

Chapter 3

NONIONIZING RADIATION

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3.1 INTRODUCTION

Microwaves and lasers are forms of nonionizing radiation. Mobile or cellular phones which transmit and receive information in the microwave part of the electromagnetic spectrum have become a \$100 billion a year industry. About 650 million phones were sold to consumers in 2005, and over 1.5 billion people around the world use them.

The World Health Organization's (WHO) International Agency for Research on Cancer (IARC) classified the risk of the fields as "Possibly carcinogenic to humans. Given the potential consequences for public health of this classification and findings, it is important that additional research be conducted into the long-term, heavy use of mobile phones. Pending the availability of such information, it is important to take pragmatic measures to reduce exposure such as hands-free devices or texting."

Preliminary findings by the National Toxicology Program in the USA released in 2016 suggested a "low incidence" of brain and heart tumors in male rats exposed to doses of radiofrequency radiation totaling up to nine hours a day over a two-year period. The study awaits scrutiny by other scientists, a process known as peer reviewing, which is generally considered an essential stage of evaluating research.

A court in April 2017, in Ivrea, Italy agreed that a man's brain tumor was linked to his mobile phone use. It awarded Robert Romero 500 euros or \$535 per month in compensation. He had claimed that using his business mobile phone for three or four hours a day, over a period of 15 years, led to the growth of the benign tumor. The money will be paid by a body established to compensate people for work-based injuries [1].

The extensive use a cellular phone for at least an hour is reported to lead to a risk of developing a brain tumor, such as an acoustic neuroma or a glioma that is 240 percent higher than a person who never uses one. Electrical hypersensitivity, which is claimed to affect 1-4 percent of the population, is blamed on unpleasant symptoms in mobile phone users, including migraine, dizziness and tingling.

The technology is relatively new and is evolving so rapidly that it is outstripping the analysis of any potential impacts on health. Some research suggests radio frequency fields could interfere with biological systems but it has not been possible to carry out human based long-term studies. Third Generation (3G) phones, which emit higher rates of radiation than earlier models are now marketed all over the world. For people who have used for more than 2,000 hours in their lifetime, the risk of getting a brain tumor may have risen by 270 percent, particularly children and teenagers. Studies suggesting mobile phones can cause non malignant brain tumors, cognitive impairment or DNA damage in humans may be inconclusive but should not be dismissed.

3.2 BACKGROUND

Cellular phones emit electromagnetic radiation in the microwave part of the electromagnetic spectrum. The energy of a photon of electromagnetic radiation is expressed as:

$$E = h\nu \text{ [eV]} \quad (1)$$

where h is Planck's constant [eV/sec] and ν is the frequency of the electromagnetic radiation, given by:

$$\nu = \frac{c}{\lambda} \text{ [Hz], [sec}^{-1}] \quad (2)$$

where c is the speed of light [cm/sec] and λ is the wave length [cm] of the radiation.

The energy of the photon is expressed in electron Volts [eV], which is the kinetic energy acquired by an electron upon being accelerated through a potential drop of 1 Volt.

Since microwaves have a longer wave length and consequently a lower frequency than x or gamma rays, the energy they carry is considerably less. Whereas x and gamma rays with their high energy in the range of kilo to million of electron volts (keV-MeV) can break molecular bonds and cause the creation of ions or ionization, microwaves do not carry enough energy to cause ionization.

Cellular phones use frequencies in the range of 900 Hz corresponding to about a 1 ft wavelength. Radiofrequency is in the 1-10 meters wavelength compared with visible light which is $\frac{1}{2}$ a millionth of a meter, whereas ionizing radiation is at a 10 billionth of a meter wavelength.

Microwave radiation from cellular phones is classified as non ionizing radiation, so its effects are considered as less serious than ionizing radiation such as x and gamma rays, electrons, protons, alpha particles and neutrons. However, cellular phones antennas emit when in use microwaves that deposit energy in vital organs particularly the brain as well as the eyes. Radiation is emitted not just during active usage, but also during the standby mode, since a cellular phone is continuously polling for the location of the nearest cellular tower.

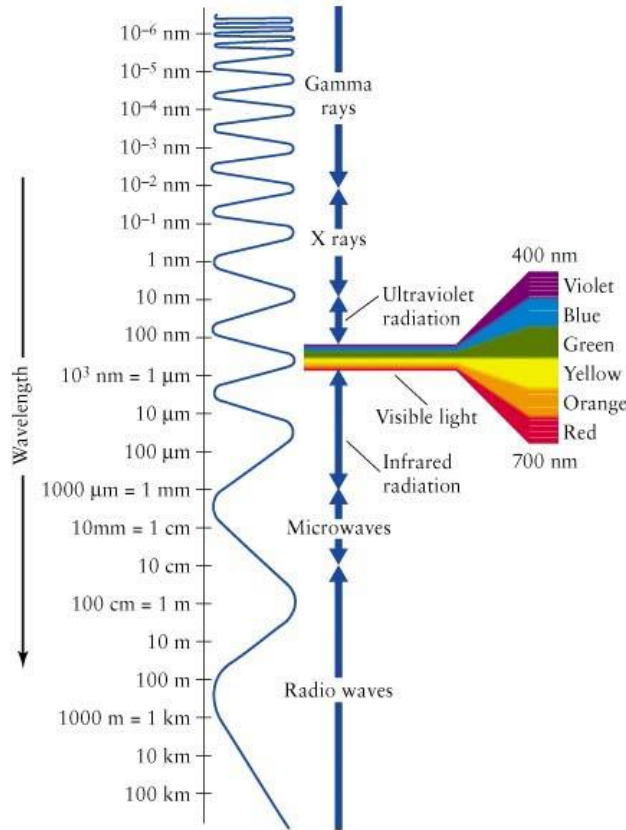


Figure 1. Microwaves cover the wave length range from about 1 mm to 10 cm in the electromagnetic spectrum.

Microwave towers themselves, with their geographical spread subject neighboring people in stationary objects such as offices and homes and mobile objects such as cars to microwave radiation. Microwave energy absorption is measured in terms of the Specific Absorption Rate (SAR), where:

$$\begin{aligned}
 SAR &= \frac{\text{Energy absorbed [Joules]}}{\text{Organ Mass[kgs].Irradiation time[secs]}} \\
 &= \frac{\text{Power [Watts]}}{\text{Organ mass [kgs]}}
 \end{aligned}
 \tag{3}$$

Most cellular phones emit radio signals at the level between 0.5-1.0 [Watts/kg]. SAR has a unit of specific power is a measure of the rate of radio energy absorption or power absorption per unit weight of body tissue. The SAR specific radiation dose rate exposure limit recommended by the International Commission on Non-Ionizing Radiation Protection is 2 [Watts/kg].

The Federal Communications Commission (FCC) and the Federal Drug Administration (FDA) regulate cell phones in the USA. The FCC requires that all cell phones sold in the USA have an SWAR of 1.6 [Watts/kg] or less.

what the SAR really measures is the heat that is generated and absorbed by the body from a cell phone. Some scientists attending the cell phone and health conference say that is a meaningless measurement since they believe damage to a cell's DNA could occur at very low temperature levels, which would not even register on the SAR scale.

Critics assert that the current standards are inadequate and misleading. Heating of tissue does not mean anything. A certain amount of energy is needed to cause a change in DNA, but that energy could be spent even before the temperature goes up and can be measured. People are led to believe that these standards say something, but they do not. Even if the SAR were the right metric to measure the safety of cell phones, several scientists suggest that the current standards used by the FCC are not good enough to protect consumers.

3.3 REFLEX EUROPEAN STUDY

Radio waves from mobile phones harm body cells and damage DNA under laboratory conditions, according to a study conducted by European Union, researchers. The Reflex study, conducted by 12 research groups in seven European countries, did not prove that mobile phones are a definite risk to health but concluded that more research is needed to see if effects can also be found outside a lab.

The \$100 billion a year mobile phone industry asserts that there is no conclusive evidence of harmful effects as a result of electromagnetic radiation. About 650 million mobile phones are expected to be sold to consumers per year, and over 1.5 billion people around the world use one.

The research project lasted for four years and was coordinated by the German research group Verum and headed by Franz Adlkofer. It studied the effect of radiation on human and animal cells in a laboratory setting.

After being exposed to electromagnetic fields that are typical for mobile phones, the cultured human and animal cells showed a significant increase in single and double strand DNA breaks. The damage was sometimes permanent and could not always be repaired by the cells. The concern arises from the fact that DNA carries the genetic material of an organism and its different cells.

There was remaining damage for future generation of the cultured cells. This means that the change had procreated. Mutated cells are seen as a possible cause of cancer.

The radiation used in the study ranged in levels between a Specific Absorption Rate (SAR) of between 0.3 and 2 [Watts/kg]. The study also measured other harmful effects on cells.

Because of the laboratory setup, the study did not prove any health risks on humans. However, the genotoxic and phenotypic effects would require further studies on animals and human volunteers. Further research would need five years to reach a conclusive result.

Previous independent studies into the health effects of mobile phone radiation have found it may have some effect on the human body, such as heating up body tissue and causing headaches and nausea.

3.4 BRITISH NATIONAL RADIOLOGICAL PROTECTION BOARD (NRPB) REPORT

A report issued in January 2006 by the UK's National Radiological Protection Board (NRPB), an independent advisory group, recommended a precautionary approach, because there is still no hard evidence that the health of the public in general has been adversely affected by the use of mobile phone technologies. The Mobile Operators Association in Britain, which represents operators on health and planning, supported the report. According to the NRPB, children might be more vulnerable to the effects of microwave radiation because their brain and nervous systems are still developing. They have a greater absorption of energy in the tissues of the head and they would have a longer lifetime exposure than adults.

3.5 SWEDISH STUDY

According to a Swedish study headed by Kjell Mild, published in the "International Archives of Occupational and Environmental Health" in April 2006, extensive use a cellular phone for at least an hour a day leads to a risk of developing a brain tumor that is 240 percent higher than a person who never uses one. The definition of extensive use is over 2,000 hours of cell phone use, spread over many years.

The results of the study contradicted another recent one carried out in the UK and published in January, 2006, which suggested that cell phone use is safe for humans.

The researchers found that the location of the tumor, for extensive cell phone users over many years, tends to be on the side of the head where the phone is frequently used. They examined cell phone use among 905 people who had a malignant brain tumor and compared them to a control group of 905 healthy people. All the volunteers were aged 20-80 years. Of the 905 people, 85 who had a malignant tumor were high users of cell or mobile phones: they started using mobile phones a long time ago, and have used extensively, on average for about an hour a day.

3.6 NORWEGIAN STUDY

A Danish study reported in December 2006 by Joachim Schuz of the Danish Cancer Society showed no rise in cancer among people who have used cell phones for 21 years. The study included more than 420,000 Danes who got their first cell phone between 1982 and 1995. Some of those people kept their phones as long as 21 years. On average, they had cell phone service for 8.5 years. It tracked cancers among the cell phone users from the start in 1982-1995 through 2002. During that period of time, the group had 14,249 cancers, slightly less than Denmark's expected cancer rate for the general population. The data showed no increase in brain cancer, leukemia, or tumors of the eyes or salivary glands among cell phone users.

3.7 BRITISH MOBILE TELECOMMUNICATIONS AND HEALTH RESEARCH (MTHR) STUDY

The UK's largest investigation into the safety of mobile phones found no evidence that they damage health. However it was impossible to rule out the possibility that ill effects including cancers could emerge in long-term users of over 10 years in the future.

Children particularly could be at risk because their brains are more vulnerable, and the advice to limit children's use of mobiles should remain.

The findings from the Mobile Telecommunications and Health Research (MTHR) program, released in September 2007 and which was launched six years earlier suggests that the worries about the effects of mobile phones on the brain and on biological processes, indicated in some earlier research, had been tested and found to be baseless.

The research is evenly co funded by the UK government and the mobile phone industry but is independently run, included 28 studies, of which 23 are complete. It reported no association between short-term mobile phone use and brain cancer and studies on volunteers showed no evidence that brain function, including memory and reaction times, was affected.

The program included the largest and most robust studies of electrical hypersensitivity, which is claimed to affect 1 per cent to 4 per cent of the population. The results showed no link between the unpleasant symptoms reported by sufferers, including migraine, dizziness and tingling, and mobile phone use.

However, according to Professor Challis an emeritus professor of physics at the University of Nottingham: "It all sounds pretty reassuring and that is good. But we cannot rule out the possibility that cancer could appear in a few years. The epidemiological evidence is not good enough and most cancers take longer than 10 years to develop."

There was a "faint hint" from two studies that use of mobile phones might be linked with malignant brain tumors and acoustic neuromas. Although the findings were of borderline statistical significance and were likely to be due to chance, they needed following up.

Children were more vulnerable to other agents such as cigarette smoke, lead and radiation and the same could be true of mobile phone signals.

3.8 ACOUSTIC NEUROMAS

Acoustic neuromas are slow growing cancers that only affect the function of the ear and can lead to loss of hearing and balance. They do not metastasize to other parts of the body.

There is public concern that use of mobile phones could increase the risk of brain tumors. If such an effect exists, acoustic neuromas would be of particular concern because of the proximity of the acoustic nerve to the handset."

Scientists at the Institute of Cancer Research in London have found that cellular phones do not increase the risk of cancer of the nerve that links the ear to the brain, during the first decade of cell phone use.

Data from 678 people with the benign tumor: acoustic neuroma of the nerve that connects the ear to the brain, and 3,553 people without it, were examined. The data came from people living in four Nordic countries and the UK, in which cell phones were introduced particularly early

No correlation was found between the number of calls, the duration of calls, or someone's lifetime cumulative hours of cell phone use and the risk of developing such a tumor.

There is a higher risk of developing a tumor on the same side of the head that people use their cell phones, after at least 10 years of use. However, the researchers conceded that there is little information on which long term effects can be judged.

Whether there are longer term risks remains unknown, reflecting the fact that this is a relatively recent technology.

3.9 GLIOMAS INCIDENCE

Gliomas are the most common type of brain tumors. A Swedish study suggested that there was an increased risk of contracting brain cancer among rural cell phone users. It also found increased incidence of brain tumors on the side of the head where people reported using their mobile phones. Early mobile phones tended to use stronger analog signals than more recent ones.

Researchers from the Universities of Leeds, Nottingham, and Manchester, and the Institute of Cancer Research in London, conducted a four year study between December 1, 2000, and February 29, 2004, on 966 adults diagnosed with glioma. A group of 1,716 healthy volunteers was used as a control group.

They found there was no correlation between the risk of glioma and the time since the adults' first use of a cell phone, the number of years they had been using a cell phone, the number of calls they made, and the hours of mobile phone usage.

However, the researchers did find a significantly increased risk for tumors that developed on the same side of the head as where the adults said they held their cell phones and a paradoxical decreased risk of tumors on the other side of the head.

A possible explanation is that people with glioma brain tumors might be over reporting their use of the phone on the same side as where the tumor developed, and under reporting their usage on the other side of their heads.

The researchers acknowledged their own study was limited in predicting the long term effects of cell phone use since mobile phones have only been popular in the UK since the late 1990s, although they have been available in the UK since 1985.

Cell phone makers have been making efforts in recent years to reduce the amount of radiation emitted from phones and listing the amount of radiation they can measure in their Specific Absorption Rate (SAR) ratings.

The study received criticism from advocacy groups such as Powerwatch, a British group that is examining the links between electromagnetic fields and health risks. It pointed out that 49 percent of the 966 brain tumor patients in the study were not interviewed by the researchers.

The University of Leeds, which helped carry out the study, received funding from various British mobile phone carriers, such as O2, Orange, T-Mobile, Vodafone, and 3, to support the research. However, they signed contractual agreements to ensure the independence of the scientific investigators.

Various mobile phone industry groups, such as the GSM Association and the Mobile Manufacturer Forum, provided funds for a larger 13 country Interphone study, of which the British study is one part.

3.10 EFFECT OF HEAD SIZE

Research indicates that cell phone radiation penetrates the heads of children much more than it does adults for a variety of reasons, including the fact that children have smaller and thinner skulls.

The FCC set standards for the amount of radio frequency that can be emitted by a cell phone based on models of a 200 pounds man's head talking with a phone to his ear for 6 minutes.

The FCC tests one device supplied by the manufacturer and then assigns the SAR number and does not randomly test samples of the device in the market. This could be a problem because even devices within the same model number may emit different levels of radiation. The manufacturers admit there is a 2:1 variability in terms of the SAR in devices of the same model number.

3.11 WORLD HEALTH ORGANIZATION (WHO) INTERNATIONAL AGENCY FOR RESEARCH ON CANCER, IARC STUDY

The World Health Organization (WHO) has conducted a 10 year survey from 2000 to 2010 of nearly 13,000 people across 13 countries. The WHO's International Agency for Research on Cancer (IARC) determined that most cell phone use did not lead to an increased risk of either meningioma, a common but typically benign form of cancer, or glioma, a rare but more dangerous type of brain cancer.

The study results did see “suggestions” that using cell phones for long periods of time on the same side of the head could lead to an increased risk of glioma, especially around the temporal lobe. However, the authors acknowledged that possible biases and errors from those participating in the survey meant that these results were not conclusive enough to directly blame cell phone radiation for such tumors. For example, people were asked to try to keep track of how often they used their cell phones and on which side of the head over a period of 10 years.

To conduct the study, 21 scientists from around the world came together in 2000 to form the Interphone International Study Group under the auspices of the IARC. Among the many people interviewed were those who had brain tumors: 2,708 individuals with glioma and 2,409 with meningioma; so the researchers could gauge their cell phone activity to see if there was a direct correlation with their cancers.

With a definitive answer still lacking, the IARC concludes that further study is needed, especially since cell phone use has increased dramatically since 2000, particularly among younger people.

3.12 EFFECT ON BRAIN ACTIVITY

A study from the National Institutes of Health suggests that cellular phones may alter brain activity, and it could be potentially damaging in the long term.

Researchers found that less than an hour of cellular phone use can cause brain activity to speed up in the area that is closest to the antenna.

The study was published in The Journal of the American Medical Association, AMA. The study documents that the human brain is sensitive to the electromagnetic radiation that is emitted by cellular phones. It also highlights the importance of conducting studies to address the question of whether there are, or are not, long-lasting consequences of repeated stimulation, of getting exposed over five, 10 or 15 years.

Participants in the study had a cell phone strapped to both ears and then underwent two 50-minute Positron Emission Tomography, PET scans, which measure brain activity by monitoring metabolism. In one scan, both cell phones were turned off; in the second, the right cell phone was turned on and played a recorded message, but with the sound muted so there would be no auditory interference.

The PET scans showed a 7 percent increase in activity in the part of the brain closest to the antenna. The researchers said the increased activity was unlikely to be associated with heat from the phone, because it happened near the antenna instead of where the phone touched the head.

The study shows that there are other physiological effects beyond tissue warming, however. Researchers not involved in the work think that the study suggests different pathways for cancer and other health problems to develop, including the formation of free radicals and tissue swelling. There are some studies showing cellular phone radiation associated with other events, like sleep disturbances.

This particular study does not enlighten us in terms of whether this is detrimental or if it could even be beneficial. It just tells us that even though these are weak signals, the human brain is activated by them.

Some other studies even suggest that electromagnetic radiation could be beneficial. In one study from 2010, University of South Florida researchers were surprised to find electromagnetic radiation from cell phones actually boosted the memories of young mice, and even reversed Alzheimer's symptoms in old mice. Other research suggests that electromagnetic waves could be used for other therapeutic purposes.

3.13 LOCAL LAWS

The city of San Francisco passed the first law in the USA requiring mobile phone retailers to display the amount of radiation they give off. The city's mayor, Gavin Newsom, hailed the law as a victory for the public's right to know what their mobile phones are doing to them even though some critics say there is no significant scientific evidence that they are hazardous to health.

The city council, known as the board of supervisors, voted 10-1 in favor of the law, which requires retailers to place information on the amount of radio waves absorbed by a mobile phone user's body next to each device to allow shoppers to choose between them.

A similar measure proposed in the California legislature was killed off amid heavy lobbying by the mobile phone industry. A law in Maine to require health warning labels on mobiles, similar to those on cigarette packets, also failed in part because the impact on health of sustained use of mobile phones remains a matter of scientific debate.

Some European countries take the risk of brain cancer more seriously. In France, legislation was passed to require cell phones to be sold with an earpiece or headset, to

forbid advertising to children under 14 or to give a cell phone to a child under six, and to require warning labels.

3.14 DISCUSSION

In Hong Kong, where consumers tend to spend more time talking on a mobile phone than in Europe, a German company, G-Hanz has been marketing a new type of mobile phone which it claims had no harmful radiation. It uses military radar technology which emits short bursts of radiation at different frequencies to avoid detection and subsequent targeting. Using short pulses instead of continuous operation is suggested as minimizing, but could not exclude the radiation exposure.

There is a need for the monitoring of base station towers, including new Third Generation 3G stations and Terrestrial Trunked Radio (TETRA), used by police and taxicab companies. These towers are in such high demand in European cities, that churches rent their steeples to be used as radio towers as an extra source of income. The use of a mobile phone when an alternative fixed line phone is available using the low frequency 60 Hz of ordinary electric current, and the use of a headset connected to a cellular phone whenever possible; are two recommended measures.

Cellular phone users can limit their exposure to cell phone radiation by keeping their devices as far away from their bodies as possible. This includes using a wired headset instead of holding a phone to their ear. Researchers differ in their opinion on whether a wireless Bluetooth headset poses a risk. Some scientists said it could be a problem, while others do not. But they all agree a wired headset is best.

Using a speaker on the phone or texting instead of talking is another good way to limit exposure. Users should avoid using a cell phone when the signal is poor, since phones emit more radiation energy when they are looking for a nearby signal tower. The Environmental Working Group recommends people make and take calls when the cell phone signal is strong.

Young adults are advised to use mobile phones for as short a time as possible, since their brain and eyes tissues are still in a formative stage and are consequently more vulnerable to the effects of radiation. Using text messaging and a phone with a low SAR value are also recommended. Turning off the phone when not in use, is also the most effective protection measure. To reduce the risk, the use of hands free cellular phones is recommended.

REFERENCE

1. BBC News "Brain Tumour Charity cautious about Italy mobile phone ruling," BBC Technology, April 21, 2017.