



Cell Phone Radiation and Health: An Outlook

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The effect of cell phone radiation on human health is the subject of recent interest and study, as a result of the enormous increase in cell phone usage throughout the world (as of June 2009, there were more than 4.3 billion users worldwide). Cell phones use electromagnetic radiation in the microwave range, which some believe may be harmful to human health. Other digital wireless systems, such as data communication networks, produce similar radiation. The International Agency for Research on Cancer (IARC: part of the World Health Organization) released a report on 31 May 2011 classifying cell phone radiation as "possibly carcinogenic to humans" (Group 2B on the IARC scale). It was classified as such after a team of scientists reviewed peer-reviewed studies on cell phone safety. One study of past cell phone use cited in the report showed a "40% increased risk for gliomas in the highest category of heavy users (reported average: 30 minutes per day over a 10-year period)."

This is a change from the prior position that cancer was unlikely to be caused by cellular phones or their base stations and that reviews had found no convincing evidence for other health effects. The evidence for glioma (a malignant type of brain cancer) was evaluated as "limited," defined as "A positive association has been observed between exposure to the agent and cancer for which a causal interpretation is considered by the Working Group to be credible, but chance, bias or confounding could not be ruled out with reasonable confidence." Evidence for other types of cancer was considered "inadequate," defined as "The available studies are of insufficient quality, consistency or statistical power to permit a conclusion regarding the presence or absence of a causal association between exposure and cancer, or no data on cancer in humans are available." The report ultimately concluded that "the evidence...is strong enough to support a conclusion and the 2B classification" and that "it is important that additional research be conducted into the long-term, heavy use of cell phones. Pending the availability of such information, it is important to take pragmatic measures to reduce exposure such as hands-free devices or texting."

Some national radiation advisory authorities have recommended measures to minimize exposure to their citizens as a precautionary approach. Many scientific studies have investigated possible health symptoms of cell phone radiation. These studies are occasionally reviewed by some scientific committees to assess overall risks. A recent assessment was published in 2007 by the European Commission Scientific Committee on Emerging and Newly Identified Health Risks (SCENIHR). It concludes that the three lines of evidence, *viz.* animal, *in vitro*, and epidemiological studies, indicate that "exposure to RF fields is unlikely to lead to an increase in cancer in humans. But the latest WHO released report on 31 May 2011 is classifying cell phone radiation as a "carcinogenic hazard."

RADIATION ABSORPTION

Calculated specific absorbed radiation (SAR) distribution in an anatomical model of head next to a 125mW dipole antenna, peak SAR is 9.5 W/kg averaged over a 1 mg cube. (USAF/AFRL). Part of the radio waves emitted by a cell telephone handset are absorbed by the human head. The radio waves emitted by a GSM handset can have a peak power of 2 watts, and a US analogue phone had a maximum transmit power of 3.6 watts. Other digital cell technologies, such as CDMA2000 and D-AMPS, use lower output power, typically below 1 watt. The maximum power output from a cell phone is regulated by the cell phone standard and by the regulatory agencies in each country. In most systems the cell phone and the base station check reception quality and signal strength and the power level is increased or decreased automatically, within a certain span, to accommodate different situations, such as inside or outside of buildings and vehicles. The rate at which radiation is absorbed by the human body is measured by the Specific Absorption Rate (SAR), and its maximum levels for modern handsets have

been set by governmental regulating agencies in many countries. In the USA, the Federal Communications Commission (FCC) has set a SAR limit of 1.6 W/kg, averaged over a volume of 1 gram of tissue, for the head. In Europe, the limit is 2 W/kg, averaged over a volume of 10 grams of tissue. SAR values are heavily dependent on the size of the averaging volume. Without information about the averaging volume used, comparisons between different measurements cannot be made. Thus, the European 10-gram ratings should be compared among themselves, and the American 1-gram ratings should only be compared among themselves.

THERMAL EFFECTS

One well-understood effect of microwave radiation is dielectric heating, in which any dielectric material (such as living tissue) is heated by rotations of polar molecules induced by the electromagnetic field. In the case of a person using a cell phone, most of the heating effect will occur at the surface of the head, causing its temperature to increase by a fraction of a degree. In this case, the level of temperature increase is an order of magnitude less than that obtained during the exposure of the head to direct sunlight. The brain's blood circulation is capable of disposing of excess heat by increasing local blood flow. However, the cornea of the eye does not have this temperature regulation mechanism and exposure of 2-3 hours duration has been reported to produce cataracts in rabbits' eyes at SAR values from 100-140W/kg, which produced lenticular temperatures of 41°C. There were no cataracts detected in the eyes of monkeys exposed under similar conditions. Premature cataracts have not been linked with cell phone use, possibly because of the lower power output of cell phones.

NON-THERMAL EFFECTS

The communications protocols used by cell phones often result in low-frequency pulsing of the carrier signal. Whether these modulations have biological significance has been subject to debate. Some researchers have argued that so-called "non-thermal effects" could be reinterpreted as a normal cellular response to an increase in temperature. The German biophysicist Roland Glaser, for example, has argued that there are several thermoreceptor molecules in cells, and that they activate a cascade of second and third messenger systems, gene expression mechanisms and production of heat shock proteins in order to defend the cell against metabolic cell stress caused by heat. The increases in temperature that cause these changes are too small to be detected by studies such as REFLEX, which base their whole argument on the apparent stability of thermal equilibrium in their cell cultures. Other researchers believe the stress proteins are unrelated to thermal effects, since they occur for both extremely low frequencies (ELF) and radio frequencies (RF), which have very different energy levels. Another preliminary study published in 2011 by *The Journal of the American Medical Association* conducted using fluorodeoxyglucose injections and positron emission tomography concluded that exposure to radiofrequency signal waves within parts of the brain closest to the cell phone antenna resulted in increased levels of glucose metabolism, but the clinical significance of this finding is unknown.

BLOOD-BRAIN BARRIER EFFECTS

Swedish researchers from Lund University (Salford, Brun, Persson, Eberhardt, and Malmgren) have studied the effects of microwave radiation on the rat brain. They found a leakage of albumin into the brain via a permeated blood-brain barrier. This confirms earlier work on the blood-brain barrier by Allan Frey, Oscar and Hawkins, and Albert and Kerns. Other groups have not confirmed these findings in vitro cell studies or whole animal studies.

CANCER

In 2006 a large Danish study about the connection between cell phone use and cancer incidence was published. It followed over 420,000 Danish citizens for 20 years and showed no increased risk of cancer. The German Federal Office for Radiation Protection (GFORP) considers this report inconclusive. The following studies of long time exposure have been published:

- The 13 nation INTERPHONE project - the largest study of its kind ever undertaken - has now been published and did not find a solid link between cell phones and brain tumours.

The *International Journal of Epidemiology* published a combined data analysis from a multi-national population-based case-control study of glioma and meningioma, the most common types of brain tumour. The authors reported the following conclusion:

Overall, no increase in risk of glioma or meningioma was observed with use of cell phones. There were suggestions of an increased risk of glioma at the highest exposure levels, but biases and error prevent a causal interpretation. The possible effects of long-term heavy use of cell phones require further investigation. In the press release accompanying the release of the paper, Dr Christopher Wild, Director of the International Agency for Research on Cancer (IARC) said:

An increased risk of brain cancer is not established from the data from Interphone. However, observations at the highest level of cumulative call time and the changing patterns of cell phone use since the period studied by Interphone, particularly in young people, mean that further investigation of cell phone use and brain cancer risk is merited. A number of independent health and government authorities have commented on this important study including The Australian Centre for Radiofrequency Bioeffects Research (ACRBR) which said in a statement that:

Until now there have been concerns that cell phones were causing increases in brain tumours. Interphone is both large and rigorous enough to address this claim, and it has not provided any convincing scientific evidence of an association between cell phone use and the development of glioma or meningioma. While the study demonstrates some weak evidence of an association with the highest tenth of cumulative call time (but only in those who started cell phone use most recently), the authors conclude that biases and errors limit the strength of any conclusions in this group. It now seems clear that if there was an effect of cell phone use on brain tumour risks in adults, this is likely to be too small to be detectable by even a large multinational study of the size of Interphone. The Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) which said in a statement that:

On the basis of current understanding of the relationship between brain cancer and use of cell phones, including the recently published data from the INTERPHONE study, ARPANSA: concludes that currently available data do not warrant any general recommendation to limit use of cell phones in the adult population, continues to inform those concerned about potential health effects that they may limit their exposure by reducing call time, by making calls where reception is good, by using hands-free devices or speaker options, or by texting; and recommends that, due to the lack of any data relating to children and long term use of cell phones, parents encourage their children to limit their exposure by reducing call time, by making calls where reception is good, by using hands-free devices or speaker options, or by texting. The Cancer Council Australia said in a statement that it cautiously welcomed the results of the largest international study to date into cell phone use, which has found no evidence that normal use of cell phones, for a period up to 12 years, can cause brain cancer. Chief Executive Officer, Professor Ian Olver, said findings from the Interphone study, conducted across 13 countries including Australia, were consistent with other research that had failed to find a link between cell phones and cancer. This supports previous research showing cell phones don't damage cell DNA, meaning they can't cause the type of genetic mutations that develop into cancer," Professor Olver said. However, it has been suggested that electromagnetic fields associated with cell phones may play a role in speeding up the development of an existing cancer. The Interphone study found no evidence to support this theory.

- A Danish study (2004) that took place over 10 years found no evidence to support a link. However, this study has been criticized for collecting data from subscriptions and not necessarily from actual users. It is known that some subscribers do not use the phones themselves but provide them for family members to use. That this happens is supported by the observation that only 61% of a small sample of the subscribers reported use of cell phones when responding to a questionnaire.
- A Swedish study (2005) that draws the conclusion that "the data do not support the hypothesis that cell phone use is related to an increased risk of glioma or meningioma."
- A British study (2005) that draws the conclusion that "The study suggests that there is no substantial risk of acoustic neuroma in the first decade after starting cell phone use. However, an increase in risk after longer term use or after a longer lag period could not be ruled out."
- A German study (2006) that states "In conclusion, no overall increased risk of glioma or meningioma was observed among these cellular phone users; however, for long-term cellular phone users, results need to be confirmed before firm conclusions can be drawn."
- A joint study conducted in northern Europe that draws the conclusion that "Although our results overall do not indicate an increased risk of glioma in relation to cell phone use, the possible risk in the most heavily exposed part of the brain with long-term use needs to be explored further before firm conclusions can be drawn."

Other studies on cancer and cell phones are:

- A Swedish scientific team at the Karolinska Institute conducted an epidemiological study (2004) that suggested that regular use of a cell phone over a decade or more was associated with an increased risk of acoustic neuroma, a type of benign brain tumor. The increase was not noted in those who had used phones for fewer than 10 years.
- The INTERPHONE study group from Japan published the results of a study of brain tumour risk and cell phone use. They used a new approach: determining the SAR inside a tumour by calculating the radio frequency field absorption in the exact tumour location. Cases examined included glioma, meningioma, and pituitary adenoma. They reported that the overall odds ratio (OR) was not increased and that there was no significant trend towards an increasing OR in relation to exposure, as measured by SAR.

In 2007, Dr. Lennart Hardell, from Örebro University in Sweden, reviewed published epidemiological papers (2 cohort studies and 16 case-control studies) and found that:

- Cell phone users had an increased risk of malignant gliomas.
- Link between cell phone use and a higher rate of acoustic neuromas.
- Tumors are more likely to occur on the side of the head that the cell handset is used.
- One hour of cell phone use per day significantly increases tumor risk after ten years or more.

In a February 2008 update on the status of the INTERPHONE study IARC stated that the long term findings '...could either be causal or artifactual, related to differential recall between cases and controls.'

- A self-published and non-peer reviewed meta-study by Dr. Vini Khurana, an Australian neurosurgeon, presented what it termed "increasing body of evidence ... for a link between cell phone usage and certain brain tumours" and that it "is anticipated that this danger has far broader public health ramifications than asbestos and smoking". This was criticised as '... an unbalanced analysis of the literature, which is also selective in support of the author's claims.'

A publication titled "Public health implications of wireless technologies" cites that Lennart Hardell found age is a significant factor. The report repeated the finding that the use of cell phones before age 20 increased the risk of brain tumors by 5.2, compared to 1.4 for all ages. A review by Hardell et. al. concluded that current cell phones are not safe for long-term exposure.

In a time trends study in Europe, conducted by the Institute of Cancer Epidemiology in Copenhagen, no significant increase in brain tumors among cell phone users was found between the years of 1998 and 2003. "The lack of a trend change in incidence from 1998 to 2003 suggests that the induction period relating cell phone use to brain tumors exceeds 5–10 years, the increased risk in this population is too small to be observed, the increased risk is restricted to subgroups of brain tumors or cell phone users, or there is no increased risk."

COGNITIVE EFFECTS

A 2009 study examined the effects of exposure to radiofrequency radiation (RFR) emitted by standard GSM cell phones on the cognitive functions of humans. The study confirmed longer (slower) response times to a spatial working memory task when exposed to RFR from a standard GSM cellular phone placed next to the head of male subjects, and showed that longer duration of exposure to RFR may increase the effects on performance. Right-handed subjects exposed to RFR on the left side of their head on average had significantly longer response times when compared to exposure to the right side and sham-exposure.

ELECTROMAGNETIC HYPERSENSITIVITY

Some users of cell handsets have reported feeling several unspecific symptoms during and after its use; ranging from burning and tingling sensations in the skin of the head and extremities, fatigue, sleep disturbances, dizziness, loss of mental attention, reaction times and memory retentiveness, headaches, malaise, tachycardia (heart palpitations), to disturbances of the digestive system. Reports have noted that all of these symptoms can also be attributed to stress and that current research cannot separate the symptoms from nocebo effects.

GENOTOXIC EFFECTS

A meta-analysis (2008) of 63 in vitro and in vivo studies from the years 1990–2005 concluded that RF radiation was genotoxic only in some conditions and that the studies reporting positive effects evidenced publication bias. A meta-study (2009) of 101 publications on genotoxicity of RF electromagnetic fields showed that 49 reported a genotoxic effect and 42 not. The authors found "ample

evidence that RF-EMF can alter the genetic material of exposed cells in vivo and in vitro and in more than one way". In 1995, in the journal *Bioelectromagnetics*, Henry Lai and Narendra P. Singh reported damaged DNA after two hours of microwave radiation at levels deemed safe according to government standards. In December 2004, a pan-European study named REFLEX (Risk Evaluation of Potential Environmental Hazards from Low Energy Electromagnetic Field (EMF) Exposure Using Sensitive in vitro Methods), involving 12 collaborating laboratories in several countries showed some compelling evidence of DNA damage of cells in in-vitro cultures, when exposed between 0.3 to 2 watts/kg, whole-sample average. There were indications, but not rigorous evidence of other cell changes, including damage to chromosomes, alterations in the activity of certain genes and a boosted rate of cell division. Research published in 2004 by a team at the University of Athens had a reduction in reproductive capacity in fruit flies exposed to 6 minutes of 900 MHz pulsed radiation for five days. Subsequent research, again conducted on fruit flies, was published in 2007, with the same exposure pattern but conducted at both 900 MHz and 1800 MHz, and had similar changes in reproductive capacity with no significant difference between the two frequencies. Following additional tests published in a third article, the authors stated they thought their research suggested the changes were "...due to degeneration of large numbers of egg chambers after DNA fragmentation of their constituent cells ...". Australian research conducted in 2009 by subjecting in vitro samples of human spermatozoa to radio-frequency radiation at 1.8 GHz and specific absorption rates (SAR) of 0.4 to 27.5 W/kg showed a correlation between increasing SAR and decreased motility and vitality in sperm, increased oxidative stress and 8-Oxo-2'-deoxyguanosine markers, stimulating DNA base adduct formation and increased DNA fragmentation.

SLEEP AND EEG EFFECTS

Sleep, EEG and waking rCBF have been studied in relation to RF exposure for a decade now, and the majority of papers published to date have found some form of effect. While a Finnish study failed to find any effect on sleep or other cognitive function from pulsed RF exposure, most other papers have found significant effects on sleep. Two of these papers found the effect was only present when the exposure was pulsed (amplitude modulated), and one early paper actually found that sleep quality (measured by the amount of participants' broken sleep) actually improved. While some papers were inconclusive or inconsistent, a number of studies have now demonstrated reversible EEG and rCBF alterations from exposure to pulsed RF exposure. German research from 2006 found that statistically significant EEG changes could be consistently found, but only in a relatively low proportion of study participants (12 - 30%).

HEALTH HAZARDS OF BASE STATIONS

Another area of concern is the radiation emitted by the fixed infrastructure used in cell telephony, such as base stations and their antennas, which provide the link to and from cell phones. This is because, in contrast to cell handsets, it is emitted continuously and is more powerful at close quarters. On the other hand, field intensities drop rapidly with distance away from the base of the antenna because of the attenuation of power with the square of distance. Base station emissions must comply with safety guidelines. Some countries however (such as South Africa for example) have no health regulations governing the placement of base stations. Several surveys have found a variety of self-reported symptoms for people who live close to base stations. However, there are significant challenges in conducting studies of populations near base stations, especially in assessment of individual exposure. Self-report studies can also be vulnerable to the nocebo effect.

Two double-blind placebo-controlled trials conducted at the University of Essex and another in Switzerland concluded that cell phone masts were unlikely to be causing these short term effects in a group of volunteers who complained of such symptoms. The Essex study found that subjects were unable to tell whether they were being exposed to electromagnetic fields or not, and that sensitive subjects reported lower well-being independently of exposure. The principal investigator concluded "It is clear that sensitive individuals are suffering real symptoms and often have a poor quality of life. It is now important to determine what other factors could be causing these symptoms, so appropriate research studies and treatment strategies can be developed." Experts consulted by France considered it was mandatory that main antenna axis not to be directly in front of a living place at a distance shorter than 100 metres. This recommendation was modified in 2003 to say that antennas located within a 100-metre radius of primary schools or childcare facilities should be better integrated into the

cityscape and was not included in a 2005 expert report. The Agence française de sécurité sanitaire environnementale currently says that there is no demonstrated short term effect of electromagnetic fields on health, but that there are open questions for long term effects, and that it's easy to reduce exposure via technological improvements.

OCCUPATIONAL HEALTH HAZARDS

Telecommunication workers who spend time at a short distance from the active equipment, for the purposes of testing, maintenance, installation, etcetera, may be at risk of much greater exposure than the general population. Many times base stations are not turned off during maintenance, but the power being sent through to the antennas is cut off, so that the workers do not have to work near live antennas. A variety of studies over the past 50 years have been done on workers exposed to high RF radiation levels; studies including radar laboratory workers, military radar workers, electrical workers, and amateur radio operators. Most of these studies found no increase in cancer rates over the general population or a control group. Many positive results could have been attributed to other work environment conditions, and many negative results of reduced cancer rates also occurred.

SAFETY STANDARDS AND LICENSING

In order to protect the population living around base stations and users of cell handsets, governments and regulatory bodies adopt safety standards, which translate to limits on exposure levels below a certain value. There are many proposed national and international standards, but that of the International Commission for Non-Ionizing Radiation Protection (ICNIRP) is the most respected one, and has been adopted so far by more than 80 countries. For radio stations, ICNIRP proposes two safety levels: one for occupational exposure, another one for the general population. Currently there are efforts underway to harmonise the different standards in existence. Radio base licensing procedures have been established in the majority of urban spaces regulated either at municipal/county, provincial/state or national level. Cell telephone service providers are, in many regions, required to obtain construction licenses, provide certification of antenna emission levels and assure compliance to ICNIRP standards and/or to other environmental legislation. Many governmental bodies also require that competing telecommunication companies try to achieve sharing of towers so as to decrease environmental and cosmetic impact. This issue is an influential factor of rejection of installation of new antennas and towers in communities. The safety standards in the U.S. are set by the Federal Communications Commission (FCC). The FCC has based its standards primarily on those standards established by the Institute of Electrical and Electronics Engineers (IEEE), specifically Subcommittee 4 of the "International Committee on Electromagnetic Safety". Switzerland has set safety limits lower than the ICNIRP limits for certain "sensitive areas" (classrooms, for example).

LAWSUITS

In the USA, a small number of personal injury lawsuits have been filed by individuals against cell phone manufacturers, such as Motorola, NEC, Siemens and Nokia, on the basis of allegations of causation of brain cancer and death. In US federal court, expert testimony relating to science must be first evaluated by a judge, in a Daubert hearing, to be relevant and valid before it is admissible as evidence. In one case against Motorola, the plaintiffs alleged that the use of wireless handheld telephones could cause brain cancer, and that the use of Motorola phones caused one plaintiff's cancer. The judge ruled that no sufficiently reliable and relevant scientific evidence in support of either general or specific causation was proffered by the plaintiffs; accepted a motion to exclude the testimony of the plaintiffs' experts; and denied a motion to exclude the testimony of the defendants' experts.

PRECAUTIONARY PRINCIPLE

In 2000, the World Health Organization (WHO) recommended that the precautionary principle could be voluntarily adopted in this case. It follows the recommendations of the European Community for environmental risks. According to the WHO, the "precautionary principle" is "a risk management policy applied in circumstances with a high degree of scientific uncertainty, reflecting the need to take action for a potentially serious risk without awaiting the results of scientific research." Other less stringent recommended approaches are prudent avoidance principle and as low as reasonably practicable. Although all of these are problematic in application, due to the widespread use and economic importance of wireless telecommunication systems in modern civilization, there is an increased

popularity of such measures in the general public, though also evidence that such approaches may increase concern. They involve recommendations such as the minimization of cell phone usage, the limitation of use by at-risk population (such as children), the adoption of cell phones and microcells with as low as reasonably practicable levels of radiation, the wider use of hands-free and earphone technologies such as Bluetooth headsets, the adoption of maximal standards of exposure, RF field intensity and distance of base stations antennas from human habitations, and so forth.

PRECAUTIONARY MEASURES AND HEALTH ADVISORIES

Some national radiation advisory authorities, including those of Austria, France, Germany, and Sweden, have recommended measures to minimize exposure to their citizens. Examples of the recommendations are:

- Use hands-free to decrease the radiation to the head.
- Keep the cell phone away from the body.
- Do not use telephone in a car without an external antenna.

The use of "hands-free" was not recommended by the British Consumers' Association in a statement in November 2000 as they believed that exposure was increased. However, measurements for the (then) UK Department of Trade and Industry and others for the French l'Agence française de sécurité sanitaire environnementale showed substantial reductions. In 2005 Professor Lawrie Challis and others said clipping a ferrite bead onto hands-free kits stops the radio waves travelling up the wire and into the head. Several nations have advised moderate use of cell phones for children.