Comparative Study of Specific Absorption Rate Analysis of Selected Cell Phone Brands around the Head in Kathmandu Valley

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ABSTRACT

The electric fields emitted by commonly used cell phones of various brands were measured at different conditions by using 'Tenmars, TM196'. The specific absorption rate (SAR) around the head was calculated using ICNIRP guidelines. SAR value is crucial to minimize radiation exposure. It was observed that the maximum regular exposure to radiation occurred in dialing, ringing, and receiving modes. Among the studied smartphones, four out of five devices from Huawei and Xiaomi were found to have more SAR values in the range of 0.009 to 0.012 W/kg at the idle condition and 0.016 to 0.021 W/kg at dialing, ringing, and receiving cases whereas four out of five devices from Samsung were found to have low SAR values in the range of 0.004 to 0.009 W/kg at the idle condition and 0.008 to 0.016 W/kg in dialing, ringing and receiving cases. Non-smart phones emitted negligible radiation in idle conditions with SAR values in the range of 9.10×10^{-5} to 1.64×10^{-4} W/kg, but in dialing, ringing, and receiving modes, these phones have higher SAR values of 0.016 to 0.022 W/kg. It is hoped that the SAR values will be useful to mobile users in selecting the appropriate brand of cell phone to minimize the long-term health implications due to radiofrequency exposure.

Keywords: Cell-phone, Electric-Field, ICNIRP, Radiofrequency, SAR

Introduction

In the global communication industry, cell phones have grown unprecedentedly and are still in progressive mode. By the end of 2018, 5.1 billion people worldwide subscribed to mobile services, accounting for 67% of the global population (Stryjak, 2019; Sivakumaran, 2019).

Cell phones function by sending and receiving signals in the form of radio waves to the nearby cell towers called a base station. Cell phones emit radiation in the range of microwaves while in use and also, low radio waves while in standby or idle cases. The human tissues contain free and bound charges which are shifted from the original position causing polarization and ionic drift when the external electric field is applied to the tissues. This may cause ionic diffusion at the site of the cell membrane and hinder the intercellular and extracellular movement of ions (Zielgelberger, 2009). Since the cell phone emits non-ionizing radiation from its antennae, parts of our body in close contact with the cell phone can absorb this energy. At such locations, living tissue becomes more susceptible to the initiation of biological effects (Panagopoulos et al., 2015). As such studies on exposures from base stations in Nepal have been reported by Parajuli et al., 2015 and Thapa et al., 2016.

The dose of the absorbed energy is estimated using a measure called the specific absorption rate (SAR), which is expressed in watts per kilogram (W/kg) of body weight. According to ICNIRP and WHO, the SAR limit for mobile devices is 2 W/kg. The FCC limit for public exposure from cellular telephones is the SAR level of 1.6 W/kg (Gandhi, 2019). A study to evaluate the effects of radiofrequency (RF) radiation emitted from a mobile phone GSM 900 MHz at SAR value of 2.287 W/kg revealed that the accumulating dose of GSM 900-MHz RF-EMF might induce devastating effects on neural stem cells (NSC) proliferation and neurogenesis which implicates a more cautious use of mobile phones especially in long durations (Eghlidospour et al., 2017). Some of the commonly reported symptoms of RF exposure sickness are due to heating of biological tissue, an increase in body temperature and tissue damage in humans along with fatigue, sleep disturbance, difficulty in concentrating, depression, memory loss, visual disruptions, hearing disruptions and nausea (Santini et al., 2003). Further overuse of mobile phones may cause psychological illness such as tactile hallucinations, insecurity, delusions, auditory sleep disturbances, insomnia, lower self-confidence, and mobile phone addiction disorders (Parasuraman et al., 2017).

Materials and Methods

The commonly available brands of cell phones in the Kathmandu valley were chosen as the sample of this experiment. It included smart cell-phones, non-smart cell-phones, and one unregistered (from the unknown company) cell phone. The electric fields emitted by those cell-phones were measured when handling under the bandwidth of 2100 MHz (3G network) of Nepal Telecom. The electric fields emitted by the cell-phones were measured by using ‘Tenmars TM-196’ by placing mobile phones near it (Fig. 1). It is the radiofrequency (RF) meter that measures

electric field strength and works on the principle of electromagnetic induction, similar to that used in any electrical transformer. The sensor present in the device consists of a simple wire coil wound around a conductive core or transformer. As the coil is moved through a static magnetic field or is exposed to a moving magnetic field, a voltage is generated within the coil which can be measured and directly related to the present level of radiation. The voltage produced within the coil by the external magnetic field is small and it needs to be amplified many times in order to be used in driving the measurement display circuit of the meter (TM-196 User Manual, 2016).

Fig. 1: Experimental set up: Recording of the electric field of a cell-phone by TM-196

The electric field present in the room due to other devices was measured as background radiation before taking a measurement of the cell-phone. Then, the maximum electric field emitted by the cell-phone was measured and noted. The electric fields emitted by the cell-phones in this experiment were recorded for idle, dialing, ringing and receiving modes. The measurement for every cell-phone was repeated ten times in every mode to avoid random errors. Those phones were kept in normal mode with disabling Bluetooth, WI-FI, and vibration mode. The battery life of every cell-phone was maintained above fifty percent during measurement. The behavior of electric fields emitted by cell-phones was analyzed at different distances in idle mode of every cell phone. Further, these phones were kept up to 60 cm at interval of 15 cm while recording the value of field strength.

The net electric fields emitted by cell-phones were then calculated as:

Electric field (mobile) = Electric field (measured) - Electric field (background).

Calculation of SAR

Specific Absorption Rate (SAR) was measured by the equation developed by the International Commission on Non-ionizing Radiation Protection (ICNIRP) (Zielgelberger, 2009).

$$SAR = \frac{\sigma |E|^2}{\rho} \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

E = induced electric field strength (V/m)
σ = tissue conductivity (S/m)
ρ = physical density (kg/m^3) and
|E| = root mean square value of the electric field.

The tissue conductivity of the tissues present in our head (brain) was taken from tissue frequency chart developed by 'The Foundation for Research on Information Technologies in Society (IT'IS)' research foundation established in 1999 through the initiative and support of the Swiss Federal Institute of Technology (ETH) Zurich, the global wireless communications industry, and several other governmental agencies (Tissue Frequency Chart, 2020) .

With the help of a tissue conductivity chart, the conductivity of the human head at 2100 MHz is found to be 1.34 S/m (Tissue Frequency Chart, 2020).

The density of the human head (ρ) for male is 1041.6 Kg/m^3 and for female is 1041.0 Kg/m^3 (Barber et al., 1970). The mean density of the human head has been taken as 1041 Kg/m^3 as an approximate value.

The root mean square (RMS) value of the electric field has been calculated by dividing the recorded maximum electric field of every cell-phone by '√2' (Ling et al., 2016).

The value of a specific absorption rate (SAR) for different cell-phones was calculated by substituting the above-generated values of electrical conductivity of head, the density of head, and average electric fields using equation 1.

Results and Discussion

Specific Absorption Rate (SAR) at the different conditions of cell phones

Cell phones do not emit radiations in switched off conditions and in flight mode as its transmitter and receivers are functionless at that moment. The electric field strength, RMS Value and the SAR value of different cell phones were measured

and their variations in different modes are shown in Fig. 2, Fig. 3 and Fig. 4 respectively.

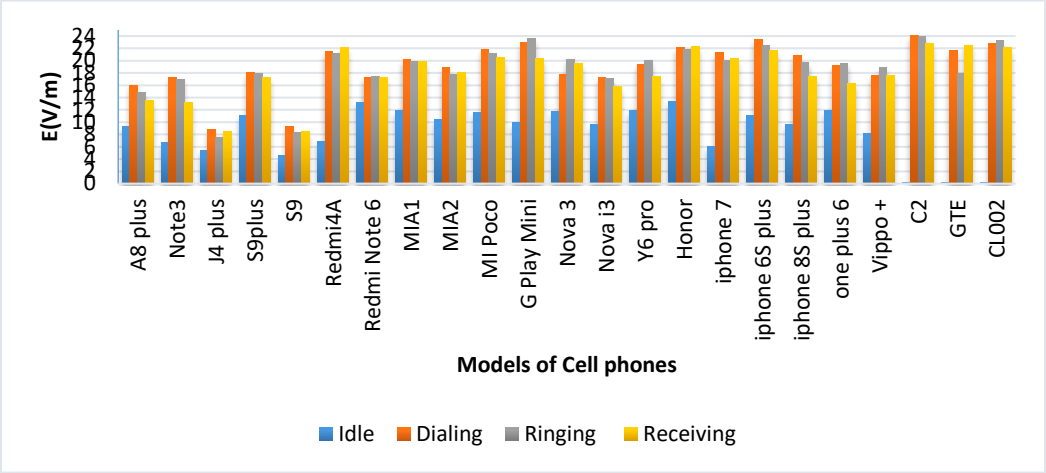


Fig. 2: Variation of the electric field of different cell phones in different modes

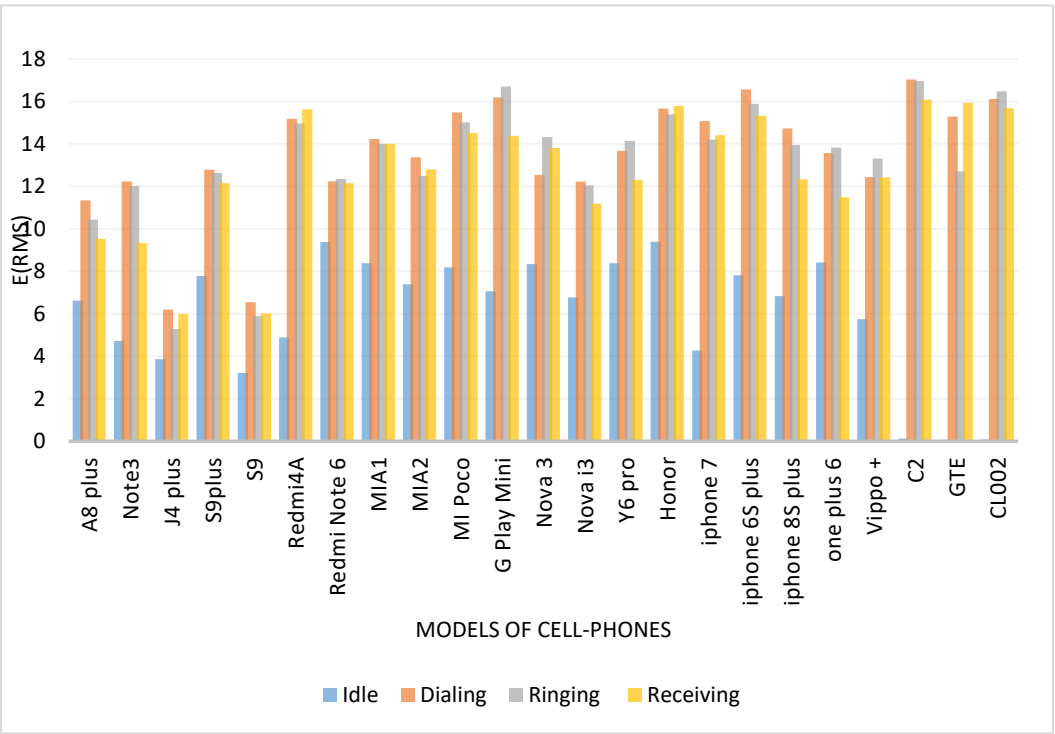


Fig. 3: Variation of E (RMS) with different cell-hones in different modes.

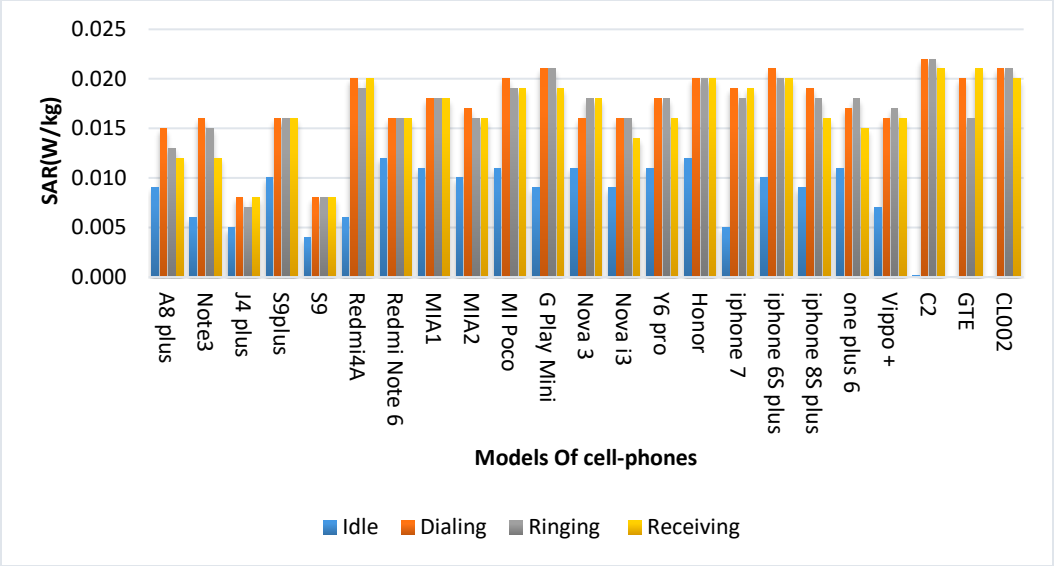


Fig. 4: Variation of SAR of different cell phones in different modes.

Variation of Electric Field Strength with distance

Measured electric field strengths with distance from the phone of various brands available in Kathmandu Valley have been plotted through Fig. 5 to Fig. 9:

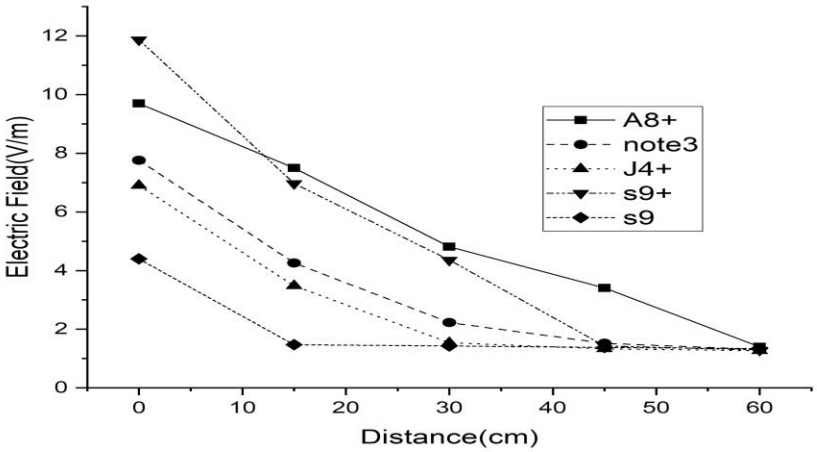


Fig. 5: Electric field strengths with distance for Samsung cell phones.

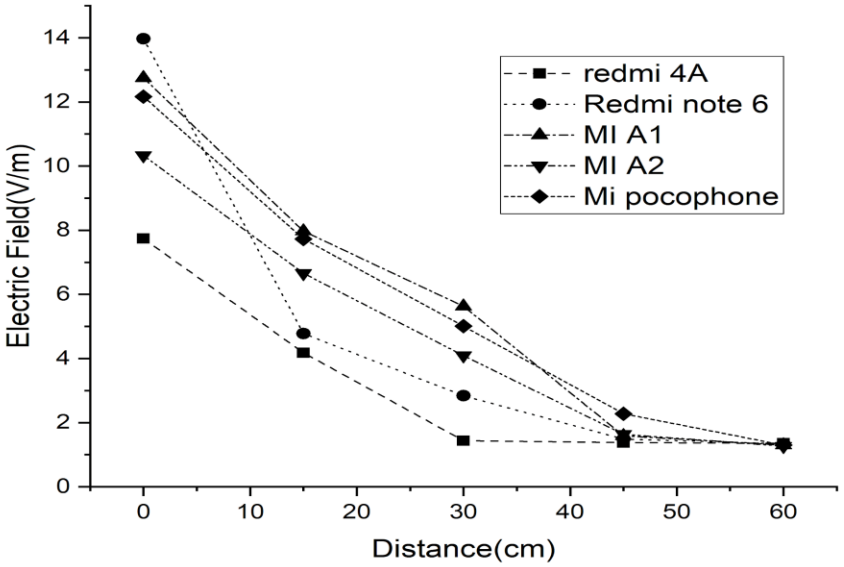


Fig. 6: Electric field strengths with distance for Xiaomi cell phones

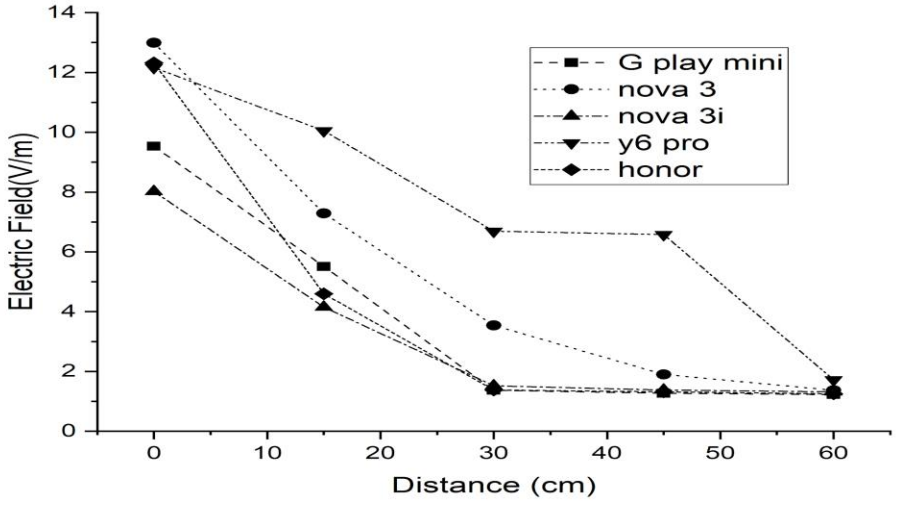
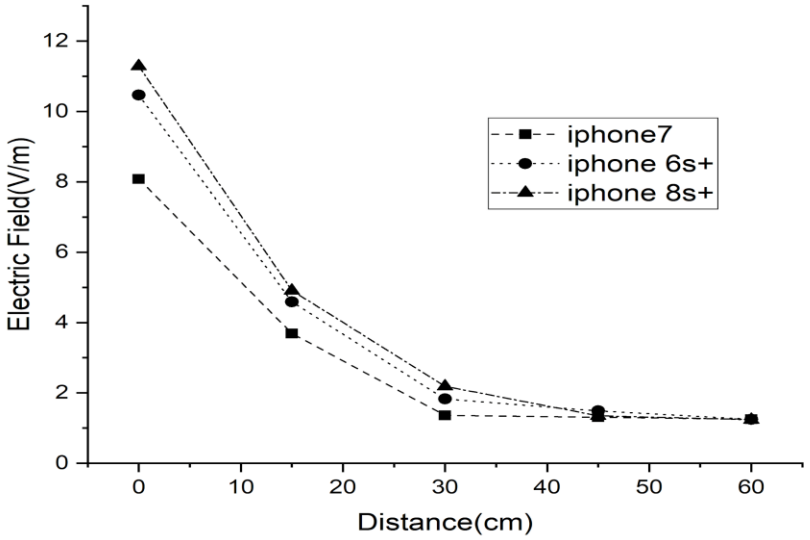


Fig. 7: Electric field strengths with distance for Huawei Cell phones.



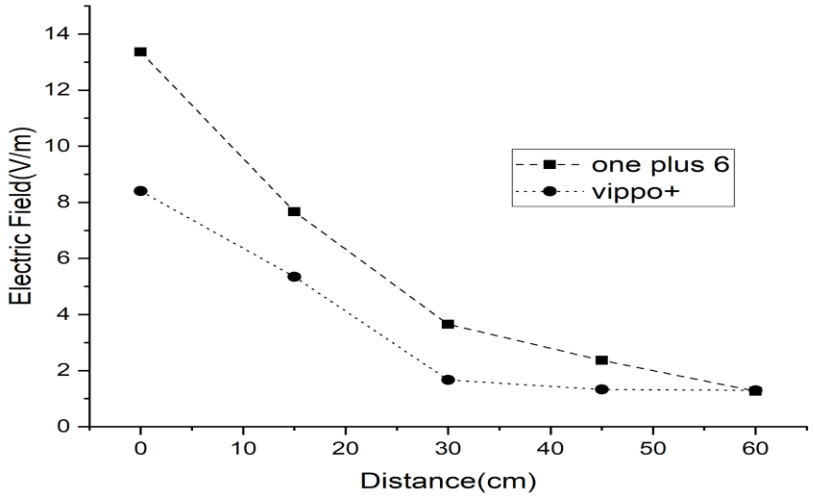


Fig. 8: Electric field strengths with distance for Apple Cell phones.

Fig. 9: Electric field strengths with distance for other cell phones.

The Figure 2 clearly shows the comparison of electric fields emitted by different models of cell phones in different conditions. In the idle case, non-smart cell phones are negligibly radiating as shown in the right-hand side of the figure

whereas the same phone is excessively radiating in dialing, ringing, and receiving cases. The phones from Huawei and Xiaomi were found to emit more electric fields both in idle and active cases as compared to other brands in this finding.

Further, it has been observed from the graphical representation in Figure 3 and Figure 4, in the active mode of cell phones (dialing, ringing, and receiving) the electric field of cell phones is greater than that placed idly resulting in more SAR values of the phone. It is also observed that the SAR values of cell phones vary with the models of phones. The smartphones emit more radiation than non-smart cell phones at idle conditions (Figure 4). The electric field emitted by cell phones is maximum at its use. At dialing, ringing, and receiving conditions the SAR values reach maximum i.e. the cell phones emit maximum radiation at those conditions, and cell phones are directly placed against the head. Our head encounters maximum radiations while dialing and receiving phones. While dialing the phone the maximum radiations are emitted due to searching of the network which indicates that SAR value rises in poor network conditions too. It is seen that Redmi Note 6 and Huawei Honor have the greatest SAR value of 0.012W/kg in idle mode whereas non-smart cell phones are negligibly radiating.

In outgoing or dialing mode non-smart cell phone Nokia C2 was found to have the highest SAR value of 0.022 W/kg whereas Samsung S9 showed the lowest SAR value of 0.008 W/kg among the phones under our investigation. Also in the ringing case, Nokia C2 was found to have a high SAR value of 0.022 W/kg and Samsung J4 plus was with the least SAR value of 0.007 W/kg. Likewise in the receiving mode, Nokia C2 and Samsung GTE have the highest SAR value of 0.021 W/kg whereas Samsung J4 plus and Samsung S9 have the least SAR value of 0.008 W/kg in our entire findings.

In addition, most of the devices from Huawei and Xiaomi were found to be more radiating with the SAR value of 0.009 to 0.012 W/kg at the idle condition and 0.016 to 0.020W/kg at dialing, ringing and receiving conditions than Samsung of which SAR value ranges from 0.004 to 0.009 W/kg in idle condition and 0.008 to 0.016 W/kg in dialing, ringing and receiving cases. Non-smart phones were found very less radiating in idle case but they showed high SAR value in the range of 0.016 to 0.022 W/kg in the active conditions like dialing, ringing, and receiving cases. SAR depends upon the strength design and positioning of the antenna on a cell phone. If the SAR value is high the antenna must be changed. The SAR value cannot be minimized below the minimum transmitting power of a device. As a result, antenna positioning is crucial. The antennas for mobile phones are typically on the bottom of the phone, to keep the radiating part of the phone away from the brain region as far as possible.

In addition to this, the electric field vs. distance plot from Figure 5 to Figure 9 shows that the electric field strength decreases with the increase in distance from the cell-phones. It shows that electric field strength emitted from cell phones or its SAR value can be minimized by keeping cell phones at a small distance away from the human body.From the plots, it is evident that one experiences negligible radiation from cell phones if kept away about 30 cm from his/her body. Further, it indicates that when holding the phone next to the ear radiations may penetrate the human brain at maximum level.

Conclusions

From the study of SAR values of cell phones, it can be concluded that the radiations from the antenna of a cell phone are continuous even at idle condition and reach the maximum at dialing, ringing, and receiving conditions. The SAR values are varying with every model of phones. Most of the models of Samsung have less SAR compared to other brands. In the case of smart phones, most of the models from Huawei and Xiaomi were found to have more SAR whereas most of the sets from Samsung were found to produce less radiation. So the user must be cautious in choosing phones. The SAR value of non-smart cell phones being negligible at the idle case but higher at its active case indicates that they have powerful antennas. Every cell phone emits higher radiation in its active mode for searching proper networks resulting in high radiation emission. So it is good to keep mobile off in low or poor network areas as the radiation from antennas increases in such areas. Carrying multiple phones and multi SIM devices may have serious issues in health. The smart phones may emit more radiation when searching or using a Wi-Fi network, Bluetooth, etc. as well as the antenna becomes active in sharing data.

Virtually for all monitored brands of cell phones, the field strength has shown a plateau after about 30 cm from the phone. So instead of putting the phone near to the head in the dialing case, one can use hands-free mode to keep some distance between head and cell phones. When the mobile phone is not in use, it is better to keep them at a certain centimeter away. Reducing time engagement with cell phones is also a better practice. Habits of keeping the phone under the pillow or around the head when it is not in use should be improved. Allowing children to play with mobile phones frequently as a means of recreation is the worst job. Long conversations in a cell phone can be made by using earphones. There are various phones available in the market from unknown brands without the SAR value of devices. Such phones cannot be trusted as low radiating. So the government should have strict guidelines in checking mobile devices and a proper network doing so in every region as far as possible.

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Author's contribution

BRN, NK, PS, SA: Performed data collection, analysis, paper preparation, editing, and revision MPK, PP, SB, KB: Contributed to manuscript revision, and examined data patterns.
HBB: Participated in manuscript modification, offered supervision, and edited the initial draft.

Data Availability

The affiliated authors may be granted permission to utilize the data that supports the study's conclusions upon reasonable request.

Conflicts of Interest

No conflicts of interest are disclosed by the authors.

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