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THE 5G TECHNOLOGY: CONCEPTS, BENEFITS AND CONCERNS

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Abstract: 5G, the fifth generation of RF (Radio Frequency) radiation, is on the verge of being implemented globally. Current communication systems/technology use electromagnetic field (EMF) in the range of Megahertz but the 5G will have EMFs in the GHz (Gigahertz) range. It is targeted to deliver huge network capacity, higher reliability, improved efficiency, extremely low latency, very high multi Gbps (Giga bytes per second) peak data speeds and a consistent higher performance user experience to more and more users. A lot is known about hazards from the 3G and 4G electromagnetic fields that are in use currently for cell phones and Wi-Fi (Wireless Fidelity) but very little is known about the 5G hazards and effects. A need to investigate its potential risks to the environment and human health is essential. In this paper we have tried to assimilate both the benefits and concerns of this new technology.

Keywords: Fifth generation, Hazards, Wireless, Radiations, Health Concerns, Spectrum, Electromagnetic

1. Introduction

5G, the highly advanced new global wireless standard networks, are cellular like its predecessors: 1G, 2G, 3G and 4G are the previous mobile network generations. The time and basic properties of each generation is summarized in Fig.1.

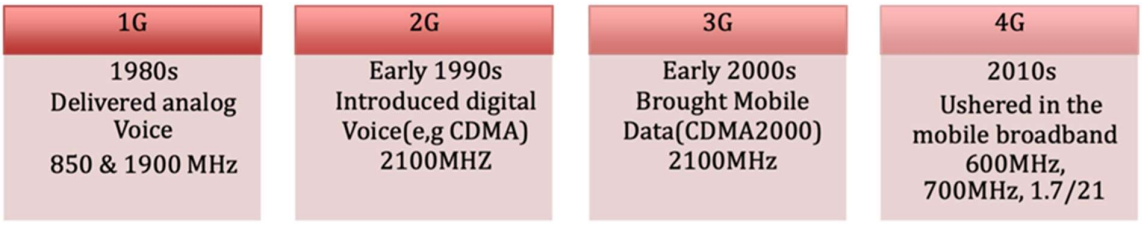

Fig.1 Past Evolution

The 2G -5G are referred to as cellular because of the creation of cells by the base stations. These refer to technology guidelines and standards for networks that are wireless and mobile. 5G, the planned successor to the 4G, is the fifth-generation technology standard in Tele-communications for broadband cellular networks and is on the cusp of leading a connectivity revolution as its implementation is steadily gaining momentum. The new wireless standard is

designed to virtually connect everything and everyone, be it devices, objects or machines. The devices that are on the move, be it an IoT (Internet of Things). device or an individual's cell phone, are provided wireless connectivity by these cellular networks. The devices include not only the traditional smartphones and tablets but will increasingly include medical devices, home appliances, robots, industrial and agricultural machines,drones, cars and many more. The GSM (Global Systems for Mobile Communication) association predicts that 5G networks will have over 1.7 billion subscribers worldwide by the year 2025. The technology has great potential and assures much faster data transfers. Lot of apprehensions are being expressed time and again around the adverse effects of this technology on the living. The debate on the possible harmful effects was rekindled by a recent lawsuit filed in the Bombay High Court by an Indian Actor who is an environmental Activist too. It [1] demands certification of safety for all living organisms besides the humans and for all times to come, not just for time being from the concerned department. The litigation demands more efficient research and data on the adverse effects of 5G. Such concerns around the safety of 5G has been raised many a times around the world.

2. Radio Spectrum and how 5G is different.

The electromagnetic spectrum includes all the different frequencies and wavelengths encompassing the Radio waves, the mm Wave (millimeter waves), microwaves, light and visible waves, X rays and gamma rays, Fig 2. The frequencies between 3kHz and 300GHz belong to the radio spectrum and all generations of the cellular networks occupy regions within this space. The effects of RF fields are relatively less studied in the millimeter(30-300Ghz) wave band, though the bio effects of RF fields of currently in use cellular bands have been undertaken extensively. As is evident from Fig. 2, [2] the millimeter waves lie just below the infra-red towards the higher end of the radio frequency spectrum.

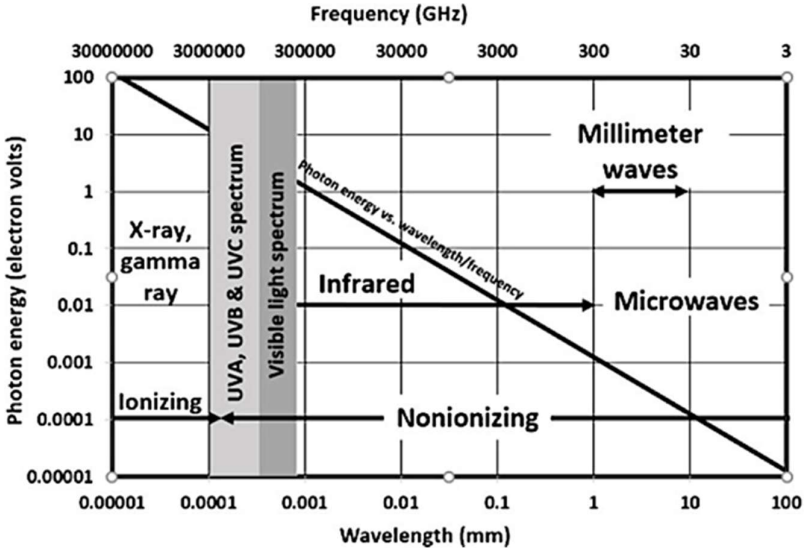

Fig. 2. Electromagnetic spectrum Vs Photon energy [2]

There are two main categories of EMF, Fig. 3

1. Ionizing: includes X, Gamma and ultraviolet rays. Energy from such radiation can cause cancer and damage human cells.

2. Non-ionizing: low frequency, large wavelength. Experts believe these produces thermal effects and biological structures that are temperature sensitive and can adversely affect if exposure levels are high [3]

5G is employing higher frequencies and millimeter wavelengths compared to the existing current technologies and therefore requires a substantial extensive grid of transmitting devices and antennas. Its an established fact that higher frequencies and shorter wavelengths are more powerful than lower frequencies and longer wavelengths in terms of energy or more specifically electromagnetic fields. The 5G networks transmit data remarkably faster than the 4G/3G/2G technologies as they have higher bandwidths, superior reliability and shorter, almost negligible, latency. As the 5G networks use higher frequency, shorter wavelength waves, these can travel shorter distances as compared to 4G. Consequently, 5G needs more ground-based transmitters and like all radio waves 5G too gives out electromagnetic radiation. The safety apprehension is about such radiations and their effect on the environment and living organisms. Further the expanding number of cellular towers or transmitters which are inevitable for 5G coverage will eventually impact a much larger number of people than ever before and increase exposure to the potential harmful effects of radiation.

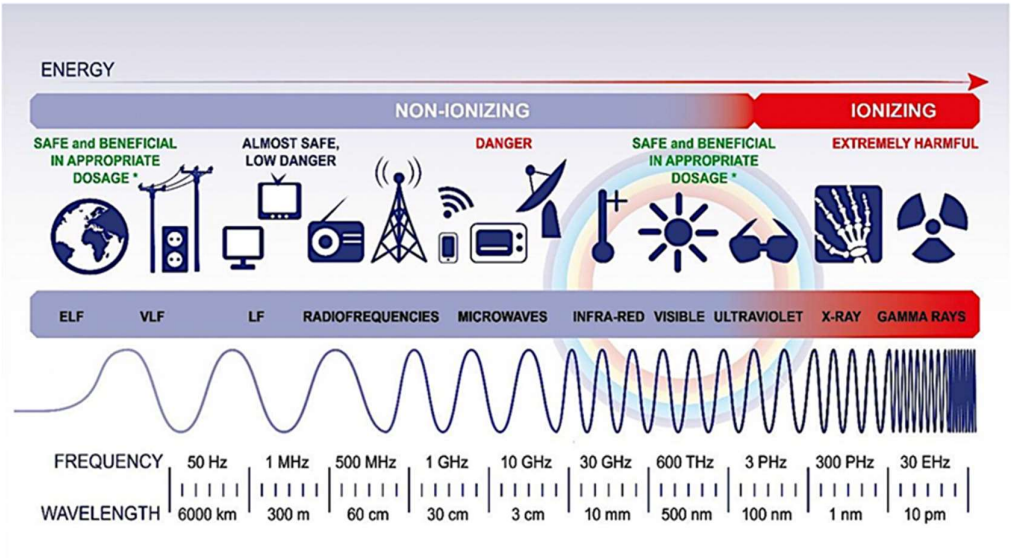

Fig. 3. Electromagnetic Spectrum: Source [3]

3. The Future Benefits with 5G

We now investigate what all is possible with 5G by delving a little deeper [4]. 5G when combined with Technologies like Augmented Reality (AR) and Artificial Intelligence (AI) can create an incredibly astounding new reality. Shopping will evolve and get a new dimension. The camera of your smartphone fortified with the power of 5G and on an AI device will enable consumers to view a 3D model of the object under consideration for purchase by simply reading the detailed specifications of the product. This will be a different feel altogether from just trying to imagine it. The 5G speed is vital with Augmented Reality to superimpose an object under consideration onto the location.

Another evolution that 5G will bring is with the concept of socializing. The fast data speeds coupled with high capacity and low latency will enable multiple people to collaboratively

share, edit videos and photos real-time in a seamless uncomplicated manner. Video especially needs higher bandwidths. Trimming them or adding filters to them or to the photos will not experience lags with 5G in place. Using Artificial Intelligence will help in recognition of family, friends, places, recurrent events and splicing will be a cinch using

recommendation models. The real-time collaboration will be an ultimate experience. We feel three main areas, Fig.4, will witness a paradigm change, [4]

- Mobile Broadband: 5G mobile technology will impact the smartphones with lower latency, uniform and fasterdata rates and lower cost per bit in addition to more riveting experience of AR and VR.
- Critical Services: The technology with its low latency and immensely reliable availability will enable new facilities and services like control of vehicles and critical or unapproachable infrastructure remotely and possibly medical procedures as well.
- (IOT): With its ability to scale down mobility, power and perhaps data rates, 5G will eventually provide low cost and lean connectivity as it is meant to connect the embedded sensors in practically everything.

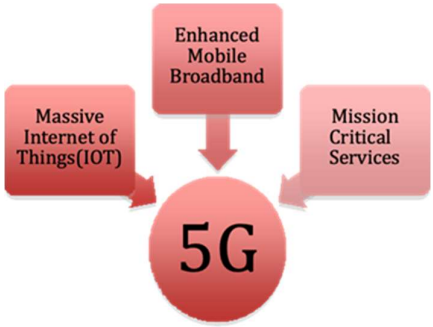

Fig 4. 5G High Impact areas

The personal mobile phones are progressively becoming the source of entertainment and media. There is a massive ever-increasing growth in video data as well as cloud computing experiences. 4G enabled us to

witness a leap in the way information is consumed. The mobile ecosystem will be further expanded to new industries with 5G. Instant cloud access, local interactive content, seamless IoT, extreme reality (XR) is some cutting edge in the pipeline experiences which 5G will contribute to. It supports augmented reality

applications and real time 5G communications will help accomplish remote repairs and surgeries significantly. Multiple users benefit simultaneously as this high-capacity upgrade permits transmission of multiple high-resolution streams without causing congestion on wireless networks. It is estimated that on an average a consumer is likely to use more than 11GB data every month by beginning 2023.

The Internet became essential to modern life, throughout the COVID-19 pandemic for a variety of reasons, including providing a source of food, employment, education, healthcare services, news information, and entertainment. With its increased speed, power, and connection, 5G will pave the way for several initiatives aimed at preserving and protecting the planet. 5G technology with IoT will lower greenhouse emissions, boost efficiency and promote renewable energy consumption. It may aid in the prevention of habitat loss, the conservation of resources

such as water and food, and the preservation of endangered species. It may also help us understand and make better decisions regarding meteorology, farming, agricultural pests, manufacturing sector, waste management, and more. [5]

Role of 5G in Reducing Wastage of Food and Water

- Water pollution as well as contamination can be detected by smart water sensor thereby preventing household waste leaks.
- Sensors can also be employed to efficiently optimize usage of water for irrigation, utilizing

smart agricultural sensors equipped with information about weather, soil and crop conditions. In addition to helping with harvest planning, the devices keep track of plant stress, nutritional levels, and pests. According to the UN, almost 1/3rd of the world's food is annually wasted, thereby squandering all the water and energy that was utilized for its production. With the agricultural sensors' ability to detect the status of a plant's withering, harvests may be timed more accurately. Sensors can check and determine whether food is fresh and safe to eat. 5G might be used to smart tag all agricultural produce from the time of its harvest at the source, till it arrives at its destination. Other sensor systems may keep tabs on the plant, like checking the food for safety and quality, in accordance with the regulations. Having the correct ingredients supplied on time and correctly packed might be facilitated by a transparent and automated system. In addition to allowing for faster responses to supply and demand challenges, this would also assist in optimizing food safety, assess a product's sustainability, and minimize any food waste [6].

Role of 5G in Reducing Energy Consumption and Emissions

- 5G is expected to use much less power than 4G while sending the same amount of data, as per international standards. In 4G, it takes 1kWh of energy to download around three hundred HD films whereas with5G, the same amount of energy may download 5,000 UHD movies.
- 5G together with Internet of Things is foreseen to reduce energy consumption since gadgets will switch on or off automatically as per the requirement. Buildings, Transportation, Appliances, Industries, Streetlights, Homes, etc. will all be equipped with sensors to optimize the energy use and demands. The installation of smart power meters would contribute to a reduction in energy expenses.
- It is anticipated that the program would decrease carbon emissions and fuel consumption because of energy conservation.
- In the event of a power outage or other disruption to the main grid, 5G and the Internet of Things will allow for the rapid deployment of alternative microgrids to sustain service. This will allow for greater integration of variable renewable sources of energy such as wind and solar into the system.
- Greenhouse emissions from automobiles will be reduced and energy will be saved with 5G and aircraft by facilitating remote work and/or entertainment thereby reducing the need to commute and travel for business.
- If traveling is necessary, 5G changes traffic signals in real-time to prevent delays, by reducing traffic congestion and maintaining traffic flow, reducing idling to save time,

fuel, and emissions from vehicles. Utilizing sensors and cameras, it facilitates ride sharing and assists drivers in finding parking spots. 5G may also help decrease the number of automobiles on the road.

Role of 5G in Protecting Nature

- To prevent sewage from polluting rivers, installation of smart sewer technology in manholes

would reduce sewage overflows and save the city from having to spend money for the task.

- Toxic Blue-green algae blooms appear in water bodies when the temperature of the water become more than usual. These are harmful to the local ecology, people, and animals. They are normally monitored by observation from the shore. Use of 5G drones equipped with sensors and cameras to detect the real time growth of blue-green algae would make it feasible to identify the algae in unreachable areas and such information would enable timely actions and protect environment.
- The use of marine buoys equipped with sensors enabled with IoT to detect real time barometric pressure, ocean surface temperatures and currents would help track ocean changes and understand its behavior.
- AI recorders help in alerting illegal activities as these perceive the sounds made by various machinery and chain saws. They help prevent illegal poaching as they pick up sounds made by distressed animals. Recorders equipped with 5G and AI could identify the sounds of chainsaws and other equipment, immediately notifying rangers of unlawful logging and averting further destruction of the forest. They would be able to tell the difference between normal animal noises and those of stressed animals, allowing rangers to act swiftly to prevent poaching.
- 5G geo location technology is being used by the International Union for the Conservation of Nature to monitor health parameters, location, and movement of the endangered animal species. The technology helps to collect data on their behavior to better protect them and promote their reproduction. Breeding them requires careful observation of their ovulation cycle and they are encouraged to mate by the technology, which recognizes their mating cries and plays them back to them.

4. Concerns around Implications of Fifth Generation, 5G, (2500 MHz) Wireless Technology

Since the 1990s the sequential generations, or as they are popularly called the G's, of wireless technology have been consistently advancing communication across the continents. Wireless technology is based on transmission of energy waves. From 2G in the early nineties to 4G, all technologies have used continuously higher frequency. The latest 5G technology will use frequencies upto 90 GHz and data carried by such waves are transmitted very rapidly. But the concern is its effect on health and well-being. Similar apprehensions surfaced for 3G and 4G too but now with 5G the risks are critically higher. The long-term ill effects of radiation are not well studied. Further the ill effects on fauna and flora too need to be studied. Dr L V Krishnan, former Director of Safety Research and Health Physics Programmes at the Indira Gandhi Centre for Atomic Research, Kalpakkam and some other visionaries have pointed out instances where animals and birds have succumbed to death after 5G experimentation. The 5G and

mortality connect has not been established yet but not conclusively refuted either. The benefit of technology cannot be undermined but comprehensive studies should be undertaken to ensure safety of all. Many recent publications have affirmed that EMF does adversely affect all living organisms. These include negative consequences on general well- being, neurological turmoil, memory and learning setbacks, increased cancer susceptibility, adverse changes in reproductive system, genetic redressal, cellular stress to name a few. More than 2000 publications in professional journals have voiced the concern, majority being experts on effects of non- ionizing radiation.

5G is a technology that is new, and how it will impact the environment over time is not fully explored. The high-frequency electromagnetic radiation and its effects have been the subject of several studies; however, they do not establish that animals are endangered by 5G technology. However, some experts do believe that 5G poses a significant danger even though it is yet uncertain how it may impact animal /human health Wildlife and birds may be affected by 5G's high-frequency electromagnetic radiation. Cell phone radiation may harm their nervous systems and induce overheating, according to scientists. These radiations might be harmful for living creatures though can't be said with certainty. And discounting the possibility that they could have an impact on ecosystems is also not happening. Researchers warn that 5G technology may harm birds, reptiles, and insects. Extended exposure to high-frequency radiation may negatively impact animals, although it's difficult to ascertain [7].

The circadian rhythms of all organisms is regulated by the electromagnetic field of the Earth. The environment stability and the properties of Earth are essential to the survival of all forms of life. A change in the Earth's natural electromagnetic environment may be a higher risk than the radiation produced by the antennas [8]. The presence of 5G satellites stationed in Earth's magnetosphere will significantly impact the natural global electrical circuit of each living organism. There are enough reasons to be anxious about the risks linked with using Smartphone's and other wireless devices, but with the advent of new generation cellular technology, there is certainly more cause for alarm.

All living things, including humans, animals, birds, insects, plants, trees, [9] and microorganisms, are currently exposed to non-ionizing microwave radiation. Immobile living trees are good candidates for investigating the effects of radio frequency radiations from phone towers on plants. It was observed that proximity to cell phone towers damages trees in such a way that the damage usually starts on one side before spreading. The damages to the crown are most significant towards the side of the crown which is facing the tower. Unusual coloration, wilting, spatial and temporal alterations in leaf colors, elongated shoots, alteration in branching characteristics, and lifeless branches are some of the visible symptoms.

A study by the Punjab University reports that sparrows with exposure of 5 to 30 minutes to radiation from cell tower radiation produced eggs which were disfigured. A study undertaken in Spain reported that this EM radiation messed up the nesting and breeding habits of birds. Since the future 5G will eventually have a high concertation of base stations over regions, birds' short-term exposure to these frequencies will be significant. So many small cells in bird environments may cause mutations that threaten their survival, [10]. Birds may suffer loss of feathers and loss of mobility; they may abandon their nests and have a lower chance of survival.

Electromagnetic noise interference caused by usage of global wireless radiofrequency is disruptive for the navigational process of insects, birds, and bees. Stars serve as a navigational aid for migratory birds. When there are more satellites than stars in the sky, we don't know how it will influence them. Carcinogenicity studies in rodents have shown that RFR exposures significantly increased chromosomal DNA damage [11].
The constructing new high- quality network infrastructure would require cutting edge components, requiring extraction of a plethora of non-recyclable minerals and use of a dwindling supply of non-renewable resources which might have negative impact on the environment according to the opponents of 5G. Mining of columbite-tantalite or coltan for beingused to make electronic devices in the Democratic Republic of Congo which is rich in minerals, is destroying forest flora and fauna and threatening to endanger primates like Grauer's Gorillas to the point of extinction.

With the advent of 5G mobile communications, it will be necessary to launch rockets to install 5G satellites throughout the globe to establish a global wireless network. Launching 5G satellites would add more toxic substances to the space debris and worsen the situation in the earth's orbit in terms of global air circulation, ozone distributions, and temperature, [12]. In addition to ruining the natural beauty of the night sky due to the bright light that the satellites emit, they will also affect supernovae, flare, measurement, and identification of variable stars. The 5G deployment will result in junking a huge number of smartphones as they will not be able to support this new technology. These huge e wastes are bound to have a negative influence on our already strained ecosystems. Concerns have also been raised that the body s circadian rhythms that is responsible for reproduction and sleep patterns may also be disturbed by the 5G frequencies, [13]. The expansion of the new communication system will also lead to a significant energy demand, which will undoubtedly hasten the onset of a new period of global warming. The implementation of cutting-edge 5G will also lead to substantial resource depletion and the production of massive amounts of waste. Furthermore, running the whole 5G network, being more energy-intensive would require three times as much energy as the current 4G network. In the next five years, the energy needs of mobile carriers may increase. The environmental cost of generation of all the additional energy required will significantly impact the environment. These are some of the concerns that need to be investigated, [14]. These initiatives will damage the land and pollute the water supply. Additionally, the process will emit a large quantity of toxic gasses into the atmosphere, which will contribute to air pollution and, in turn, global warming. The world is facing a global crisis that, if not addressed immediately, threatens all aspects of our lives. 5G is being implemented at a time when energy optimization is a big challenge, and it can play a significant role in assisting every industry in meeting sustainability goals by enabling them to transform their processes and behavior, [6].
Exposure to radiation has been a cause of anxiety for the general public and policymakers. Radio frequency radiation and its exposure to humans has increased dramatically since the invention of radar during World War II. RFR was deemed as a "possible" carcinogen in the year 2011 by IARC. Although 5G is non-ionizing because of its low wavelength and range, it still presents a potential threat. 5G will certainly raise the quantity of radiation in the air, which could lead to a higher risk of disease and mortality. There may also be a huge increase in the

digital carbon footprint, which would mean that 5G has the potential to add significantly to climate change.

5. Ostensible Health Concerns of 5G RF radiation on Humans

- Skin Effects: High power density levels of RF exposure can cause rise in the temperature of body tissue exposed to it and lead to mild skin burns [15]
- Eye Damage: Excessive high density RF exposure can lead to serious cornea issues, retinas damages, cataracts, and other eye distresses [16]
- Cancer: The IARC (The International Agency on Research on Cancer) in 2010 claimed that the non- ionizing cell phone RF radiation has a high likelihood of being carcinogenic. Since then, various studies on rats exposed to RF have statistically established a marked rise in atypical cancers [17].
- Fertility: The fertility ability of the male sperm has been found to be negatively affected under high

RF exposure though it's not yet proven if the same will happen from exposure to communication resources.

- Electromagnetic Hypersensitivity: Some studies have reported hypersensitivity issues and symptoms like rashes, burning sensations, stress, fatigue, and headaches when exposed to RF radiation. Though some independent parallel researches have demonstrated otherwise too [18]
- Disease Spread: Some theories have lately claimed a connect between spread of COIVD -19 and 5G equipment RF radiation which so far have not been proved [19].
- Metabolism: A study has shown the adverse effect of RF on glucose metabolism in cells of humans. To improve the 5G signal strength trees are being cut which may increase the air carbon dioxide lining RF from 5G to health issues. [20]

6. Conclusion

There has been a lot of anxiety and fear around the use of wireless signals, and these predate 5G technology. To allay public fears, several government and telecom providers have issued statements to assure the public about the safety of 5G radiation. Despite the confirmation from the FCC (Federal Communication Commission) that 5G technology is safe for human, numerous concerns remain. 5G's usage of energy, the infrastructure and gadgets have raised worries about its environmental impact. Several research have raised concerns on these grounds. 5G has been designed to operate across awide range of the RF spectrum. Despite grave health concerns on 5G, the fifth generation, wireless communications is set to hit the world. Many concerns have been raised and debates created by people worldwide. The belief that "the lower frequency bands for 5G (up to 3.5 GHz) have already been used for telecommunications applications and Wi-Fi for years without resulting in any proven adverse health effects" is misleading. There is enough evidence from experimentation on humans, animals and cells showing that the telecommunications frequencies are harmful for the environment and the humans [21],[22],[23]. The populations are threatened and a proper unbiased risk evaluation is needed. Variations in the cell membrane permeability, effects due

to elevation of temperature and nerve stimulation are the substantiated pernicious effects on health caused by exposure to RF emfs (radio frequency radiation) [24].

While the smart mobile phone has become an indispensable appendage for almost all of us, we need to ensure that we undertake certain precautions to remain safe, till more research is undertaken: We are totally dependent on our smartphones. We rely on them for every aspect of our life today, and it is difficult to think how we could get by without them. People could not be bothered about the thought that smartphones are potentially harmful for their health. Probably the following will be useful while using a smartphone.

- Limit your use.
- Talk for short durations.
- Texting should be preferred.
- Preferable to use phones with lower Specific Absorption Rate (SAR) value.

Acknowledgement

None

Compliance with Ethical Standards

1. Disclosure of Potential Conflict of Interest:

The authors declare that they have no potential conflict of interest.

2. Statement of Animal and Human Rights

i. Ethical Approval

All applicable institutional and/or national guidelines for the care and use of animals werefollowed.

ii. Informed Consent

For this type of analysis formal consent is not needed

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