D. et al., 2002). Another study has also shown that the phosphorylated form of Hsp27 has the ability to translocate to the nucleus and to induce changes in gene expression (Geum D., 2002). French PW. et al., (2001), stated that heat shock proteins were involved in cancer promotion.
Megha K et al., (2012) found a significant increase in cytokines (IL-6 and TNF-alpha) in brain of Fischer rats exposed to microwave radiation of 900 MHz (SAR = 5.953 x 10(-4) W/kg) and 1800 MHz (SAR = 5.835 x 10(-4) W/kg) for 30 days (2 h/day), which indicated that increased oxidative stress due to microwave exposure may contribute to cognitive impairment and inflammation in brain. According to Guha SK., (2011), non-thermal effects of RF-EMF accumulate over time and the risks are more pronounced after several years of exposure. The effects are not observed in the initial years of exposure as the body has certain defence mechanisms and the pressure was on the stress proteins of the body, namely the heat shock proteins (HSPs). If the stress goes on for too long, there was a reduced response, and the cells are less protected against the damage. This was the reason why prolonged or chronic exposures may be quite harmful, even at very low intensities. One of the current theories is that heat generation by RF-EMF is the cause, in spite of the fact that a great number of studies under isothermal conditions have reported significant cellular changes after exposure to RF-EMF.

Velizarov S. et al., (1999), reported that certain classes of heat-shock proteins are involved in the stress reactions induced by RF-EMF. In their study, exposure from GSM960 MHz was induced on cell cultures, growing in microtiter plates in a specially constructed chamber, a Transverse Electromagnetic (TEM) cell at a temperature of 39 or 35 +/- 0.1 degrees C. The corresponding sham experiments were performed under exactly the same experimental conditions. The results showed that there was a significant change in cell proliferation in the exposed cells in comparison to the non-exposed (control) cells at both temperatures. On the other hand, no significant change in proliferation rate was found in the sham-exposed cells at both temperatures. This shows that biological effects due to RF-EMF radiation cannot be attributed only to a change of temperature.

In a recent study which was part of the Fifth Framework Programme project REFLEX (Risk Evaluation of Potential Environmental Hazards From Low-Energy Electromagnetic Field Exposure Using Sensitive In Vitro Methods), six human cell types, immortalized cell lines and primary cells were exposed to 900 and 1800 MHz. RNA was isolated from exposed and sham-exposed cells and labelled for transcriptome analysis on whole-genome cDNA arrays. NB69 neuroblastoma cells, T lymphocytes, and CHME5 microglial cells did not show significant changes in gene expression. In EA.hy926 endothelial cells, U937 lymphoblastoma cells and HL-60 leukaemia cells, between 12 and 34 genes were up- or down-regulated including bcl-2-associated transcription factor BTF gene.
The findings conclude that analysis of the affected gene families does not point towards a stress response, however, following RF-EMF exposure, some but not all human cells might react with an increase in expression of genes encoding ribosomal proteins and therefore up-regulating the cellular metabolism (Remondini D. et al., 2006).

The effects of radiofrequency electromagnetic field (RF-EMF) exposure on neuronal phenotype maturation have been studied in two different in vitro models: murine SN56 cholinergic cell line and rat primary cortical neurons. The samples were exposed at a dose of 1 W/kg at 900 MHz GSM modulated. The phenotype analysis was carried out at 48 and 72 hours (24 and 48 hours of SN56 cell line differentiation) or at 24, 72, 120 h (2, 4 and 6 days in vitro for cortical neurons) of exposure, on live and immunolabeled neurons, and included the morphological study of neurite emission, outgrowth and branching. Cortical neurons were studied to detect alterations in the expression pattern of cytoskeleton regulating factors, such as beta-thymosin and early genes like c-Fos and c-Jun through real-time PCR on mRNA extracted after 24-hour exposure to EMF. It was found that RF-EMF exposure reduced the number of neurites generated by both cell systems and this alteration correlated to increased expression of beta-thymosin mRNA (Del Vecchio G. et al., 2009). López-Martín E. et al., (2009), found that GSM and unmodulated RF-EMF radiation caused different effects on c-Fos gene expression in the rat brain.

Whole-body microwave sinusoidal irradiation of male mice, exposure of macrophages in vitro, and preliminary irradiation of culture medium with 8.15-18 GHz at a power density of 10 mW/sq.m caused a significant enhancement of tumor necrosis factor (TNF) production in peritoneal macrophages (Novoselova and Fesenko, 1998). Hence, RF-EMF radiation does interfere with the process of cell immunity. Under similar exposure conditions, the tumor necrosis factor (TNF) production and immune response was tested by Novoselova EG. et al., (1999), and it was observed that a single five-hour whole-body exposure induced a significant increase in TNF production in peritoneal macrophages and splenic T cells. The mitogenic response in T lymphocytes increased after this exposure.

In an investigation by Carballo-Quintás M. et al., (2011), rats were exposed to 900 MHz RF-EMF radiation at an intensity similar to mobile phone emissions and acute subconvulsive doses of picrotoxin were administered to the rats. An experimental model of seizure-proneness was created from the data. Immunochemical testing of relevant anatomical areas was done to measure induction of the c-fos neuronal marker after 90 minutes and 24 hours and of the glial fibrillary
acidic protein (GFAP) 72 hours after acute exposure. Ninety minutes after radiation, high levels of c-fos expression was recorded in the neocortex and paleocortex along with low hippocampus activation in picrotoxin treated animals. Most brain areas, except the limbic cortical region, showed important increases in neuronal activation 24 hours after picrotoxin and radiation. Three days after picrotoxin treatment, radiation effects were still apparent in the neocortex, dentate gyrus and CA3, but a significant decrease in activity was noted in the piriform and entorhinal cortex. During this time, glial reactivity increased with every seizure in irradiated, picrotoxin-treated brain regions. Hence, results revealed c-fos and glial markers were triggered by the combined stress of non-thermal irradiation and the toxic effect of picrotoxin on cerebral tissues.

According to Laming PR. et al., (2000), neurons and glia cells interact dynamically to enable information processing and behaviour. Mobile phone RF-EMR exposure significantly altered the passive avoidance behaviour and hippocampal morphology in rats (Narayanan SN. et al., 2010). Glial cells, damaged by RF-EMF radiation, altered the neuronal activity in rat hippocampus and amygdala. Brillaud E. et al., (2007) demonstrated that an a single GSM exposure of 15 minutes to 900 MHz RF-EMF radiation induced glial reactivity and biochemical modifications in the rat brain. Chronic exposure to GSM 900 MHz microwaves induced persistent astroglia activation in the rat brain, which is the sign of a potential gliosis (Ammari M. et al., 2008). Signalling pathways are complex, the cellular systems are interconnected and the electromagnetic fields stimulate the synthesis of many genes, proteins and the binding of specific transcription factors like AP-1 and AP-2 (Lin H. et al., 2001). RF-EMF produces more than one gene effect for many regulatory events, in addition to stress response (Cogreave, 2005).

A research as early as 1985, led by Michealson and Lin, to test test animals to known high-level thermal doses of RF energy (16,50,000 mW/sq.m) was done to establish the features of thermally caused bio-effects, whereas other experiments were designed to determine how the excess heat affected the animals’ bodies. The results unexpectedly indicated that high-level, short-term exposures produced effects could be duplicated by lower-level, longer-term exposures, suggesting that duration of exposure may be a factor to consider. The current decline of amphibian species are positively associated with streams at high elevations in the tropics and negatively associated with still water and low elevations. In high places, the electromagnetic contamination was usually higher (Balmori, A., 2005).
According to Levitt B. (2010), RF-EMF penetrates deeper into the head of children and certain tissues of a child’s head, like the bone marrow and the eye, absorb significantly more energy than those in an adult head (Christ A. et al. 2013). The EMR alters the immune, nervous, and endocrine systems, and operates independent or together with other factors like ultraviolet radiation or chemical pollutants (Blaustein and Johnson, 2003; Middleton EM et al., 2001). EMR produces stress on the immune system that obstructs DNA repair (Hallberg and Johansson, 2004).

According to Cherry N (2002), a water-filled upright human is a sizeable antenna. Since all moving electrons generate electrical current, all those electromagnetic waves inundating everyday lives pass into our bodies, where they each generate an electric current. These induced electric currents change the charge on which the complex bioelectrical body, brain and heart network operates to maintain health and vitality. Cell phones and cellular networks are so named, as every transmission disrupted the cells directly. RF-EMR can affect ear, skin, inner ear, cochlear nerve and temporal lobe surface. Increasing in temperature of the inner fluids of the vestibular apparatus theoretically could induce neural responses in the receptor cells, such as vertigo and nystagmus. Vertigo is one of the complaints frequently made by people who are hypersensitive to RF-EMF radiation. The proximity of RF-EMF exposure to the human eye also raises the question as to whether RF-EMF could affect the visual functions. There was no study with respect to chemical senses systems (taste and olfaction) and RF-EMF exposure.

The action of RF-EMF radiation from cell phone towers has been suggested as a physical phenomenon that might have biological effects on the mammalian central nervous system. RF-EMF studies of gene expression have focused typically on early response genes, otherwise known as proto-oncogenes, oncogenes, and stress responsive genes. In correlation with the above studies, this study showed up-regulation of genes of interest including Fos (proto-oncogene), TNF-alpha (pro-inflammatory cytokine), GFAP (marker of neuroinflammation), TGF-beta (both a tumor suppressor and a promoter), HSB1 (stress responsive gene), and VEGF (angiogenesis inducer). The evidence suggests that different types of cells from different species might respond differently to RF-EMF radiation or might have different sensitivity to this non-ionizing, non-thermal stimulus. Exposure to RF-EMF radiation can induce alterations in membrane potential and calcium efflux with resultant calcium depletion. It leads to decreased activity of protein kinase C (PKC). This decrease leads to alteration in many enzymes, ion pumps, channels and proteins as well as inducing
apoptosis. RF-EMF induces ROS production through effect on mitochondrial membrane-bound NADPH oxidase. ROS has impact on PKC, histone kinase, heat shock proteins, DNA and apoptosis. Heat shock proteins (HSP) increase in response to RF-EMF radiation and ROS. HSP slows metabolism and interferes with apoptosis. Genotoxic effects of RF-EMF is either through ROS production or through direct elastogenic chromatin breaking effect. Listed below in Table 6.4 are the bioeffects of RF-EMF radiation from various studies done, where the biological effects are seen starting from 0.003 mW/sq.m up to 1200 mW/sq.m.

Table 6.4: Power Densities at which bioeffects are seen (Bioinitiative Report, 2012)

<table>
<thead>
<tr>
<th>Power Density</th>
<th>Bioeffects</th>
<th>Author, Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.003 mW/sq.m</td>
<td>Significantly reduced sperm count</td>
<td>Behari and Kesari, (2006)</td>
</tr>
<tr>
<td>0.005 mW/sq.m</td>
<td>decreased cell proliferation</td>
<td>Velizarov S. et al., (1999)</td>
</tr>
<tr>
<td>0.006 - 0.128 mW/sq.m</td>
<td>Fatigue, depressive tendency, sleeping disorders, concentration difficulties, cardio-vascular problems</td>
<td>Oberfeld G. et al., (2004)</td>
</tr>
<tr>
<td>0.009 mW/sq.m</td>
<td>Induced 10%-40% increase in DNA synthesis in glioma cells (brain)</td>
<td>Stagg RB. et al., (1997)</td>
</tr>
<tr>
<td>0.03 - 0.2 mW/sq.m</td>
<td>In children and adolescents (8-17 yrs) short-term exposure caused headache, irritation, concentration difficulties in school</td>
<td>Heinrich S. et al., (2010)</td>
</tr>
<tr>
<td>0.03 to 0.5 mW/sq.m</td>
<td>Behavioral problems in children and adolescents</td>
<td>Thomas S. et al., (2010)</td>
</tr>
<tr>
<td>0.05 mW/sq.m</td>
<td>In adults (30-60 yrs) chronic exposure caused sleep disturbances, (but not significantly increased across the entire population)</td>
<td>Mohler E. et al., (2010)</td>
</tr>
<tr>
<td>0.05 - 0.4 mW/sq.m</td>
<td>Adults exposed to short-term cell phone radiation reported headaches, concentration difficulties (differences not significant, but elevated)</td>
<td>Thomas S. et al., (2008)</td>
</tr>
<tr>
<td>0.06 - 0.1 mW/sq.m</td>
<td>Chronic exposure to base station RF (whole-body) in humans showed increased stress hormones; dopamine levels substantially decreased; higher levels of adrenaline and nor-adrenaline; dose-response seen; produced chronic physiological stress in cells even after 1.5 years.</td>
<td>Buchner and Eger, (2011)</td>
</tr>
<tr>
<td>Radiation Intensity (mW/sq.m)</td>
<td>Effect on Health</td>
<td>Study Reference</td>
</tr>
<tr>
<td>-----------------------------</td>
<td>------------------</td>
<td>----------------</td>
</tr>
<tr>
<td>0.1 - 1.1</td>
<td>RFR from cell towers caused fatigue, headaches, sleeping problems</td>
<td>Navarro EA. et al., (2003)</td>
</tr>
<tr>
<td>0.1 - 0.5</td>
<td>Adults (18-91 yrs) with short-term exposure to GSM cell phone radiation reported headache, neurological problems, sleep and concentration problems.</td>
<td>Hutter HP. et al., (2006)</td>
</tr>
<tr>
<td>0.15 - 2.1</td>
<td>Changes in mental state in adults</td>
<td>Augner and Hacker, (2009)</td>
</tr>
<tr>
<td>0.5 - 1.0</td>
<td>Adverse neurological, cardio symptoms and cancer risk. Headache, concentration and sleeping problems, fatigue</td>
<td>Khurana VG. et al., (2010)</td>
</tr>
<tr>
<td>0.7 - 1</td>
<td>Sperm head abnormalities in mice</td>
<td>Otitoloju AA. et al., (2010)</td>
</tr>
<tr>
<td>3.8</td>
<td>Affected calcium metabolism in heart cells</td>
<td>Schwartz JL. et al., (1990)</td>
</tr>
<tr>
<td>1.3</td>
<td>RFR from 3G cell towers decreased cognition, well-being</td>
<td>Zwamborn APM. et. al., (2003)</td>
</tr>
<tr>
<td>1.6</td>
<td>Affected motor function, memory and attention of Latvian school children</td>
<td>Kolodynski AA. et al., (1996)</td>
</tr>
<tr>
<td>1.68 - 10.53</td>
<td>Irreversible infertility in mice after 5 generations of exposure to RFR from an 'antenna park'</td>
<td>Magras and Zenos, (1997)</td>
</tr>
<tr>
<td>5 - 10</td>
<td>Wi-Fi level laptop exposure for 4-hr resulted in decrease in sperm viability, DNA fragmentation with sperm samples placed in petri dishes under a laptop connected via WI-FI to the internet.</td>
<td>Avendano C. et al., (2012)</td>
</tr>
<tr>
<td>15</td>
<td>Reduced memory function in rats</td>
<td>Nittby H. et al., (2007)</td>
</tr>
<tr>
<td>20</td>
<td>RFR induced-strand DNA damage in rat brain cells</td>
<td>Kesari and Behari, (2008)</td>
</tr>
<tr>
<td>25</td>
<td>RFR affected calcium concentrations in heart muscle cells</td>
<td>Wolke S. et al., (1996)</td>
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CONCLUSION

World Health Organization’s research agenda for radiofrequency fields (2010), after terming RF radiations as carcinogenic, bringing to light the lacunae in studies related to dosimetry, epidemiology, human and animals, emphasised the need for urgent research on the bioeffects of RF-EMF radiation. Although there was an unprecedented boom of mobile telephony in India, due to its immense benefits, all caution was thrown in the wind when it came to being aware about the proper use of a wireless device and placement of supporting infrastructure like the cell phone towers in our densely populated country. When there was a tremendous amount of interest and research in this field abroad, in India it remained unexplored to a large extent with negligible scientific exploration. Hence, this research was designed to decipher these topics in real-time exposures.
bioelectrical system, regulated by internal bioelectrical signals, which can be disturbed by the constant onslaught of RF-EMF radiation exposures from cell phones and cell phone towers. The evidence from this study points to quite a substantial hazard of RF-EMF radiation from the cell phone towers. Overall results of this investigation into the effects of exposure to cell tower signals are mirroring the broader spectrum of studies on cell phones and RF-EMF in general.

Perturbed levels of the antioxidant enzymes and the natural antioxidants is attributed to oxidative stress. The resulting damage to proteins, lipids, and the DNA lead to adverse health effects, which may cause cancer and degenerative diseases. Non-repairable DNA damage constitutes a very valid indirect evidence for the involvement of oxidative stress, as long as it is evaluated quantitatively as DNA fragmentation. Various studies have shown that RF-EMF radiation has the capacity to induce blood-brain barrier alterations, whereby it loses the precise control to block toxic molecules from entering the brain. Animals exposed to RF-EMF radiation also exhibit alarm, aversion and avoidance behaviour with visible panic reaction, disorientation, and anxiety. Many organisms from bees, birds to bats have traces of magnetic materials within their body, which on interaction with the earth’s subtle magnetic fields, enable them to navigate. Researchers have found that when bats are placed in a strong artificial magnetic field, they tend to become erratic. Ants have tiny magnetic iron particles throughout their body, which reacts with the earth’s magnetic core and guides them in their movement. Birds are not new to this migratory magnetism, along with other environmental cues such as sun, stars, visual references and polarisation of light (Holland RA. et al., 2006). Research done in Germany has shown that sparrows when exposed to increasing RF-EMF radiation tend to get disturbed and exhibit erratic behaviour.

The BioInitiative Report (2014) compiled by an international team of experts to review the biological effects of non-thermal, non-ionising, low-intensity electromagnetic field exposure (both extremely low frequency and radiofrequency) reported abnormal gene transcription, genotoxicity, loss of DNA repair capacity, reduction in free radical scavengers like melatonin, neurotoxicity, carcinogenicity, sperm morphological and functional deregulation, offspring behavioural issues, and improper bone development of fetes during pregnancy. Bioinitiative Report of 2012, which assessed research from 2006 to 2011, included health effects such as childhood leukemia, brain tumor, neurodegenerative diseases, breast cancer, miscarriage, cardiovascular problems, genotoxicity, immune system disruption, allergies and electrohypersensitivity. The conclusion of
the study was that risks were present at current exposure levels and that prolonged exposures may reasonably be presumed to result in health implications. On a precautionary basis, a safe power density was considered to be below 0.03 mW/sq.m above which bioeffects were observed from studies based on cell phone towers.

The mechanism of action from studies done so far shows that the observed biochemical and molecular changes are a consequence of resonance caused by external radiation, leading to homeostatic imbalance in the internal cellular environment. RF-EMF radiation creates electric oscillations, which in turn activates enzyme cascades transferring cell surface signals to the intracellular system, leading to significant non-thermal biological changes. Melatonin is known to act alongside glutathione and stimulates the antioxidant enzymes like superoxide dismutase. According to Kumar (2013), microwave oven operate at a frequency of 2450 MHz, water molecules vibrate at a speed of 2.45 billion times per second, which creates friction, leading to heating. In many countries, frequency of 915 MHz (Osepchuk, 1983) is also used for industrial microwave heating. Human body consists of 70% liquid and brain contains 90% liquid. Microwave radiation from cell phone and cell tower penetrates the skin and at a frequency of 900 MHz, water molecules vibrate at a speed of 900 million times per second, which creates friction, damages DNA and also leads to heating. This heating is from inside to outside and the heat is trapped inside the human body with no escape through the skin. Also, affect of microwave radiation is cumulative in nature and the harmful effects are noticed after a few months to a few years depending upon the intensity of the radiation. If DNA damage is greater than DNA repair, it initiates mutation and cancer.

According to Goldsworthy, (2012), many of the reported biological effects of non-ionising electromagnetic fields occur at non-thermal levels due to electrical effects on living cells and their membranes. The alternating fields generate alternating electric currents that flow through cells and tissues and remove structurally-important calcium ions from cell membranes, which then makes them leak, leading to a high electrochemical gradient. This leads to stimulation of normal growth and repair if the exposure is not prolonged. If the exposure is chronic and these mechanisms are disturbed, the results can be quite harmful, like stimulating hyperactivity, electromagnetic hypersensitivity (EHS), and blood-brain barrier permeability leading to death of neurone and onset of early dementia and Alzheimer’s disease. The opening of other barriers (respiratory, liver and gut
barriers) lead to increased risk of asthma, liver disease, promote allergies and has been linked autoimmune diseases and chronic fatigue syndrome.

Cumulative DNA damage in cells in the central nervous system could be a cause of accelerated ageing and neurodegenerative disorders. Therefore, it is imperative that the long-term effects of RF-EMF on DNA in brain cells be further studied and understood, keeping in mind the adaptive responses of cells to repeated insults and perturbation (Fan S. et al., 1990; Osmak et al., 1990). An investigation in 2013 by Centre for Climate Change and Adaptation Research Centre (CCAR), Anna University, Chennai, with the support from Regional Meteorological Centre, Chennai, led to the conclusion that there were heat pockets in Chennai that prevent surface heat from reaching the sky. Increasing commercial activity and lack of open spaces have led to an increase in temperature levels in some parts of Chennai. Areas with dense vegetation were found to be cooler. India is a tropical country and mobile telephony in India has sky rocketed leading to numerous supporting infrastructure like cell phone towers and diesel generators being placed in every nook and corner, on terrace of commercial buildings to rooftops and balconies of apartments, near schools and hospitals, where human inhabitation is found even at 10 m from the cell phone antenna. More research tailor-made to Indian conditions needs to be carried out in the coming years, as the environment gets saturated with RF-EMF radiation as well as coupled with rising temperature. Children are more vulnerable to radiofrequency radiation emissions as their skulls are thinner, their nervous system still developing.

**PRECAUTION**

Cell phone manuals do accept that cell phones are neither absolutely safe nor unsafe. The advice ranges from using hands free, keeping device away from abdomen of pregnant women and lower abdomen of teenagers, limiting call time and not allowing it to come too close to human body and to consult a physician in case of eye or muscle twitching, loss of awareness, involuntary movement or disorientation. In order to reduce the risk of headaches, blackouts, seizures, and eyestrain, to avoid prolonged use, hold the wireless device at a distance from the eyes, to use in a well-lit room and to take frequent breaks. Only precaution to be taken to avoid constant RF-EMF radiation from cell phone towers is not to live within 300 m of a cell phone tower, beside the antenna and never facing an antenna. In case of hypersensitivity to RF-EMF exposure, shielding materials such as clay or even food-grade aluminium can be incorporated either into buildings or
plastered on the walls, as well as, protection in the form of anti-radiation curtains can be used to lessen the exposure. Earthing is also a concept that is gaining momentum as an effective way to cleanse the toxins accumulated in the body. In children using mobile phones, the average deposition of RF energy may be two times higher in the brain and up to ten times higher in the bone marrow of the skull than in adult users. The use of hands-free kits lowers exposure of the brain to less than 10% of the exposure from use at the ear, but it may increase exposure to other parts of the body (WHO-IARC, 2013). In order to promote effective dialogue between cell tower planners, cell phone operators and the community in decisions regarding installation location of cell phone towers, there must be an emphasis to make available to the public detailed data on the type and location of cell phone towers, like in the UK (http://www.sitefinder.ofcom.org.uk/), in Italy (http://www.monitoraggio.fub.it/) and in the USA (http://www.antennasearch.com/).

**FUTURE SCOPE**

The voluntary exposure of the brain to cell phones and the involuntary whole-body cell phone tower exposure of the world’s population has been termed as the largest human biological experiment ever. Due to the overcrowding wireless signals from communications technologies, the air is being altered in unprecedented ways that have enormous consequences for life on earth. The future of communication technology is pervasive and ubiquitous computing, completely dependent on the non-ionising RF-EMF radiation, where people will live in an electronic environment enabled by wireless devices, which will help them carry out their everyday life activities. Devices will grow smaller, getting integrated into the environment and the technology will become invisible. Research tailor-made to Indian lifestyle, diet and environmental conditions, high-throughput screening techniques and mechanism of action, epidemiology data on cancer cases around cell phone towers, dosimetry measurements with sophisticated sensitive instruments and public awareness about the responsible use of cell phone technology need to be carried out in the coming years, as the environment gets saturated with RF-EMF radiation, coupled with rising temperature. The government and industry should actively involve in addressing concerns about the installation of cell phone towers in densely populated areas with substandard infrastructure. One must exercise caution and common sense in dealing with mobile telephony, in order to enjoy its immense benefits, while keeping a cautious eye as to where one lives, away from the presence of a cell phone tower (>300 m), never facing the antenna or being in the line of propagation of the main beam of the antenna and how one uses the wireless devices, especially the women, children and the elderly.