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Impact Of Cell Tower And Cell Phone Radiations On Human- A Study Conducted In An Indian State With A Of Population 35 Million

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Abstract

We investigated the effect of Cell tower and cell phone radiations in an Indian state of Kerala which has a population of about 35 million and has a teledensity equal to that of the United States. The examination area is divided into two categories - core zone, the highly exposed area and outer zone, area above 300m from a cell tower. The power, electric field and magnetic field densities of both the zones are measured using MECHO's radiation meter 9720. In addition, a survey is conducted in the personal interview method to collect data about ten relevant diseases. Statistical tests namely T-test, Independent sample test, Levene's test for equality of variance and ANOVA were carried out on the collected data using the software SPSS. Out of the ten diseases which were examined, nine are found to have a close relationship with the cell tower exposure. Females are found to be more affected. It is also found that more than 22% of the people are forced to live in a higher exposure level than the current Indian standard. It is also found that some phone habits are very harmful to human health. Based on our study, we designed a new standard, for maximum power density (280mW/m^2) and maximum emitted radiated power (1407W) irrespective of the number of antennas, carriers, and operators.

I. INTRODUCTION

Telecommunication technologies dramatically changed the world in the last two decades. The advantages of wireless communication play a major role. Technologies like 3G and 4G allow higher bandwidths; enable the users to switch from desktops to cell phones. Higher bandwidth internet connects the world in just clicks. About 73% of the world population (7740 million) is using cellular technology (As on 2017). In 2017-18 India overtook the US to have the world's largest wireless sector. The US has about 1150 million mobile cellular subscriptions whereas India has 1207 million subscriptions. The entire Europe has only 745 million subscriptions (Telecom statistics of India, 2017).[1]

The radio frequency spectrum used for cellular technology comes under Non-Ionizing Radiations (NIR). NIR is the portion of Electromagnetic Spectrum from radio waves to near ultraviolet region. NIR does not generally have sufficient energy to expel electrons from the atomic shells and to ionize matter and so is said to be less harmful. However, the long term exposure to NIR also may cause several health issues. The World Health Organization's agency for research on cancer described cell radiations as "possibly carcinogenic to human" in 2011[2]. There is no a clear boundary that separates the ionizing from the non-ionizing radiations. Ionization depends on many factors like characteristics of the tissues underexposure etc.

The International Commission on Non- Ionizing Radiation Protection (ICNIRP) issued guidelines for limiting radiation exposure to time-varying electric, magnetic and electromagnetic fields under 300GHz[3].There are two types of effects in the body due to radio frequency (RF) exposure – thermal effects and non- thermal effects. There are three basic coupling mechanisms through

which the time-varying fields interact with the body and other living matter (ICNIRP Guidelines, 1998; UNEP/WHO/IRPA, 1993).

- Coupling of the electric field
- Coupling of the magnetic field
- Absorption of energy from the electromagnetic field

Coupling of the electric field

The coupling of time-varying electric field produces a flow of charges (electric current) and polarization of bound charges in the human body, thus producing electric dipoles in the exposed tissues or reorients the existing dipoles. The magnitudes of the effects will depend on the electrical conductivity and permittivity of the tissues. This will depend on the type of tissues and the frequency of the applied field. As a result, the external field will induce a current inside the body and the magnitude will depend on the size of the exposed body parts and its orientation to the external field.

Coupling of the magnetic field

When the human body is in interaction with time-varying magnetic field, it induces electric fields and circulating electric currents (eddy currents) in the body. The magnitude of the current and the induced field will depend on the radius of the loop, electrical conductivity of the tissue and the rate of change of magnetic flux. The induced electric field will be directly proportional to the loop dimensions which in turn depends on the electrical conductivity and arrangement of tissues.

Absorption of energy from the electromagnetic field

Regarding absorption, the electromagnetic fields can be divided into four ranges

(1)Frequencies from 100 KHz – 20 MHz. Here significant absorption occurs at neck and legs.

(2)Frequencies from 20 MHz – 300MHz

Human body as a whole or parts of the body absorb electromagnetic energy. In some cases, partial absorption is higher than the whole body absorption due to multiple resonant. (Where the length of the body part is having similar length with the wave length, multiple resonances may occur).

(3)Frequencies from 300MHz – 10 GHz. Here absorption is mainly at partial body parts.

Frequencies above 10GHz. Here absorption is mainly at the body surface.

The effects due to the above three coupling mechanisms can be divided into two categories – thermal effects and non-thermal effects. The heating of body parts by absorption from the exposure fields is termed as thermal effects. When a human body is exposed to RF, it absorbs it because the body constitutes more than 70% of liquid. The water has the ability to absorb the RF and to produce heat. But the human body has the ability to dissipate the excess heat. But in parts like brain, joints, eyes, abdomen etc, where there is less mobilization of fluid, the heating effect may be cumulative. The effects due to the induction of electric current , electric dipoles or electric fields inside the body due to the electric and magnetic field coupling is termed as non-thermal effects. It may cause serious issues in tissues and nerves. This may damage the tissue, its characteristics or functions or may cause rupture of the narrow capillary walls, through which minerals come in and the toxins go out (e.g. Blood-brain barrier). The brain controls parts of the body by the communication through the nerves. The current flow through the nerves may be seriously affected by the induced currents and fields.

When the main axis of the body is in parallel with the radiation, the coupling and absorption will be the maximum. Also, children are more susceptible to the radiation because of their lesser height. The exposure may occur in both near field and far-field. In far-field conditions, the amount of exposure can be more accurately calculated because it completely obeys the electromagnetic field equations. But in near field conditions, the relation is more complicated (ICNIRP Guidelines, 1998).

There were no international standards exist for RF exposure control. Only two recommendations are available – by International Commission on Non-Ionizing Radiation Protection (ICNIRP) and by the

Federal Communications Commission (FCC). Many countries follow either of the two recommendations. Others follow their own rules. But actually both the recommendations consider only the thermal effects.

Many studies revealed the harmful effects of RF exposure. Bio-initiative reports in 2007 have been prepared by a group of scientists after a careful survey of several studies and reports, concluded that the existing RF exposure standards are inadequate to protect the safety of the public. (Bio-initiative reports, 2007.)[4] They proposed a maximum power density of1000 $\mu W/m^2$ for public exposure.

Experiments conducted by Young lab on rats found that the mobile phone radiation significantly opens the blood-brain barrier (Salford et al., 2003; Salford et al, 2009.)[5],[6] A study by Bahriye Sirav and Nesrin Seyhan of Gazi University (Bahriye et al, 2009[7]; Bahriye et al, 2016; Bahriye et al, 2011)[8] found a significant increase in albumin in the brain of rats after giving them sufficient amount of RF exposure. They also suggested that exposure to 0.9 to 1.8 GHz at levels below the international limits can affect the vascular permeability of the brain in male rats. The other studies which also concluded with similar results are (Smirnov et al, 2018; Emanuele, 2017; Farzaneh, 2017 Chauhan, 2017).[9]-[12]

Children are usually more susceptible to RF exposure. This is due to their lesser height, smaller head, higher conductivity etc. Many studies reported these facts. (Chhavi Raj Bhatt et al, 2017[13]; Camelia et. al, 2018[14]; Premlal et.al., 2018)[15]

Women, especially pregnant women, are at more risks than men.(Hava Bektas, 2018[16]; Hong Chen, 2017[17]; Murbach et.al, 2017[18]; Premlal et.al., 2018.) [19]Microwave radiation can damage the placental barriers and also affect the fetus. It also leads to malformation and behavioral problems in children. RF exposure can affect male fertility. Studies revealed that the exposure seriously affects the sperm count, quality and mobility.(Merhan, 2015[20]; Damayanthi, 2018[21]; Jong Jin Oh ET.AL., 2018)[22] .

Some studies confirm the release of calcium from cell membranes.(Zeinab et.al , 2017[23]; Shang-Ru et.al, 2017[24]; Buckner et.al., 2017[25]) This leads to neurological disorders in the brain. Studies reported that RF exposure causes single and double-strand breaks in DNA.(Kanu Megha et.al, 2015[26]; Tze Khee Chan, 2016[27]; Qingxia Hou et.al., 2015[28]) It also affects the replication and repair (Frauke Focke et.al, 2010[29]).

Tinnitus and ear damage are one relevant other effects of microwave exposure. Irreversible hearing loss is also reported. This is mainly due to the prolonged use of mobile phones.(Suhag AK et.al., 2016[30]; Yakymenko et.al., 2016[31]; Veronica Silva et.al., 2016[32]). Joint pain is another serious issue. Due to the long term exposure, the fluid in the joints will get heated up and evaporated slowly. This allows the links to come in to contact. The result is the wear and tear. (Dhami, 2012[33]; Nermin et.al., 2014[34])

Thermal effects can affect the vision system also. Prolonged exposure may cause a raise in temperature of the eye liquids and that may affect the lens transparency. Cataract at younger ages is one result. It may also affect the eye muscles and which in turn may affect the focusing abilities.(Wessapan et.al., 2012[35][36]; Havas et.al, 2010[37], Premlal et.al., 2017 [38]).

The habit of keeping the mobile phone in the bed during sleep or residing near the cell towers will cause sleep disorders and memory loss. Recuperation of the brain and the body will be affected by sleep time exposure.(Sage et.al., 2018[39]; Meysam et.al., 2016)[40].

The aim of this study is to examine whether any relationship exists between cell tower exposure and the above mentioned health issues. Also, we examined the common cell phone habits and the related exposure issues. The study was carried out in the state of Kerala, which has the highest population density and tower density in India, the largest mobile sector in the world. The mobile teledensity in India is 93.01(for 100 inhabitants). But Kerala has a teledensity of 114 which is equal to the teledensity of the United

States and more than that of Europe (108).(As on 2017-18).(Telecom statistics of India, 2017). Kerala has a population of 35 million with 43.28 million mobile subscriptions with 79247 Base Transceiver Stations (BTS). This may be the first time in the world, that a field study in such a larger area is conducted on this subject.

II. METHOD OF RESEARCH

There are four methods to study RF exposure.
Anatomical Model
Phantom Model
Computer Model
Power density approach
In Anatomical modelling, dead animals or their parts are used. In some cases living animals or plants are also used. In Phantom models, artificially created models are used. Numerical models and their simulations are the main components in Numerical modelling.
The three basic quantities are used to measure the level of radiation absorption,
Current density (J)
Specific Absorption Rate (SAR)
Power density (P_d)
Current density is an indication of the amount of induced current inside the body. But it is difficult to measure in real time. SAR is a measure of the amount of energy absorbed by the exposed body part. SAR has several disadvantages. It is the average of a small sample volume. It does not have a universal standard. In the United States, the sample tissue mass is 1gram and in Europe it is 10gram. Moreover, real time measurement of SAR is very difficult and not accurate. Power density is the amount of energy receives at a unit area. Power density S = E X H where E is the electric field intensity and H is the intensity of magnetic field. Only power density can be measured outside the body. It is accurate for far-field exposure measurements but less accurate in near fields. In near-fields, the relation between E and H are more complicated.
In the study of mobile tower exposure, power density approach (field study) is more accurate and convenient because it comes under far-field exposure.
Power density P_d at a distance R is given by

$$P_d = \left[\frac{P_T G_T}{4\pi R^2}\right]$$

Where P_T – Power of the transmitting antenna W

G_T – Gain of the antenna V/V

Sample size Calculation

Sample size has an important role in statistics to create accurate survey results. It depends on many factors like population size, the margin of error and confidence level. Higher confidence level and lesser margin of error will give the suited sample size for statistically significant results.

Necessary sample size

$$= (\text{Zscore}^{2)})2\text{STD. DEV}(1 - \text{STD. DEV}) / \text{margin of error}^2$$

Zscore depends on the confidence level and its value can be assigned from the Zscore charts.
In this study, the population size is 35 million, confidence level is 95% and the margin of error assigned is 3.5. Zscore value for the above confidence level is 1.96 (as from the Zscore chart). Assign a standard deviation value of 5, the sample size calculated is 784. So we took a higher value of 804 for our study.
For our study, we divided the state of Kerala into three regions – North, Central and South; each includes four or five districts. One district was chosen from each region considering several factors like geographical, cultural, food habits etc. The selected districts were, Alappuzha Idukki and Kozhikode . Alappuzha is a fully coastal district with the highest population density. Idukki is a high altitude district with a cool climate and is a part of the Western Ghats and most of its parts are ecologically sensitive. Kozhikode, on the other hand, is a district with coastal lands, plane lands and hilly forests. 44 cell towers were then selected for our examination purposes.
The examination area was then divided into two categories – Core Zone (CZ) and Outer Zone (OZ). CZ is the highly exposed area near any cell tower within a distance 300 meter. OZ is an area beyond CZ. Measured power density, electric field intensity and magnetic field intensities from the residences. In our examination, we included

ten diseases which were found to be relevant in previous studies. Data was collected using personal Interview method from the inhabitants. The device used is MECHO's radiation meter 9720. It is a three axes meter, can measure radiation strength from any direction. P, E, and H can be measured in various scales within 50MHz to 3.5 GHz.

Statistical analysis was done using the software SPSS. The tests conducted were T- test, independent sample test, Levene's test for equality of variance and ANOVA.

The diseases examined were

III. Infertility
IV. Autism, Down syndrome etc. in children
V. Ophthalmic problems at younger ages
VI. Joint pain, Rheumatic pain, Bone weakness
VII. Cancers and Tumors
VIII. Sleep disorder
IX. Memory loss
X. Headaches and related digestive issues (Migraine, IBS etc.)
XI. Heart Diseases, Hipper Blood pressure etc.
XII. Ear and hearing problems.

III.RESEARCH RESULTS

1. Cell Tower Exposure

We have conducted the above mentioned examinations in both CZ and OZ areas. Out of ten diseases, which were examined, nine are found to be closely related to the Cell tower exposure. The only variable which differentiates the two zones is RF exposure from the cell towers. The following diseases are found to be relevant.

1. Infertility

About 2.87% of married people under 40 years are found to be affected by infertility. Among this 78.26% are from Core Zone (CZ) and 21.74% are from Outer Zone (OZ). The mean power density is 467.98 W/m^2 with a standard deviation of 227.92 from the normal. This shows that the cause of 56.52% increase is due to mobile tower exposure.

2. Autism, Down syndrome and other such disabilities found in children

About 5.21% of the surveyed children are affected by these diseases. Among which 87.5% are from CZ and only 12.5% are from OZ. The 75% hike shows that the cell tower plays a major role. The mean radiation power density value of the victims' residence is 325.05 W/m^2 with a standard deviation of 277.88 from the normal.

3. Ophthalmic problems at younger ages

We studied the ophthalmic problems of the younger ones, it is found that 12.13% of the children under 15 years are affected while 18.64% of the youth under 30 years are also among the victims. Among them, 63.29 % are from CZ and 36.17% are from OZ. 27.12% increase is definitely due to the radiation exposure. Their residential exposure mean is 449.69 W/m^2 with a standard deviation of 277.72 from the radiation-free zone.

4. Joint pain,/Rheumatic pain,/Arthritis / Bone weakness

21.47% of the people under study are affected. Among this 72.67% are from CZ and 27.33% are from OZ. 45.34% increase is definitely due to mobile tower exposure. Gender wise study shows that among the affected, 63.95% are females while 36.05% are males. The victims live under a mean exposure of 365.89 W/m^2 with a standard deviation of 214.56 from the normal. The age wise comparison is as shown in Fig.1

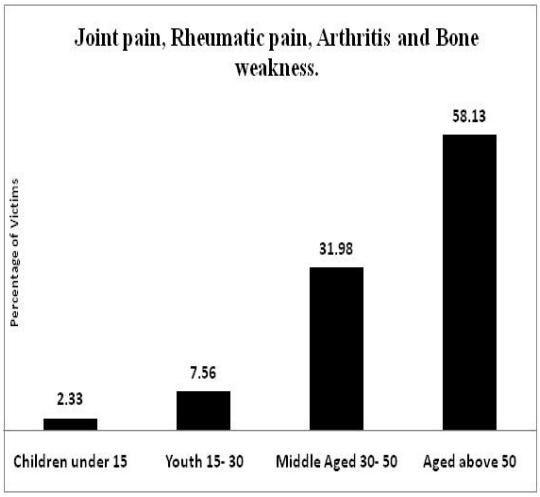

Fig.1 Age wise comparison of victims affected by Joint pain,/Rheumatic pain,/Arthritis / Bone weakness

5.Tumors and cancers

3.37% of the people are suffering. Among them, 81.48% are from CZ and 18.52% are from OZ. 62.96% increase is due to cell tower exposure. The victims' exposure level is 459.57W/m^2 with a standard deviation of 277.57 from the normal. Major victims are
male (59.26%), while females contribute 40.74%. The age wise comparison is as shown in Fig.2.

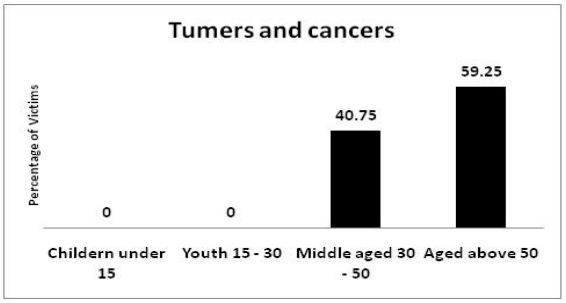

Fig.2. The age wise comparison of victims affected by tumors and cancers

6.Sleep Disorder

About 12.98% of the people are suffering from sleep disorder. Among them, 89.42% are from Core Zone and only 10.58% are from Outer radiation-free zone.78.84% increase points to the role of mobile tower radiation exposure The average radiation exposure of the victims is 470.38 W/m^2 with a standard deviation of 277.22. Females are more affected (53.85%) while male's contribution is 46.15%. The age wise comparison is as shown in Fig. 3.

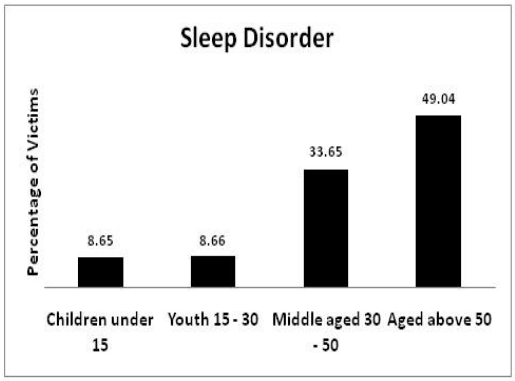

Fig.3 The age-wise comparison of victims affected by sleep disorder

7.Memory Loss

About 10.99% of the surveyed are suffering. Among them, 75% are from CZ and only 25% are from OZ. The 50% increase is definitely due to cell tower radiation. The mean power density of them is 399.93 W/m^2 with a standard deviation of 297.80. Female's contribution is 52.27% while males contribute 47.73%. The age wise comparison is as shown in Fig.4.

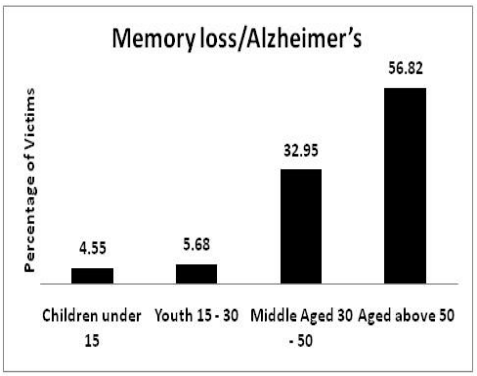

Fig.4 The age-wise comparison of victims affected by memory loss.

8.Headaches/Digestive problems

About 25.34% of the people suffering from the above diseases. Among them 63.05% from CZ and 36.95% from OZ. The mean exposure level is 314.61 W/m^2 with a standard deviation of 291.69 from the normal. The radiation plays a major role. Among the victims, 64.53% are females while 35.47% are males. The age wise contribution is as shown in Fig.5.

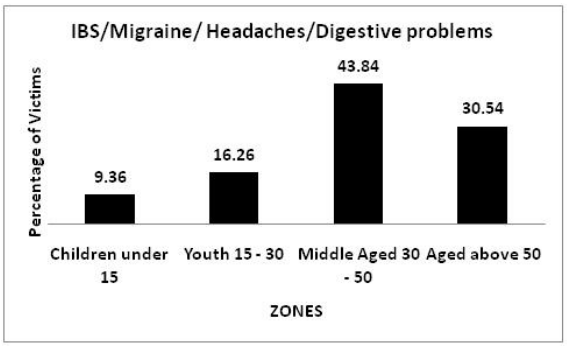

Fig.5 The age-wise comparison of victims affected by Headaches/Digestive problems

9.Ear and Hearing problems

About 15.61% of the surveyed are affected by ear related problems.70.40% are from CZ and 29.60% are from OZ. The mean radiation exposure level is 487.34 W/m^2 with a standard deviation of 315.46. Males affected are 53.91% and females affected are 46.09%. The age wise contributions are as shown in Fig.6.

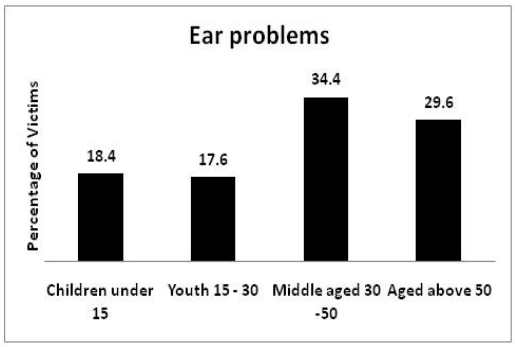

Fig.6 The age wise comparison of victims affected by ear problems.

People Living under Different Exposures

We also examined the number of people living in different exposure limits. The result is shown in Fig. 8. Our survey confirmed that more than 22% of the Kerala society is forced to live under an exposure more than the current Indian standard(470mW/m^2).This shows that the operators do not always implement the standards. The situation is disastrous.

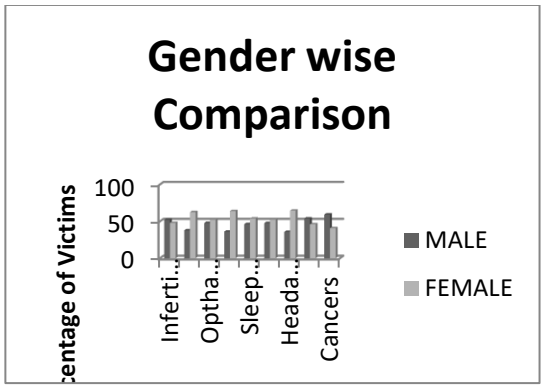

Fig.7 The gender wise comparison of victims affected by RF related problems

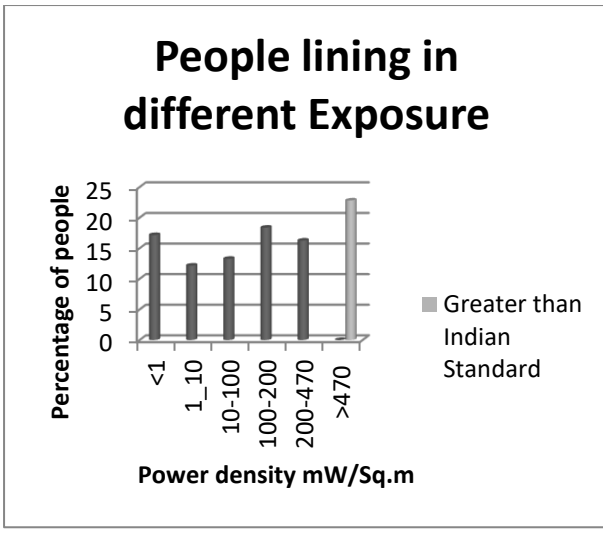

Fig. 8 Percentage of people living in different exposure limits.

Proposing a new RF exposure standard

Our study reveals that the current Indian standard for RF exposure is inadequate to protect society from the harmful effects of cell tower radiation. The Fig.9 shows that even well below the Indian standard (470 mW/m^2) , people have to suffer from the above diseases and the reason for such diseases is confirmed as RF exposure. In order to secure the society, we have to lower the limit. To find out an accurate and balanced value, we kept lowering the value of power density. At each of these values, we examined how many of the victim's current exposure level raised above that value. At a value of 280 mW/m^2, we found that 90% of the victims' exposure values have crossed that point. So we selected 280 mW/m^2 as the new standard value for power density instead of 470 mW/m^2.

Another term used is Emitted Radiated Power (ERP). It is the product of P_TG_T. The ERP for a cell tower must be standardized so that the maximum value of power density will not exceed 280 mW/m^2. This limit should be from 20m distance.

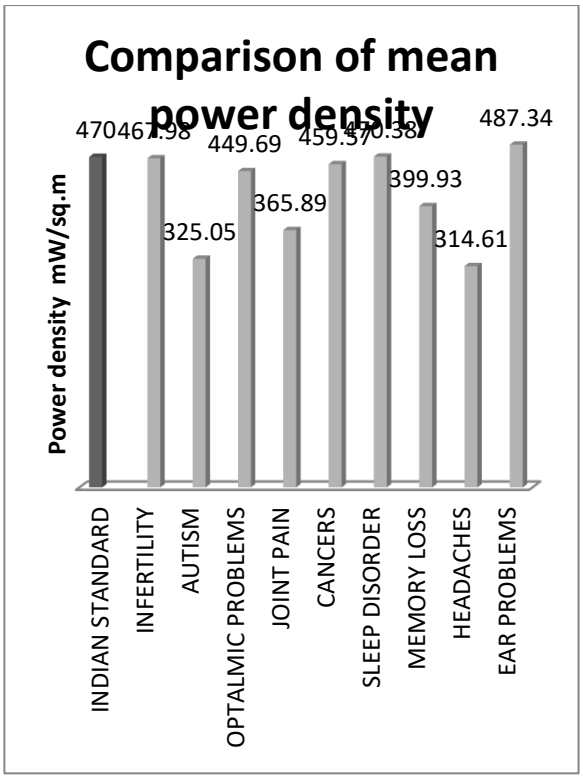

Fig.9 Comparison of the mean power density of victims with the Indian standard.

We have,

$$P_D = \frac{P_T\ G_T}{4\pi\ R^2}$$

$$P_TG_T = \text{ERP}$$

Therefore,

$$P_D = \frac{\text{ERP}}{4\pi\ R^2}$$

The new value for power density is 280 mW/m^2 and R = 20m

Then, ERP = 1407W

The cell tower emitted power should be minimized to 1407 W in a direction and it should be for the whole tower irrespective of the number of service providers and the number of antennas in that tower.

In our analysis, it is seen that the power density needed to operate a cell phone near full range is 0.2 mW/m^2. For an ERP of 1407W, at a distance of 1 km, the power density available is 0.399 mW/ m^2. That shows that the ERP of 1407W is very sufficient for proper coverage up to 1 Km from the cell tower.

IV Conclusion

Cell tower radiation levels in different areas of the state of Kerala have been measured. It is found that more than 22% of the people are forced to live in a higher exposure level than the current Indian standard of 470 mW/m^2 . Out of the ten diseases examined, nine are found to be strongly related to cell tower exposure. Females are found to be more prone to RF exposure ill effects. We designed a new standard based on our field study, for maximum power density (280 mW/m^2) and maximum emitted radiated power for a cell tower (1407W) irrespective of the number of antennas, carriers or operators. Our conclusion is that even though cell tower radiations are harmful, by implementing proper norms and better habits, we can live in harmony with the most wonderful communication technology. Our study area is limited to Kerala. But many studies in different parts of the world are required to confirm the results. Its effect on other biological species may also be examined.

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