



ELECTROMAGNETIC FIELDS (EMF) AND EFFECTS ON PUBLIC SAFETY

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EXECUTIVE SUMMARY

The Nigerian Communications Commission being the National telecoms regulatory authority in Nigeria has been facing an increasing number of enquiries and sundry questions from the public with respect to the effects of “Electromagnetic Fields (EMF) on human health.” Notwithstanding the efforts being made by the Consumer Affairs Bureau of the Commission in educating and informing the general public on the subject matter (EMF and effects on human health), the Commission is guided by a report or working document on the subject to form the position of the Commission and which can be referred to at any point in time.

Consequently, the Research and Development Department carried out this study to enable the Commission form its opinion and will also continuously monitor new information on the subject that may influence the assessment of risks to human health.

For this research report, the term “electromagnetic frequency” has been clearly defined, previous literature analyzed and studied in-depth, several scientific data published including World Health Organization (WHO) studies were reviewed and impacted hugely on the conclusions drawn to espouse adequate information on the Electromagnetic Frequency and effects on Human Health. The main focus is on whether hazardous health effects occur at different exposure levels of electromagnetic frequency and in particular, in relation to long term exposure at such levels.

Electromagnetic frequency is a measure of how many times the peak of a wave passes a particular point each second. It is measured in Hertz, which also can be written as simply “per second”. The frequency of a wave is one of its most fundamental principles, and the range of possible frequencies makes up something known as the electromagnetic spectrum. This runs from low-energy

radio waves to high-energy gamma rays. Unlike its wavelength, the electromagnetic frequency of a wave doesn't change.¹

The electromagnetic frequency is divided according to frequency bands. The figure below is a graphical representation of the spectrum of electromagnetic energy or radiation in ascending frequency (decreasing wavelength). The general nature of the effects is noted for different ranges.

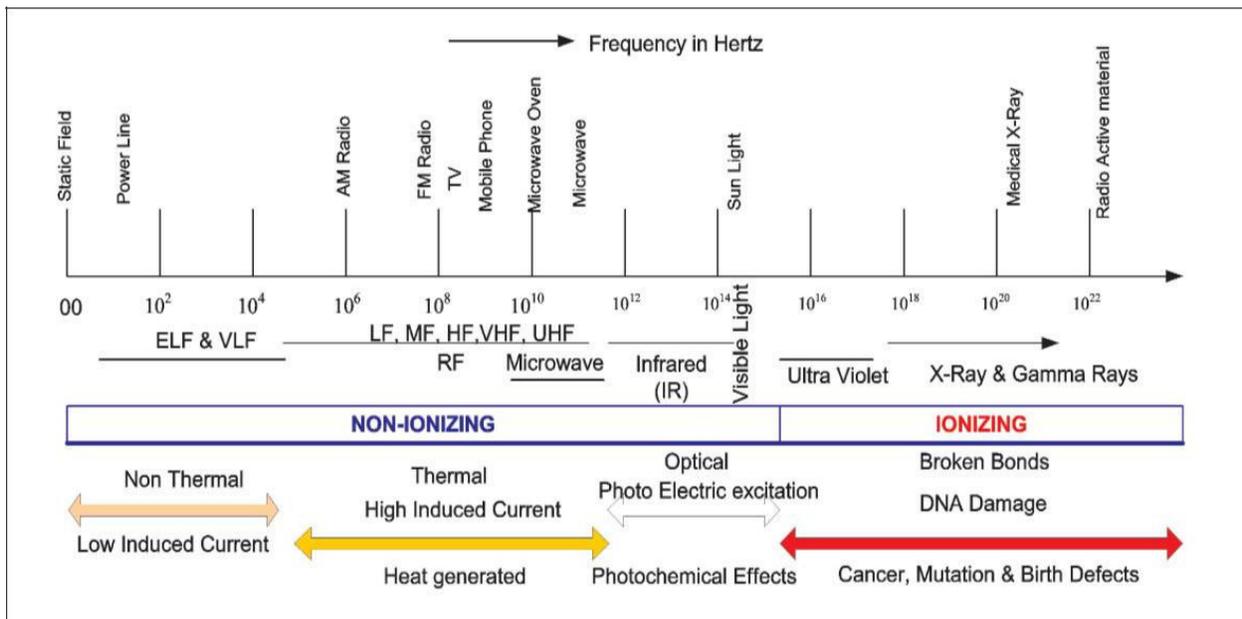


Figure 1: Electromagnetic Field Range

Most credible data on the possible effects of Electromagnetic Fields (EMF) on Human Health has shown, no health effect has been consistently demonstrated at exposure levels below the International Commission on Non-Ionizing Radiation Protection (ICNIRP) - limits established in 1998. However, the data base for this evaluation is limited especially for long-term low-level exposure.

¹ www.wisegeek.com clear answers to common questions

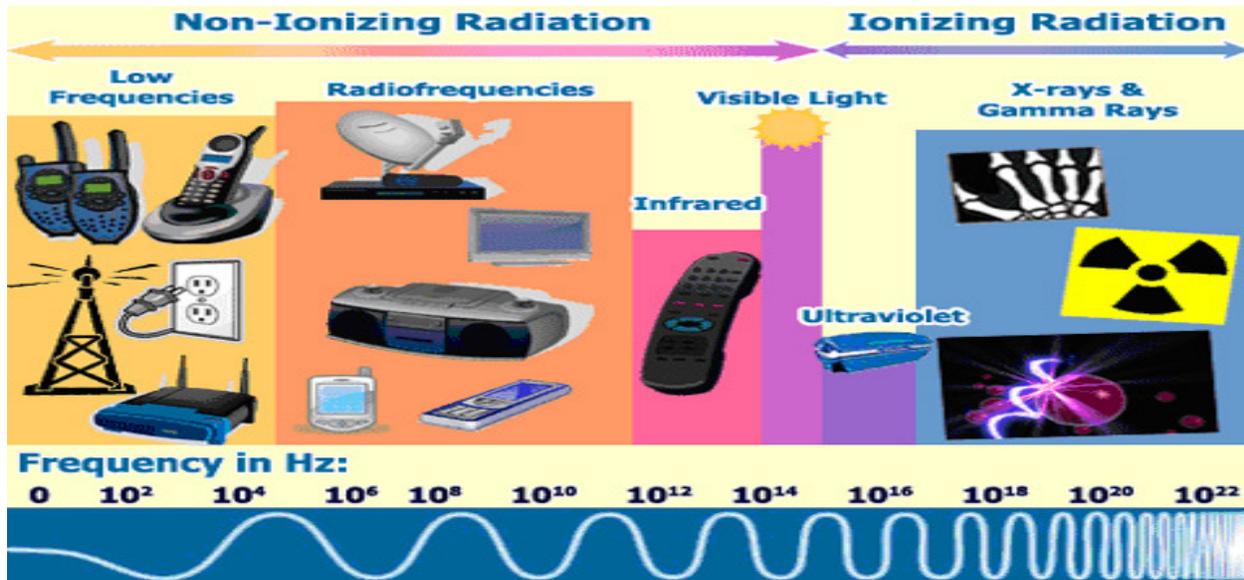


Figure 2: High Frequency Magnetic Fields

- a. **Intermediate Frequency Fields (IF fields):** Experimental and epidemiological data from the IF range are very sparse. Therefore, assessment of acute health risks in the IF range is currently based on known hazards at lower frequencies and higher frequencies. Proper evaluation and assessment of possible health effects from long term exposure to IF fields are important because human exposure to such fields is increasing due to new and emerging technologies.
- b. **Extremely low frequency fields (ELF fields):** Some studies which stated that ELF fields are possibly carcinogenic, chiefly based on childhood leukaemia results is still valid. There is no known mechanism to explain how electromagnetic field exposure may induce leukaemia. The effects have not been replicated in animal studies. However, calculations in some previous opinions of the possible proportion of childhood leukaemia cases that might be attributed to ELF fields still hold. For breast cancer and cardiovascular disease, recent research has indicated that an association is unlikely. For neurodegenerative diseases and brain tumours, the link to ELF fields remains uncertain. A relation between ELF fields and symptoms (sometimes referred to as electrical hypersensitivity) has not been demonstrated.

Public health policy recommendations

Although effects of EMF are minimal, it is highly recommended that the public undertake precautionary and preventive measures.²

The precautionary principle should be used when there is reasonable ground for concern. In general, based on the BioInitiative Report³, precaution is advised when there is exposure to both extremely low and higher frequency electromagnetic and radiofrequency fields. Recommendations are hereby made as follows:

1. ELF limits should be set below those exposure levels that have been linked in childhood leukaemia studies to increased risk of disease, plus an additional safety factor. It is no longer acceptable to build new power lines and electrical facilities that place people in ELF environments that have been associated with an increased risk of adverse health effects, levels generally at 2mG (0.2mT) and above.

A new, lower planning limit for habitable space adjacent to all new or upgraded power lines and for all other new construction should be applied. A lower limit should also be used for existing habitable space for children and/or women who are pregnant. .

2. A precautionary limit should be adopted for outdoor, cumulative RF exposure and for cumulative indoor RF fields with considerably lower limits than existing guidelines. It should reflect the current RF science and prudent public health response that would reasonably be set for pulsed RF (ambient) exposures where people live, work and go to school. This level of RF is experienced as whole-body exposure, and can be a chronic exposure where there is wireless coverage present for voice

² Hardell L, Walker M, Walhjalt B, Friedman LS, Richter ED. Secret ties to industry and conflicting interests in cancer research. *Am J Ind Med* 2007;50:227e33

³ BioInitiative report: a rationale for a biologically-based public exposure standard for electromagnetic fields (ELF and RF). <http://www.biointiative.org>

and data transmission for cell phones, pagers and personal digital assistants (PDAs) and other sources of radio- frequency radiation. Although this RF target level does not preclude further rollout of WI-FI technologies, wired alternatives to WI-FI should be implemented, particularly in schools and libraries so that children are not subjected to elevated RF levels until more is understood about possible health impacts.

3. The current guideline for microwave exposure from mobile phones in Europe is 2W/Kg for the brain. This is based on thermal effect using cataract development in animal eyes induced at 100W/Kg with a safety factor of 50 for standard setting. There were also considerations about the relationship between the whole-body Specific absorption rate (SAR) SAR and local hot spots and local SAR in relation to whole-body SAR. Since use of mobile phones is associated with an increased risk for brain tumours (glioma, acoustic neuroma) after 10 years a new biologically based guideline should be applied. This new guideline should be based on non-thermal (low-intensity) effects from microwave exposure. It should be added that in toxicology normal practice is to add a safety limit of at least factor 100, which is factor 10 from animal to human beings and factor 10 for individual variability.⁴
4. The same standard should be applied to cordless phones as for new guidelines for mobile phones based on biological effects. This is a reasonable suggestion to address the condition where occupied interior space is affected by cordless phones or other RF-emitting devices installed by the occupants. As with ELF fields also for RF fields different limits may be needed in the future as science progresses.

⁴ Scinicariello F, De Rosa CT. Genetic heterogeneity and its effect on susceptibility to environmental factors. Eur J Oncol 2007;12(3): 155e70.

5. There is the need for continuous education to consumers and the general public on the issue of effect of RF on the community. They need to be enlightened on the range of the electromagnetic frequencies i.e. low frequencies to high frequencies and the resultant effects of exposure to the frequencies. Mobile phones and base stations (BTS) fall under the low frequencies category and have no adverse effect on health, but X-RAYS on the other hand fall under the high frequency category and may impact negatively on human health. The public should be more concerned with exposure to these high frequencies such as X-rays and radioactive elements/materials.

CHAPTER ONE

1.0 INTRODUCTION

Telecommunications have become an integral part of our life; providing services that range from phone connection, entertainment, information and learning over a broad range of media. This wireless technology relies upon an extensive network of fixed antennae, or base stations, relaying information via radio frequency waves or signals that travel at the speed of light.⁵

Apart from telecoms base station facilities, broadcast towers, radar facilities and even domestic electrical and electronic home appliance such as microwave ovens, television, radio and even remote controls also act as sources of radio frequency emissions.

There has been a steady increase in public concerns pertaining to the possible effects of electromagnetic radiation emanating from telecommunications equipment/infrastructure on human health. It should however be noted that people are often misled to think that electromagnetic emissions from telecommunication facilities is the same as or similar to nuclear and radioactive radiations. There are several reasons for these public fears and these include media announcements of new and unconfirmed scientific studies, leading to a feeling of uncertainty and a perception that there may be unknown or undiscovered hazards.

Given the large number of mobile phone users, it is important therefore to investigate, understand and communicate any potential public health impact from mobile phones which work by transmitting radio waves through a network of fixed antennas called base transceiver stations (BTS).⁶

⁵ emfrefugee.blogspot.com/.../nigeria-emf-what-experts-say...base.html What Experts Say About Base Station Radiation BY CHIMA AKWAJA, 29 JULY 2012

⁶ Nigerian Communications Commission (NCC) 2012 at the Conference of first West African conference on EMF exposure and health

While mobile phones are becoming beneficial as a tool for monitoring and improving health, the radio frequency (RF) emission radiated by phones has called into question its effect on human health. In the last 15 years several researches have been conducted to establish mobile phone usage health risks. Globally, the number of cell phone subscriptions is estimated by the International Telecommunications Union (ITU) to be five billion.

1.1 Electromagnetic frequency

Electromagnetic frequency is a measure of how many times the peak of a wave passes a particular point each second. It is measured in Hertz, which also can be written as simply “per second”. The frequency of a wave is one of its most fundamental principles, and the range of possible frequencies makes up something known as the electromagnetic spectrum. This runs from low-energy radio waves to high-energy gamma rays. Unlike its wavelength, the electromagnetic frequency of a wave doesn’t change.⁷

Electromagnetic radiation is a type of wave that travels at the speed of light. It is a transverse wave, which means it oscillates up and down in a direction opposite that in which it is moving. The electromagnetic frequency of a wave is defined as how many times the peak of this oscillation moves past a point each second. This has a major effect on the properties of the wave, including its energy. The wavelength, on the other hand, is the distance between two peaks of the wave or, in other words, the length of a full cycle.⁸

A wave's electromagnetic frequency is directly related to the amount of energy carried by the wave. Low-frequency electromagnetic waves, for example, have small amounts of energy and, therefore, are relatively safe. These are more

⁷ www.wisegeek.com clear answers to common questions

⁸ www.wisegeek.com clear answers to common questions

commonly known as radio waves. Low-frequency waves, such as radio waves and microwaves, have long wavelengths.

If the electromagnetic frequency of a wave is high, then the wave carries a large amount of energy. Conversely, the wavelength of the wave in this situation is very short. X-rays and gamma rays are two examples of high electromagnetic frequency waves, which is why these types are dangerous when humans are exposed to them. Visible light also is a type of electromagnetic wave with a frequency somewhere around the middle of the electromagnetic spectrum.⁹

When a wave passes from one medium to another, such as from air to water, it changes direction as the result of a phenomenon known as refraction. This is because the wave changes speed as it enters a material with a different density. A common mistake is to assume that this changes the electromagnetic frequency of the wave. This is not the case, because the frequency of a wave stays the same, regardless of the medium. It is the wavelength and speed of the wave that change, resulting in a slower wave of the same energy.

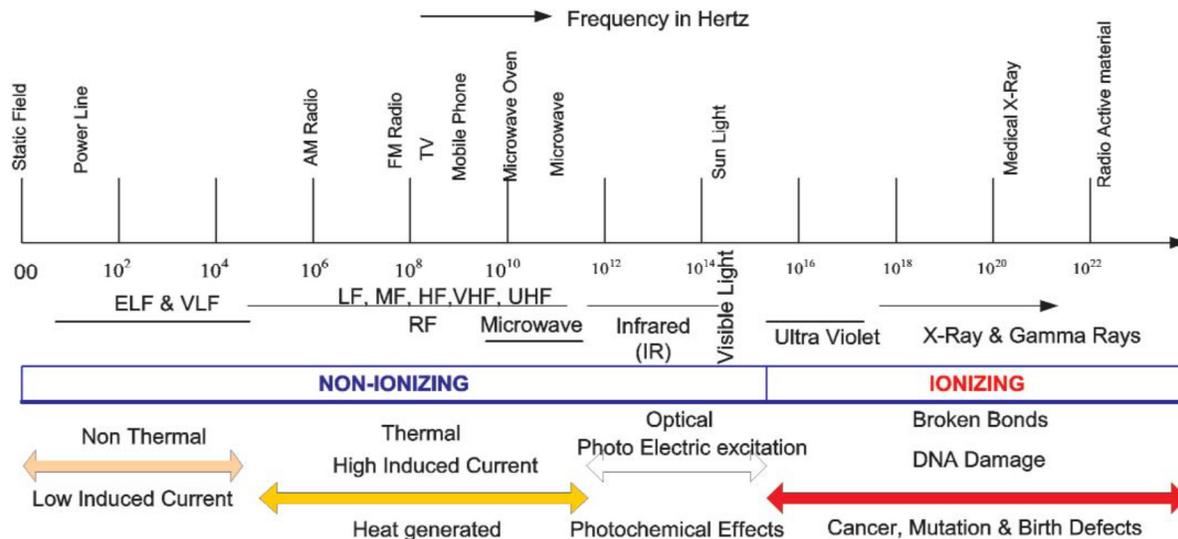


Figure 3: Electromagnetic spectrum

⁹ www.wisegeek.com clear answers to common questions

1.2 What is Electromagnetic Radiation?

Electromagnetic (EM) radiation is a form of energy that is all around us and takes many forms, such as radio waves, microwaves, X-rays and gamma rays. Sunlight is also a form of EM energy, but visible light is only a small portion of the EM spectrum, which contains a broad range of electromagnetic wavelengths.¹⁰

Electricity and magnetism were once thought to be separate forces. However, in 1873, Scottish physicist James Clerk Maxwell developed a unified theory of electromagnetism. The study of electromagnetism deals with how electrically charged particles interact with each other and with magnetic fields.¹¹

There are four main electromagnetic interactions:

- The force of attraction or repulsion between electric charges is inversely proportional to the square of the distance between them.
- Magnetic poles come in pairs that attract and repel each other much as electric charges do.
- An electric current in a wire produces a magnetic field whose direction depends on the direction of the current.
- A moving electric field produces a magnetic field and vice versa.
- A wavelength is the distance between two consecutive peaks of a wave. This distance is given meters (m) or fractions thereof. Frequency is the number of waves that form in a given length of time. It is usually measured as the number of wave cycles per second, or hertz (Hz). A short wavelength means that the frequency will be higher because one cycle can pass in a shorter amount of time, according to the University of Wisconsin.¹²

¹⁰ www.livescience.com/38169-electromagnetism.html

¹¹ Jim Lucas, Live Science | Contributor | March 12, 2015

¹² (<http://cmb.physics.wisc.edu/pub/tutorial/light.html>)

Similarly, a longer wavelength has a lower frequency because each cycle takes longer to complete.

- Electromagnetic radiation spans an enormous range of wavelength and frequencies. This range is known as the electromagnetic spectrum. The EM spectrum is generally divided into seven (7) regions, in order of decreasing wavelength and increasing energy and frequency. The common designations are: radio waves, microwaves, infrared (IR), visible light, ultraviolet (UV) X-rays and gamma rays. Typically, lower-energy radiation, such as radio waves, is expressed as frequency, microwaves, infrared, visible and UV light are usually expressed as wavelength and higher-energy radiation such as X-rays gamma rays is expressed in terms of energy per photon.

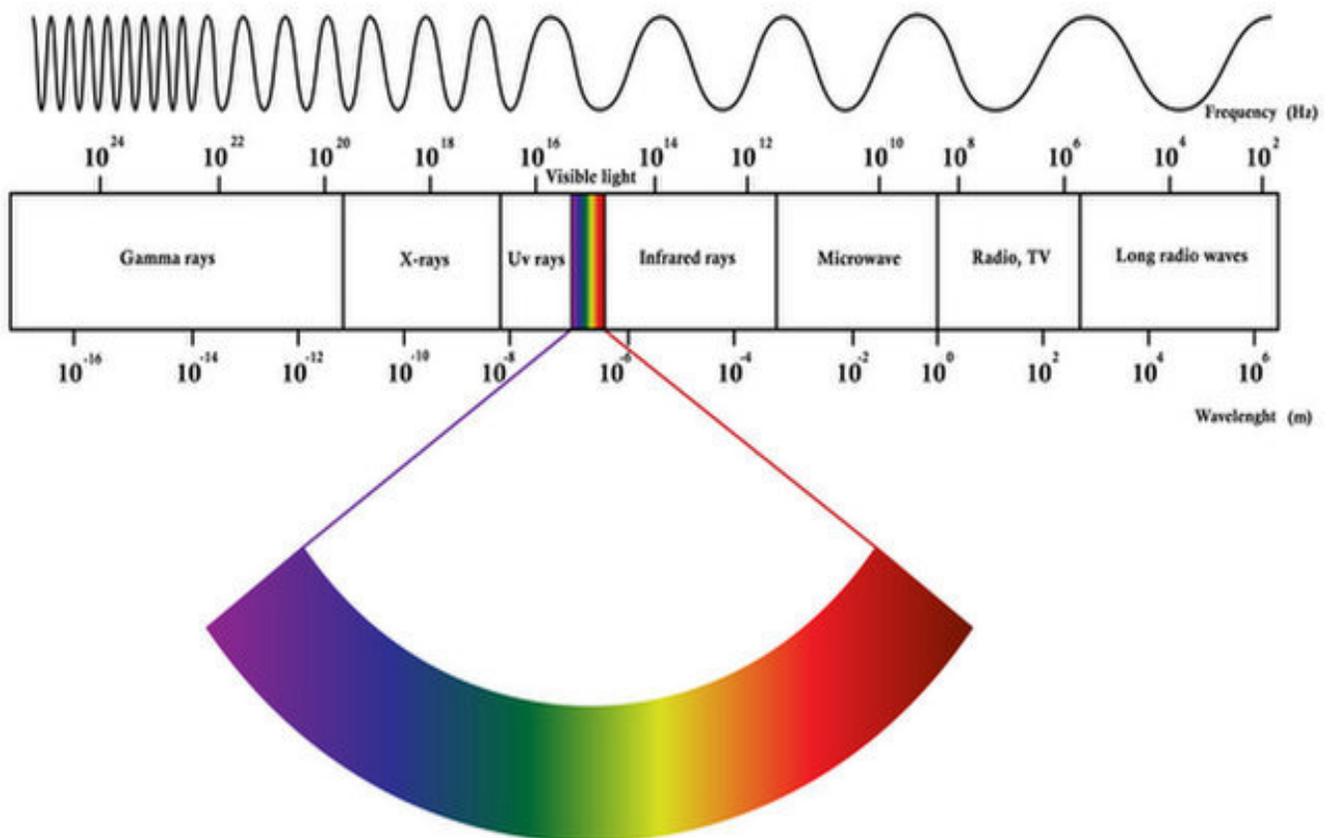


Figure 4: Electromagnetic Frequency Range

The electromagnetic spectrum is generally divided into seven regions, in order of decreasing wavelength and increasing energy and frequency: radio waves, microwaves, infrared, visible light, ultraviolet, X-rays and gamma rays.¹³

a. Radio waves

Radio waves are at the lowest range of the EM spectrum, with frequencies of up to 30 million hertz or 30 gigahertz (GHz) and wavelengths greater than about 10 millimeters (0.4 inches). Radio is used primarily for communications including voice, data and entertainment media.

b. Microwaves

Microwaves fall in the range of the EM spectrum between radio and IR. They have frequencies from about 3 GHz trillion hertz or 30 terahertz (THz) and wavelengths of about 10 mm (0.4 inches) to 100 micrometers (um), or 0.004 inches. Microwaves are used for high-bandwidth communications, radar and as a heat source for microwave ovens and industrial applications.

c. Infrared

Infrared is in the range of EM spectrum between microwaves and visible light. IR has frequencies from about 30THz up to about 400 THz and wavelengths of about 100 um (0.004 inches) to 740 nanometers (nm) or 0.00003 inches. IR light is invisible to human eyes but we can feel it as heat if the intensify is sufficient.

d. Visible Light

Visible light is found in the middle of the EM spectrum, between IR and UV. It has frequencies of about 400 THz to 800 THz and wavelengths of about 740 nm

¹³ Credit: Biro Eموke Shutterstock

(0.00003inches) to 380 nm (0.000015 inches). More generally, visible light is defined as the wavelengths that are visible to most human eyes.

e. Ultraviolet Light

Ultraviolet light is in the range of the EM spectrum between visible light and X-rays. It has frequencies of about 8×10^{14} to 3×10^{15} and wavelengths of about 380 nm (0.000015 inches) to about 10 nm (0.0000004 inches). UV light is a component of sunlight, however, it is invisible to the human eye. It has numerous medical and industrial applications but it can damage living tissue.

f. X-rays

X-rays are roughly classified into two types: soft X-rays and hard X-rays. Soft X-rays comprise the range of the EM spectrum between UV and gamma rays. Soft X-rays have frequencies of about 3×10^{16} to about 10^{18} Hz and wavelengths of about 10nm (4×10^{-7} inches) to about 100 picometers (pm) or 4×10^{-8} . Hard X-rays occupy the same region of the EM spectrum as gamma rays. The only difference between them is their source: X-rays are produced by accelerating electrons while gamma rays are produced by atomic nuclei.

g. Gamma-rays

Gamma-rays are in the range of the spectrum above soft rays. Gamma rays have frequencies greater than about 10^{18} Hz and wavelengths of less than 100 pm (4×10^{-7} inches). Gamma radiation causes damage to living tissues which make it useful for killing cancer cells when applied in carefully measured doses to small regions. Uncontrolled exposure though is extremely dangerous to humans.

1.3 What are Mobile phone base stations?

Mobile phone base stations are radio transmitters with antennas mounted on either freestanding masts or on buildings. Radio signals are fed through cables to the antennas and then launched as radio waves into the area, or cell, around

the base station.¹⁴ A typical larger base station installation would consist of a plant room containing the electronic equipment as well as the mast with the antennas.

Several types of antenna are used for the transmissions; panel-shaped sector antennas or pole-shaped omni antennas are used to communicate with mobile phones. Dish antennas form terminals for point-to-point microwave links that communicate with other base stations and link the network together. Sometimes the base stations are connected together with buried cables instead of microwave links.¹⁵

Depending on the location of the base station and the level of mobile phone usage to be handled, base stations may be anything from only a few hundred meters apart in major cities, to several kilometers apart in the countryside.

a. Types of base stations

There are many different types of base station used by operators and it is not always easy to categorize them firmly as macrocell, microcell or picocell. Categorizations tend to be based on the purpose of the site rather than in terms of technical constraints such as radiated powers or antenna heights.

Macrocellular base stations provide the main infrastructure for a mobile phone network and their antennas tend to be mounted at sufficient height to give them a clear view over the surrounding geographical area. For this reason they tend

¹⁴ <https://www.gov.uk/government/publications/mobile-phone-base>

¹⁵ <https://www.gov.uk/government/publications/mobile-phone-base-stations-radio-waves-and-health/mobile-phone-base-stations-radio-waves-and-health>

to be obvious, particularly for the older sites with freestanding steel lattice towers.

Microcell base stations provide additional radio capacity where there are a high number of users such as in cities and towns. Microcell antennas tend to be mounted at street level, typically on the external walls of existing buildings. Microcell antennas are a great deal smaller than macrocell antennas and can often be disguised as building features.

b. Transmissions from base stations

Base stations in areas of low mobile phone usage may only have one transmitter connected to their antennas; hence, they will transmit only on one frequency. Base stations in busier areas may have up to ten or more transmitters connected to their antennas, allowing them to transmit on several frequencies at the same time, and to handle communications with many mobile phones.

The power of each base station transmitter is set to a level that allows a mobile phone to be used within the area for which the base station is designed to provide coverage, but not outside the coverage area. Higher powers are needed to cover larger cells and also to cover cells with difficult ground terrain. Typical maximum powers for individual macrocellular base station transmitters are around 5 to 10 watts (W), although the total radiated power from an antenna could be up to around 100 W with multiple transmitters present.

For a low-capacity base station with only one transmitter, the radiated power does not vary over time, or with the number of phone users. Up to seven phone calls can be handled simultaneously by such a base station.

With larger capacity base stations having multiple transmitters, the output power can vary over time and with the number of calls being handled. One of the transmitters will transmit continuously at full power, whereas the other transmitters will operate intermittently and with varying power levels up to the

maximum. As an example, the power output of a macrocellular base station with ten 10 W transmitters could vary between a minimum of 10 W and a maximum of 100 W over time. Microcellular base stations tend to operate at lower power levels around 1 to 2 W and have fewer transmitters because of their smaller coverage areas.

c. Beam shapes and directions

The power from antennas used with macrocellular base stations is radiated in conical fan-shaped beams, which are essentially directed towards the horizon with a slight downward tilt. This causes the radiowave strengths below the antennas and at the base of masts to be very much lower than directly in front of the antennas at a similar distance.

The beams from the antennas spread out with distance and tend to reach ground level at distances in the range 50 to 300m from the antennas. The radiowave levels at these distances are much less than those directly in front of the antennas and can easily be calculated.¹⁶ At distances closer to the mast than where the main beam reaches ground level, exposure occurs due to weaker beams known as sidelobes the power density of which is not so easy to calculate unless one has detailed technical information about the beam pattern from the antennas.

¹⁶[http://hpa.org.uk/publications/radiation/nprarchive/miscellaneousnrpbreports/abstracts/NRPB_report_NRPB-R321, Exposure to Radio Waves near Mobile Phone Base Stations.](http://hpa.org.uk/publications/radiation/nprarchive/miscellaneousnrpbreports/abstracts/NRPB_report_NRPB-R321,Exposure_to_Radio_Waves_near_Mobile_Phone_Base_Stations.)

CHAPTER TWO

2.0 LITERATURE REVIEW

For some time now, the general public has been concerned with the following two questions: “What are the effects of radio waves on human health?” and, more specifically, “What health risks are associated with the use of cell phones, mobile radios, microwave radios, microwave ovens, broadcast radio and television transmitters, power lines and X-rays?”

Electromagnetic waves are produced by the motion of electrically charged particles. These waves are also called electromagnetic radiation because they radiate from the electrically charged particles. They travel through empty space as well as through air and other substances. Electromagnetic waves at low frequencies are referred to as electromagnetic fields and those at very high frequencies are called electromagnetic radiations¹⁷.

In recent times, many people have expressed an interest in learning if the use of cell phones is associated with cancer. Many have heard or read about possible links between cell phones and cancer, but conclusions are rarely definitive.¹⁸.

2.1 Electromagnetic Frequency Spectrum

Wireless communication links have been used worldwide for many years as solutions for connectivity in point-to-point and point-to-multipoint applications. The most common wireless solutions include AM and FM radio, television broadcast stations, mobile and cellular phones, radar and microwave systems.

The electromagnetic (EM) spectrum contains an array of electromagnetic waves increasing in frequency from Extremely Low Frequency and Very Low Frequency

¹⁷ Feyyaz Ozdemir and Aysegul Kargi (2011). Electromagnetic Waves and Human Health, Electromagnetic Waves, Prof. Vitaliy Zhurbenko (Ed.), ISBN: 978-953-307-304-0, InTech, Available from: <http://www.intechopen.com/books/electromagnetic-waves/electromagnetic-waves-and-human-health>

¹⁸ “Opinion on Possible Effects of Electromagnetic Fields (EMF), Radio Frequency Fields (RF) and Microwave Radiation on Human Health,” Scientific Committee on Toxicity, Ecotoxicity and the Environment (CSTEE).

(ELF/VLF), through Radio Frequency (RF) and Microwaves, to Infrared (IR) light, Visible Light, Ultraviolet (UV) light, X-rays, and Gamma rays.

2.2 EMR & HUMAN HEALTH

2.2.1 Ionizing Radiation

Ionizing radiation contains sufficient electromagnetic energy to strip atoms and molecules from the tissue and alter chemical reactions in the body (converting molecules totally or partly into ions). X-Rays and Gamma rays are two (2) forms of ionizing radiation. These rays are known to cause damage, which is why a lead vest must be worn when X-rays are taken of our bodies and heavy shielding surrounds nuclear power plants.

Human beings are constantly exposed to low levels of ionizing radiation from natural sources. This type of radiation is referred to as natural background radiation, and its main sources are:

- Visible light, ultraviolet light and infrared light (sunlight)
- Radioactive materials on the earth's surface (contained in coal, granite, etc.)
- Radioactive gases leaking from the earth (radon)
- Cosmic rays from outer space entering the earth's atmosphere through the ionosphere
- Natural radioactivity in the human body

2.2.2 Non-Ionizing Radiation

The lower part of the frequency spectrum is considered non-ionizing Electromagnetic Radiation (EMR), with energy levels below that required for effects at the atomic level. Examples of non-ionizing radiations are:

- Static electromagnetic fields from direct current (0 Hz).
- Low-frequency waves from electric power (50-60 Hz).

- Extremely Low Frequency (ELF) and Very Low Frequency (VLF) fields (up to 30 kHz).
- Radio Frequencies (RF), including Low Frequency (LF), Medium Frequency (MF) High Frequency (HF), Very High Frequency (VHF), Ultra High Frequency (UHF) and Microwave (MW) and Millimeter-wave (30 kHz to 300 GHz).
- Infrared (IR) light, Visible light and Ultraviolet (UV) light (above 300 GHz).

Note: the frequencies between the highest microwave bands and infrared light are rarely used, but are being studied for future applications¹⁹.

Some heating effect is generated by all of these waves. Insufficient energy is available from most common sources to produce any type of damage to human tissue, although it is probable that higher power densities, such as those densities very near high-voltage power lines or high-power (megawatt) broadcast transmitters, could have long-term health effects.

The power density of any source of EMR is not only related to the power level at the source, but increases rapidly as the distance from the source decreases. A common concern today, since more and more people are using cell phones than ever before, is that cell phone antennas radiate near a person's head. Cell phones, however, radiate very little power. So, even while close to the head, they are not considered a danger.

Some studies suggest that potential health hazards could be linked to excessive exposure to high-power densities of non-ionizing radiation. These health hazards include:

- Cancer
- Tumors

¹⁹ *Guidance for Industry and FDA—Regulation of Medical Devices*, U.S. Department of Health and Human Services, Food and Drug Administration, Center for Devices and Radiological Health.

- Headaches
- Fatigue
- Alzheimer's Disease
- Parkinson's Disease

Researchers, however, are unsure of specific long-term effects resulting from prolonged exposure to non-ionizing radiation.

2.3 Extremely Low Frequency (ELF) and Very Low Frequency (VLF) Electromagnet Radiation (EMR)

EMR in the ELF and VLF range is both naturally occurring and man-made. Natural EMR includes a background electromagnetic field created by the earth as well as additional EMR created by thunderstorms, as well as solar and cosmic activity. The strength of an electromagnetic field depends both on the power at the source and the distance from the source²⁰.

Exposure to man-made ELF/VLF occurs primarily due to the generation, transmission and use of electrical energy. Electromagnetic fields are created whenever electricity passes through a conductor. Actually, two (2) interdependent fields are created: an electric field and a magnetic field. The strength of the electric field depends on the voltage being carried, while the magnetic field strength depends on the amount of current being carried (amperage). Thus, electromagnetic fields are created by a variety of electrical household appliances such as motors in refrigerators, vacuum cleaners, hair dryers, irons, electric blankets, microwaves, televisions, stereo receivers, and computers. In fact, because of the individual's proximity to household appliances, the level of electromagnetic fields is often far greater than those levels produced by transmission lines strung on high towers. However, the appliances

²⁰ *Electromagnetic Fields and Human Health*, by John E. Moulder, Ph.D., Professor of Radiation Oncology.

only create electromagnetic fields while in use, whereas the transmission line electromagnetic fields are continuous. While these man-made ELF/VLF electromagnetic fields may cause biological effects, the adverse effects on human health are highly controversial.

2.4 Electrical Power Line Effects

The concern over electromagnetic fields emitted by power lines (Figure 2) has long been a topic of conversation in the real estate and power industries. New studies and conflicting reports are published every year. While it is easy to shield a house against the electric field generated by nearby power lines, it is much more difficult to shield against the magnetic fields they generate²¹. The magnetic field can best be shielded by burying power transmission lines, but at a much higher cost compared to over-headlines.



Figure 5: Electric power line

²¹ Ali Zamanian and Cy Hardiman Fluor Corporation, Industrial and Infrastructure Group

Animal experiments, laboratory studies of cells, clinical studies, computer simulations, and human population (epidemiological) studies have been conducted to determine the relationship between exposure to electro-magnetic fields and a number of disorders, including depression, childhood leukemia, central nervous system disorders, cancer, melanoma, breast cancer, etc. In the past, numerous reports have presented conflicting information. Some of these reports have provided evidence of adverse health effects, and some other reports have failed to find any such correlation. Recently, the National Academy of Sciences and the National Cancer Institute have released major studies finding no evidence of a link between electromagnetic fields and cancer. These studies suggest that power transmission lines are much less likely to cause cancer than was previously suspected.

2.5 Radio Frequency (RF) Radiation

RF energy in the frequency range of LF, MF, HF VHF, UHF or Microwaves is often referred to as radio waves, RF radiation, or RF emissions. Here, the term “RF energy” is used for all frequencies between 30 kHz and 300 GHz. Some known facts about RF energy are:

- The biological effects of RF energy are proportional to the rate of energy absorption, and the level of absorption varies little with frequency.
- RF energy has the ability to heat human tissue, much like the way that microwave ovens heat food, and can be hazardous if the exposure is sufficiently intense or prolonged.
- Damage to tissue may be caused by exposure to high levels of RF energy because the body is not equipped to dissipate the excessive amounts of heat generated. Possible injuries include skin burns, deep burns, heat exhaustion and heat stroke.

Eyes are particularly vulnerable to extended exposure to RF energy; the lack of blood flow to cool the cornea can result in cataracts.

2.6 Broadcast Stations

Commercial AM/FM radio and TV broadcast stations transmit very high levels of RF energy. Some of their antennas radiate power levels of several megawatts but, fortunately, these antennas are generally placed on high towers or buildings where no humans are nearby. Even so, humans absorb more RF energy from AM/FM radios and TV broadcast station antennas than from mobile telephone and base station antennas. However, once the energy is absorbed from either source, the effects are basically the same.

An Australian group claimed to have evidence that living near television broadcast station towers causes an increase in childhood leukemia. However, follow-up studies conducted in Australia and in the UK contradicted this claim. The follow-up studies found no significant correlation between RF exposure and the rate of childhood leukemia in these cases²².

Cellular Telephones, Cordless Phones and Hand-Held Radios

Type of mobile radio	Frequency (MHz)	Average radiated power
Cellular/PCS	824-849 MHz 1850-1990 MHz	A few hundred milliwatts
Two-way, hand-held (walkie-talkie)	30, 50, 150, 450 and 800 MHz bands	Between 2 and 5 watts

²² *Electromagnetic Fields and Human Health*, by John E. Moulder, Ph.D., Professor of Radiation Oncology.

Cordless telephone	49, 915, 2450 MHz	Tens of milliwatts
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Table 1. Table showing typical portable/mobile radio equipment.

Most cellular/PCS and cordless telephones have either a small antenna attached or the antenna is integrated into the body of the telephone. Because the antenna of a cellular phone is close to the user's head, such telephones create greater RF exposure than other types of RF systems. Home cordless telephones and other two-way hand-held radios have a similar effect. However, cordless telephones have very low RF power output and two-way hand-held radios are generally used in the push-to-talk mode, therefore, transmission is not continuous. Table 1 illustrates the frequency bands and average radiated power for cellular, PCS, hand-held radios and cordless telephones in the United States.

2.7 Vehicular Mobile Telephones and Radios

Vehicular mobile telephones (not cellular) and radios have an antenna mounted outside a vehicle, usually on the roof, window, trunk or fender. The metal surface of a vehicle provides a shield between the mobile telephone or radio user and the RF energy radiated by the antenna. The distance between the user and the antenna also serves as protection against RF energy. Because of these two factors, users of mobile equipment have little exposure to RF energy, even though the average radiated power is significant, between 10 and 100 watts.

2.8 Base Stations and Radio Sites

Cellular/PCS and other two-way radio system base stations (radio sites) produce RF energy. Therefore, people near the base stations are exposed to this type of energy. However, the exposure is generally minimal due to the low level of power (less than 100 watts) produced and the distance between the tower-mounted antennas and any humans in the area.

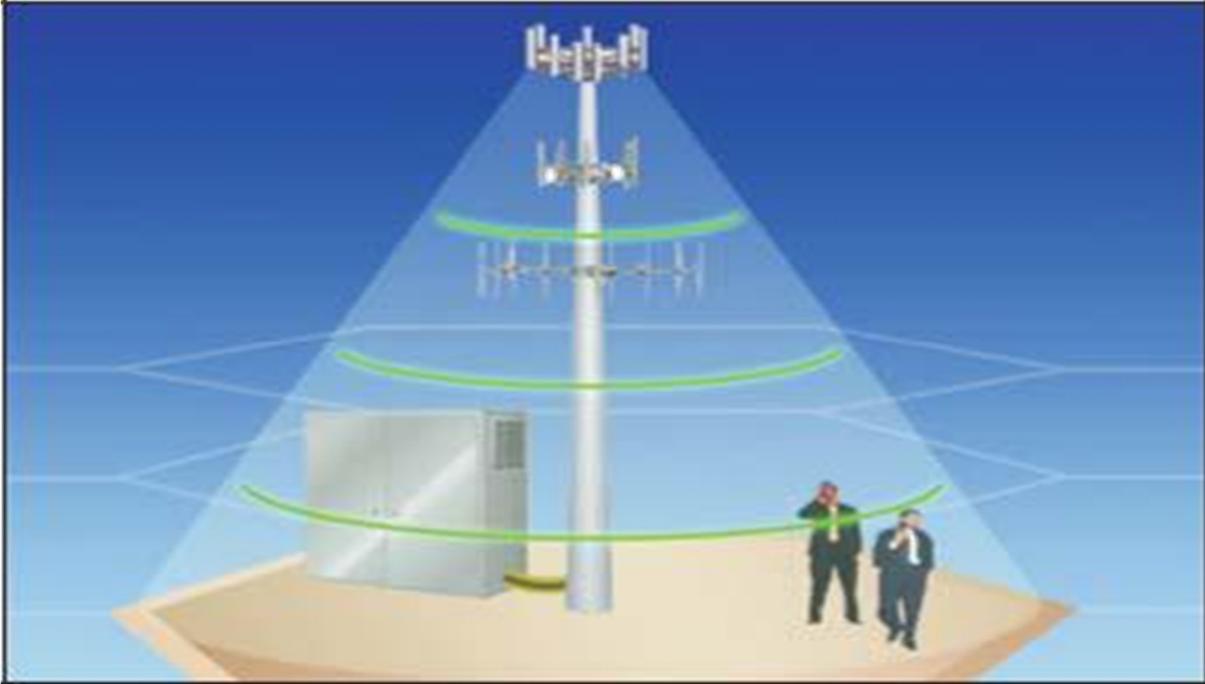


Figure 6: Exposure of humans to RF energy from radio sites

2.9 RF Exposure Concerns

EMR from cellular/cordless and hand-held radios have billions of times less energy needed to cause ionization or damage to DNA contained in human tissue. The rapid and widespread use of this technology, however, has raised concern over possible adverse health effects, in particular brain cancer. Several studies which addressed this concern have been conducted in the United States and other countries. These studies seem to rule out, with a reasonable level of confidence, any association between EMR from these devices and cancer.

A growing number of scientific experts have shifted positions regarding the use of these types of wireless devices. Many of these experts believe that a cancer risk is associated with EMR in the higher wattage ranges.

For base stations located at radio sites, the consensus of the scientific community is that the power produced is far too low to cause health hazards so long as people are prevented from being in close proximity to the antennas.

No study, to date, has provided conclusive evidence that cell phones can cause any illnesses. However, ongoing studies are examining the issue more closely. Recent reports from Europe raised concern over possible links between cell phone use and tumors in the ear, with the risk being greater for children than adults.

It is important to note that cellular/PCS and cordless telephones are relatively new technologies, and it is impossible to prove that any product or exposure is absolutely safe in the absence of long-term research. Therefore, a good “precautionary” approach would be for adults to keep cell phone conversations short and to discourage the frequent, extended use of cell phones by children²³.

A notable danger involving the use of cellular phones is not radiation related, but is rather the increased risk of driving accidents while using them. The results of several studies indicate that talking on a cellular telephone while driving significantly increase the risk of accidents with some suggesting that it is almost as dangerous as driving while drunk.

2.10 Effect of Microwave Ovens on Human Health and Food

Concerns are often expressed regarding the effects of EMR from microwave ovens on people nearby and on the food prepared in them. Many people believe that microwave ovens may cause cancer and that food prepared by them becomes toxic.

This belief is simply not true. While forms of ionizing radiation such as X-rays usually have sufficient localized energy to cause chemical damage to the molecules in their path, non-ionizing radiation, such as microwaves, does not damage molecules. Microwaves generate purely thermal energy, creating heat in moist food or tissue placed in the oven.

²³ *Electromagnetic Fields and Human Health*, by John E. Moulder, Ph.D., Professor of Radiation Oncology.

Microwave ovens are designed and tested so that negligible micro-wave radiation escapes when the door is closed, making the level of the RF radiation outside the oven quite safe. However, leakage from a worn or damaged gasket around the oven's door can allow radiation leakage which can create an unsafe condition.

Foods cooked in a microwave oven suffer no lasting effects. No conclusive evidence exists of any chemical changes in microwave-prepared food beyond those effects caused by heating, as in a normal oven.

2.11 Microwave Communication Links

Microwave communication links operate in frequency bands between 1 GHz and 60 GHz. As mentioned previously, heat will be generated in living tissue exposed to RF frequencies, including microwave radiation. The human eye is particularly susceptible to damage from microwave energy. In extensive, but controversial, research on the ocular effects of microwaves on animals, lens cataracts have been produced after exposure to very high frequencies.

Microwave links used for communications employ highly focused beams of energy sent through space directly between antennas usually placed high on special towers. This practice makes it unlikely that anyone can inadvertently come directly in the path of this type of energy.

2.12 Magnetic Resonance Imaging

MRI is based on the magnetic properties of atoms. Magnetic resonance technology is based on the absorption and emission of energy in the radio frequency from various body tissues. MRIs use a powerful magnet to produce a magnetic field approximately 10,000 times stronger than the natural background magnetic field produced by the earth, and generate a variable RF radiation in the 1 MHz to 100 MHz range. A very small percent-age of hydrogen atoms within a human body will align with the static magnetic field. When focused, radio wave pulses are transmitted toward the aligned hydrogen atoms

in tissues of interest, where they will reflect a weak signal. Images are created through the reception and analysis of the reflected weak radio signals. These slight differences in the signal received from various body tissues enable the MRI to produce images of extraordinary resolution that differentiate organs, and potentially contrast benign and malignant tissue.

Although power deposition in the patient can be substantial, no side effects or after effects are experienced, since MRI does not utilize ionizing radiation. However, hazards of improperly applied MRI therapy do exist that can cause severe injuries or even death. These hazards are primarily the result of:

- Strong magnetic fields from MRIs causing interference with implanted electronic devices such as pacemakers.
- RF burns resulting from induced currents in conductors accidentally placed on the patient's skin surface (e.g., leads from electro-cardio-graphs and other monitoring devices).

Optical Effects (Ultraviolet, Visible and Infrared Light) Sources of optical radiation exposure include:

- Sunlight
- Heat lamps
- Lasers
- Other incandescent sources

Intense optical radiation will cause electron excitation. This means that electrons in tissue near the body's surface can absorb energy from intense optical sources, thereby causing heating and even burning.

2.13 Visible light spectrum

Optical radiations are not very penetrating; therefore, the eye and the skin are the organs of greatest concern. The immediate effects can be retinal injury to the

eye as well as abnormal redness and burning of the skin due to solar radiation (sunburn). Delayed effects include cataract formation, retinal degeneration, accelerated aging, and skin cancer.

2.14 Effects of Infrared (IR)

Infrared (IR) is an energy field similar to visible light but with a longer wavelength. This radiation, typically emitted by heat lamps, molten metal or glass, fireplace embers and other “hot” objects, is invisible to the human eye. The thermal effects, characteristic of the IR region, extend into the spectrum of visible light. However, while visible light energy is emitted by objects only at a high temperature, infrared energy is emitted by all objects at ordinary temperatures. Some studies have shown that infrared energy can have positive effects on human cells in that it can help to rebuild connective tissue. Infrared radiation has no correlation with ultraviolet radiation and applied in moderation, has no damaging effect on human health.

2.15 Effects of Ultraviolet (UV)

The main effect of Ultraviolet (UV) radiation is photochemical; this effect is also the case, but to a lesser degree, with visible light. Everyone is exposed on a daily basis to the UV radiation contained in sunlight. The harmful effects of UV exposure depend on the level of exposure, the duration of exposure and differences in the susceptibility of individuals to UV light. UV radiation has both positive and negative effects. The positive effects of UV radiation include warmth, photosynthesis in plants, and vitamin D synthesis in the human body. However, overexposure to UV radiation has adverse health effects. In addition to the immediate effect of sunburn, overexposure to UV radiation can cause skin cancer, eye damage, immune system suppression, and premature aging. Children are highly susceptible to harmful UV radiation. Because of its greater biological effects, some references consider UV to be ionizing radiation.

2.16 X-rays, Gamma Rays and Other Nuclear/Cosmic Rays

The adverse effects of large doses of ionizing radiation were seen shortly after the discovery of radioactivity and X-rays in the 1890s. In 1902, skin cancers were reported in scientists who were studying radioactivity. The role of radiation in causing leukemia in humans (primarily in physicians and radiologists) was first reported in 1944.

2.17 X-rays and CT Scan

Due to the extremely high frequencies and energies of these forms of EMR, they have sufficient energy to break chemical bonds in living tissue. The well-known biological effects of X-rays are associated with the ionization of molecules. The many types of X-ray devices include:

- Radiographic systems (dental, podiatry, veterinary, medical, chiropractic)
- Fluoroscopic imaging systems; (hospitals, radiologists)
- Cancer therapy
- CT Scan (Computed Tomography)
- Mammography
- Cabinet X-ray systems for security (baggage inspection at airports)
- Industrial radiography (pipe welds, circuit board analysis)
- Bone Density Scans for detection of osteoporosis
- Other medical and research applications

A CT scan is essentially a sophisticated type of X-ray that can take cross section images of the body. These scans provide excellent bone detail by shooting multiple X-ray beams through the body to create a computer-generated image. Whole-body scans require higher doses of the X-ray radiation to make these

images. As is the case with other forms of ionizing radiation, X-rays, over the long term can modify genetic material in cells and cause mutations leading to cancer.

It is important to realize that the amount of X-ray radiation used in most diagnostic procedures is so small that the risk is extremely low. Multiple X-Ray examinations do not appear to increase risk, and no limits have been placed on the number of medically necessary X-ray examinations a person may undergo. However, it is always safe to assume that the same kind of effects that occur at high doses of radiation could occur at low doses; therefore, it is better to try to reduce exposure as much as possible. Patients should, if possible, minimize their exposure to X-rays, especially to CT scans which should not be performed on women who may be pregnant.

2.18 Gamma Rays

Everybody is basically aware of the high degree of danger associated with atomic radiation. Gamma rays, as well as Alpha and Beta particles emitted from radioactive material and nuclear reactions, are forms of ionizing radiation; these rays and particles can cause chemical or physical damage when they deposit energy in living tissue.

Health effects resulting from exposure to radiation vary from no effect at all to death, and can cause disorders such as leukemia or bone, breast, and lung cancer. In addition, the children of pregnant women who were exposed to high doses of radiation have shown an increased risk of birth defects. These effects have been observed in various studies of medical radiologists, uranium miners, radium workers, radiotherapy patients, and the people exposed to radiation from Chernobyl and the atomic bombs dropped on Hiroshima and Nagasaki.

CHAPTER THREE

3.0 Categories of Electromagnetic Fields

Electromagnetic fields (EMF) are characterized by their frequency or their corresponding wavelength. We are constantly surrounded by electromagnetic radiations that are invisible to the human eyes. Electromagnetic radiation can range from high frequency which referred to ionizing radiation to low frequency also referred to non-ionizing radiation.²⁴ However, the fields from different frequencies interacts with the body in different ways, while the ionizing radiations are known to be hazardous the non- ionizing radiations are presumed to be too weak to pose threat to public health.



Figure 7: High Frequency Magnetic Fields

²⁴ Grasso L, (1998) Virginia Journal of Law and Technology Cellular Telephones and the Potential Hazards of RF Radiation: Responses to the Fear and Controversy

High frequencies magnetic fields are classified under ionizing radiations. They exist as X-rays, Gamma rays, and other forms of nuclear radiations.²⁵ These category of radiation carries so much energy per quantum which can be lethal to human body.

3.1 Low frequency Magnetic Fields

The low frequency magnetic fields are classified under the non-ionizing radiations and electromagnetic radiations emitted from our cellular phone falls under these category²⁶. The levels of radiofrequency that individuals are regularly exposed to when using handset is pressured lower than those expected to pose danger through heating. The heating effects of these device forms the underlying effects for most guidelines. Researchers are also investigating possible effects below the threshold level for body heating as a result of long-term exposure to non-ionizing radiation.

3.2 Extremely low frequency (ELF) fields

ELF fields induce electric fields and currents in tissues that can result in involuntary nerve and muscle stimulation, but only at very high field strengths. These acute effects form the basis of international guidelines that limit exposure. However, fields found in our environment are so low that no acute effects result from them, except for small electric shocks that can occur from touching large conductive objects charged by these fields.

No adverse health effects have been established below the limits suggested by international guidelines.

²⁵ Extract from Electromagnetic fields, WHO Publication: Electromagnetic fields and public health: mobile phones

²⁶ International Journal of Occupational Safety and Ergonomics (JOSE) 2009, Vol. 15, No. 1, 3–33

3.3 Effects of EMF Radiation Associated with Base Station and Using Mobile Phone

According to the World Health Organization (WHO) publication in October 2014²⁷, cellular phones are now an integral part of modern telecommunication with an estimated 6.9 billion subscription globally. Given this vast number of cell phone clients, it is critical to examine, comprehend and screen for potential public health hazards.

The International Commission on Non -Ionizing Radiation Protection (ICNIRP) and the Institute of Electrical and Electronics Engineers (IEEE)²⁸ indicates that strong exposure to EMF can cause harmful health effects. However, the ICNIRP in cooperation with the WHO developed guidelines for limiting exposure to time-varying electric, magnetic and electromagnetic fields.²⁹

While a few research findings has concluded that exposure to radio frequencies (RF) radiations from cellular phones has adverse effects, other findings propose that cellular phones are safe. This highly debated topic on the impact of new technologies on public health often place policy makers with difficult choices of intense of protecting the public without the risk of driving useful product out of the market.

Studies shows that EMF emission from mobile phones, base stations usually complies with the set limitation of exposure for the general public. However most high level exposure are often occupational exposure occur with results from

²⁷ Philips J, Singh N, lai H. (2009). Electromagnetic fields and DNA damage Pathophysiology. 16 (2-3), 79-88

²⁸ Institute of Electrical and Electronics Engineers (IEEE). *IEEE standard for safety levels with respect to human exposure to radio frequency electromagnetic fields, 3 kHz to 300 GHz*, IEEE Std C95.1, 2005.

²⁹ ICNIRP *Guidelines, Health physics* 74(4):494-522; 1998

technical activities in close vicinity with antenna of base station Belyaev, (2005)³⁰.

3.4 Exposure Levels

Mobile phones are low-powered radiofrequency transmitters, operating at frequencies between 450 and 2700 MHz with peak powers in the range of 0.1 to 2 watts. The handset only transmits power when it is turned on. The power (and hence the radiofrequency exposure to a user) falls off rapidly with increasing distance from the handset. A person using a mobile phone 30–40 cm away from their body – for example when text messaging, accessing the Internet, or using a “hands free” device – will therefore have a much lower exposure to radiofrequency fields than someone holding the handset against their head.

In addition to using "hands-free" devices, which keep mobile phones away from the head and body during phone calls, exposure is also reduced by limiting the number and length of calls. Using the phone in areas of good reception also decreases exposure as it allows the phone to transmit at reduced power. The use of commercial devices for reducing radiofrequency field exposure has not been shown to be effective.

Mobile phones are often prohibited in hospitals and on airplanes, as the radiofrequency signals may interfere with certain electro-medical devices and navigation systems.

³⁰ Belyaev I. (2005). Nonthermal biological effects of microwaves: current knowledge, further perspective, and urgent needs. *Electromagnetic Biology and Medicine* 24,375-403.

3.5 Are there any health effects?

A large number of studies have been performed over the last two decades to assess whether mobile phones pose a potential health risk. To date, no adverse health effects have been established as being caused by mobile phone use³¹.

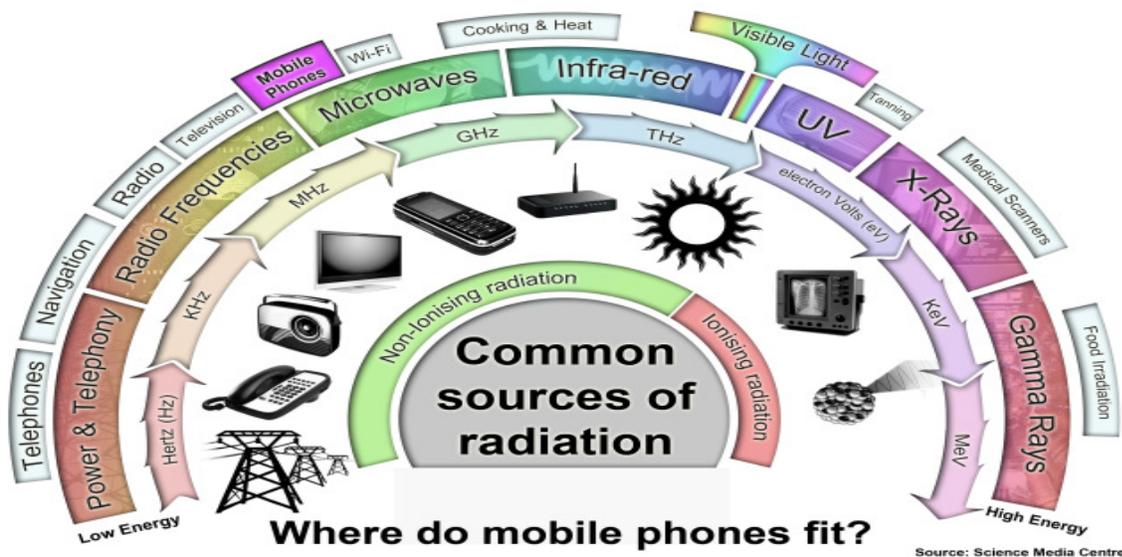


Figure 8: Areas of Fit of Terminal Equipment

3.5.1 Short –Term Effects

Tissue heating is the principal mechanism of interaction between radiofrequency energy and the human body. At the frequencies used by mobile phones, most of the energy is absorbed by the skin and other superficial tissues, resulting in negligible temperature rise in the brain or any other organs of the body.

A number of studies have investigated the effects of radiofrequency fields on brain electrical activity, cognitive function, sleep, heart rate and blood pressure in volunteers. To date, research does not suggest any consistent evidence of

³¹ Akan Z, Aksu B, Tulunay A, Bilsel S, Inhan-Garip A. (2010). Extremely Low – Frequency Electromagnetic Fields Affect the Immune Response of Monocyte_derived Macrophages to Pathogens. *Bioelectromagnetics* 31:603-612.

adverse health effects from exposure to radiofrequency fields at levels below those that cause tissue heating. Further, research has not been able to provide support for a causal relationship between exposure to electromagnetic fields and self-reported symptoms, or “electromagnetic hypersensitivity”.³²

3.5.2 Long- Term Effects

Epidemiological research examining potential long-term risks from radiofrequency exposure has mostly looked for an association between brain tumors and mobile phone use. However, because many cancers are not detectable until many years after the interactions that led to the tumor, and since mobile phones were not widely used until the early 1990s, epidemiological studies at present can only assess those cancers that become evident within shorter time periods. However, results of animal studies consistently show no increased cancer risk for long-term exposure to radiofrequency fields³³.

Several large multinational epidemiological studies have been completed or are ongoing, including case-control studies and prospective cohort studies examining a number of health endpoints in adults.

The largest retrospective case-control study to date on adults, Interphone, coordinated by the International Agency for Research on Cancer (IARC), was designed to determine whether there are links between use of mobile phones and head and neck cancers in adults.

The international pooled analysis of data gathered from 13 participating countries found no increased risk of glioma or meningioma with mobile phone use of more than 10 years. There are some indications of an increased risk of glioma for those who reported the highest 10% of cumulative hours of cell phone

³² Extract from Electromagnetic fields, WHO Publication: Electromagnetic fields and public health: mobile phones

³³ Moore K., Roberts JL., 1998. Measurement of lipid peroxidation. Free Radical Research 28:659-671.

use, although there was no consistent trend of increasing risk with greater duration of use. The researchers concluded that biases and errors limit the strength of these conclusions and prevent a causal interpretation.

Based largely on these data, IARC has classified radiofrequency electromagnetic fields as possibly carcinogenic to humans (Group 2B), a category used when a causal association is considered credible, but when chance, bias or confounding cannot be ruled out with reasonable confidence. While an increased risk of brain tumors is not established, the increasing use of mobile phones and the lack of data for mobile phone use over time periods longer than 15 years warrant further research of mobile phone use and brain cancer risk. In particular, with the recent popularity of mobile phone use among younger people, and therefore a potentially longer lifetime of exposure, WHO has also promoted further research of this group. Several studies investigating potential health effects in children and adolescents are underway³⁴.

3.5.3 Exposure Limit Guidelines

In the United States, federal, state and local authorities require that all equipment and facilities emitting electromagnetic radiation comply with their exposure guidelines. These guidelines are designed to protect both occupational workers and the general public with a very large margin of safety. These limits have been endorsed by federal health and safety agencies such as the Environmental Protection Agency, the Food and Drug Administration, etc. These standards limit exposure to levels many times below those levels generally accepted as having the potential to cause adverse health effects.

Radiofrequency exposure limits for mobile phone users are given in terms of Specific Absorption Rate (SAR) – the rate of radiofrequency energy absorption per

³⁴ Kula B, Sobczak A, Kuska R. (2000). Effects of static and ELF magnetic fields on free –radical processes in rat liver and kidney. *Electromagnetic Biology and Medicine* 19 (1), 99-105.

unit mass of the body. Currently, two international bodies^{35 36} have developed exposure guidelines for workers and for the general public, except patients undergoing medical diagnosis or treatment. These guidelines are based on a detailed assessment of the available scientific evidence.

3.6 Relationship between the Human Body and Electromagnetic Fields

The human body grounds electromagnetic radiation in the environment because of the electrical conductivity of our body. It is attracted to us. All living systems are based on electromagnetic energy. Every cell in your body is generating an electromagnetic field, every plant, every rock, the planet itself, the whole universe is made up of energy. It is true that man-made electromagnetic radiation is not the only source of random photons in the environment, but the problem is these frequencies which we have never encountered before are a whole different spectrum of frequencies than the living system uses.³⁷

3.7 World Health Organization Response on EMF

In response to public and governmental concern, WHO established the International Electromagnetic Fields (EMF) Project in 2006 to assess the scientific evidence of possible adverse health effects from electromagnetic fields.³⁸ WHO conducted a formal risk assessment of all studied health outcomes

³⁵ International Commission on Non-Ionizing Radiation Protection (ICNIRP). *Statement on the "Guidelines for limiting exposure to time-varying electric, magnetic and electromagnetic fields (up to 300 GHz)"*, 2009.

³⁶ Institute of Electrical and Electronics Engineers (IEEE). *IEEE standard for safety levels with respect to human exposure to radio frequency electromagnetic fields, 3 kHz to 300 GHz*, IEEE Std C95.1, 2005.

³⁷ The negative effects of electromagnetic fields by: Hall, Joe

³⁸ http://www.who.int/peh-emf/project/IAC_2006_Progress_Report.pdf

from radiofrequency fields exposure by 2016. In addition, and as noted above, the International Agency for Research on Cancer (IARC), a WHO specialized agency, reviewed the carcinogenic potential of radiofrequency fields, as from mobile phones in May 2011.

WHO also identifies and promotes research priorities for radiofrequency fields and health to fill gaps in knowledge through its research agendas. WHO develops public information materials and promotes dialogue among scientists, governments, industry and the public to raise the level of understanding about potential adverse health risks of mobile phones.

CHAPTER 4

4.0 WORLD HEALTH ORGANISATION (WHO) RESEARCHES AND OTHER SCIENTIFIC RESULTS

The use of electricity and electronic devices has become an integral part of everyday life. Whenever electricity flows, both electric and magnetic fields exist close to the lines that carry electricity, and close to appliances. Since the late 1970s, questions have been raised whether exposure to these extremely low frequency (ELF) electric and magnetic fields (EMF) produces adverse health consequences. Since then, much research has been done, successfully resolving important issues and narrowing the focus of future research³⁹. In 1996, the World Health Organization (WHO) established the International Electromagnetic Fields Project to investigate potential health risks associated with technologies emitting EMF. A WHO Task Group recently concluded a review of the health implications of ELF fields (WHO, 2007). This Fact Sheet is based on the findings of that Task Group and updates recent reviews on the health effects of ELF EMF published in 2002 by the International Agency for Research on Cancer (IARC), established under the auspices of WHO, and by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) in 2003. ELF field sources and residential exposures Electric and magnetic fields exist wherever electric current flows - in power lines and cables, residential wiring and electrical appliances⁴⁰.

Electric fields arise from electric charges, are measured in volts per metre (V/m) and are shielded by common materials, such as wood and metal. Magnetic fields arise from the motion of electric charges (i.e. a current), are expressed in tesla (T), or more commonly in millitesla (mT) or microtesla (μ T). In some countries

³⁹ WHO - World Health Organization. Extremely low frequency fields. Environmental Health Criteria, Vol. 238. Geneva, World Health Organization, 2007

⁴⁰ ICNIRP - International Commission on Non-Ionizing Radiation Protection. Exposure to static and low frequency electromagnetic fields, biological effects and health consequences (0-100 kHz). Bernhardt JH et al., eds. Oberschleissheim, International Commission on Non-ionizing Radiation Protection, 2003 (ICNIRP 13/2003).

another unit called the gauss, (G), is commonly used ($10,000 \text{ G} = 1 \text{ T}$).⁴¹ These fields are not shielded by most common materials, and pass easily through them. Both types of fields are strongest close to the source and diminish with distance. Most electric power operates at a frequency of 50 or 60 cycles per second, or hertz (Hz). Close to certain appliances, the magnetic field values can be of the order of a few hundred microtesla (μT). Underneath power lines, magnetic fields can be about $20 \mu\text{T}$ and electric fields can be several thousand volts per meter. However, average residential power-frequency magnetic fields in homes are much lower - about $0.07 \mu\text{T}$ in Europe and $0.11 \mu\text{T}$ in North America. Mean values of the electric field in the home are up to several tens of volts per meter.

In October 2005, WHO convened a Task Group of scientific experts to assess any risks to health that might exist from exposure to ELF electric and magnetic fields in the frequency range >0 to $100,000 \text{ Hz}$ (100 kHz). While IARC examined the evidence regarding cancer in 2002, this Task Group reviewed evidence for a number of health effects, and updated the evidence regarding cancer. The conclusions and recommendations of the Task Group are presented in a WHO Environmental Health Criteria (EHC) monograph (WHO, 2007). Following a standard health risk assessment process, the Task Group concluded that there are no substantive health issues related to ELF electric fields at levels generally encountered by members of the public. Thus the remainder of this fact sheet addresses predominantly the effects of exposure to ELF magnetic fields. Short-term effects⁴².

There are established biological effects from acute exposure at high levels (well above $100 \mu\text{T}$) that are explained by recognized biophysical mechanisms. External ELF magnetic fields induce electric fields and currents in the body

⁴¹ IEEE Standards Coordinating Committee 28. IEEE standard for safety levels with respect to human exposure to electromagnetic fields, 0-3 kHz. New York, NY, IEEE - The Institute of Electrical and Electronics Engineers, 2002 (IEEE Std C95.6-2002).

⁴² WHO - World Health Organization. Extremely low frequency fields. Environmental Health Criteria, Vol. 238. Geneva, World Health Organization, 2007.

which, at very high field strengths, cause nerve and muscle stimulation and changes in nerve cell excitability in the central nervous system.

4.1 Potential long-term effects

Much of the scientific research examining long-term risks from ELF magnetic field exposure has focused on childhood leukaemia. In 2002, IARC published a monograph classifying ELF magnetic fields as "possibly carcinogenic to humans". This classification is used to denote an agent for which there is limited evidence of carcinogenicity in humans and less than sufficient evidence for carcinogenicity in experimental animals (other examples include coffee and welding fumes). This classification was based on pooled analyses of epidemiological studies demonstrating a consistent pattern of a two-fold increase in childhood leukaemia associated with average exposure to residential power-frequency magnetic field above 0.3 to 0.4 μT .⁴³

The Task Group concluded that additional studies since then do not alter the status of this classification. However, the epidemiological evidence is weakened by methodological problems, such as potential selection bias. In addition, there are no accepted biophysical mechanisms that would suggest that low-level exposures are involved in cancer development. Thus, if there were any effects from exposures to these low-level fields, it would have to be through a biological mechanism that is as yet unknown. Additionally, animal studies have been largely negative.

Thus, on balance, the evidence related to childhood leukaemia is not strong enough to be considered causal. Childhood leukaemia is a comparatively rare disease with a total annual number of new cases estimated to be 49,000 worldwide in 2000. Average magnetic field exposures above 0.3 μT in homes are rare: it is estimated that only between 1% and 4% of children live in such

⁴³ Cooke R, Laing S, Swerdlow AJ. (2010 Nov. 23). A case- control study of risk of leukaemia in relation to mobile phone use. *Br. J. Cancer.* ;103 (11) :1729-35.

conditions. If the association between magnetic fields and childhood leukaemia is causal, the number of cases worldwide that might be attributable to magnetic field exposure is estimated to range from 100 to 2400 cases per year, based on values for the year 2000, representing 0.2 to 4.95% of the total incidence for that year. Thus, if ELF magnetic fields actually do increase the risk of the disease, when considered in a global context, the impact on public health of ELF EMF exposure would be limited.

A number of other adverse health effects have been studied for possible association with ELF magnetic field exposure. These include other childhood cancers, cancers in adults, depression, suicide, cardiovascular disorders, reproductive dysfunction, developmental disorders, immunological modifications, neuro behavioral effects and neurodegenerative disease. The WHO Task Group concluded that scientific evidence supporting an association between ELF magnetic field exposure and all of these health effects is much weaker than for childhood leukaemia. In some instances (i.e. for cardiovascular disease or breast cancer) the evidence suggests that these fields do not cause them.⁴⁴

4.2 International exposure guidelines

Health effects related to short-term, high-level exposure have been established and form the basis of two international exposure limit guidelines (ICNIRP, 1998; IEEE, 2002). At present, these bodies consider the scientific evidence related to possible health effects from long-term, low -level exposure to ELF fields insufficient to justify lowering these quantitative exposure limits. WHO's guidance For high-level short-term exposures to EMF, adverse health effects have been scientifically established (ICNIRP, 2003). International exposure guidelines designed to protect workers and the public from these effects should be adopted by policy makers. EMF protection programs should include exposure

⁴⁴ Cooke R, Laing S, Swerdlow AJ. (2010 Nov. 23). A case- control study of risk of leukaemia in relation to mobile phone use. *Br. J. Cancer.* ;103 (11) :1729-35.

measurements from sources where exposures might be expected to exceed limit values.⁴⁵

During recent years there has been increasing scientific evidence for, and public concern on potential health risks from power-frequency fields (extremely low frequency electromagnetic fields; ELF) and from radiofrequency/micro-wave radiation emissions (RF) from wireless communications and data transmission. So far, guidelines for exposure to microwaves have been based on thermal (heating) effects. Non-thermal (low-intensity) effects have not been considered for regulation of exposure.

Recently a more comprehensive report was published online that documents considerable scientific evidence for bioeffects and adverse health impacts at exposure levels far below current public safety standards.⁴⁶

Everyone is exposed to two types of electromagnetic fields:

(EMFs): (a) ELF fields from electrical and electronic appliances and power lines, and (b) RF radiation from wireless devices such as cell phones and cordless phones, cellular antennas and towers, and broadcast transmission towers. In this report we will use the term EMFs when referring to all electromagnetic fields in general, and the terms ELF and RF when referring to the specific type of exposure. They are both types of non-ionizing radiation, which means that they do not have sufficient energy to break off electrons from their orbits around atoms and ionize (charge) the atoms, as ionizing radiation.

4.3. Mobile phone use and evidence for brain tumors and acoustic neuroma

We made a review including 18 studies, two cohort studies and 16 case-control studies. Most studies have published data with rather short latency period and

⁴⁵ ICNIRP – International Commission on Non-Ionizing Radiation Protection (1998). Guidelines for limiting exposure to time varying electric, magnetic and electromagnetic fields (up to 300 GHz). Health Physics 74(4), 494-522.

⁴⁶ BioInitiative report: a rationale for a biologically-based public exposure standard for electromagnetic fields (ELF and RF). <http://www.bioinitiative.org>

limited information on long-term users. Thus, a meta-analysis of the risk for acoustic neuroma, glioma and meningioma was performed for mobile phone use with a latency period of 10 years or more⁴⁷. Overall OR ¼ 1.3, 95% CI ¼ 0.6e2.8 was obtained increasing to OR ¼ 2.4, 95% CI ¼ 1.1e5.3 for ipsilateral mobile phone use. For glioma OR ¼ 1.2, 95% CI ¼ 0.8e1.9 was calculated. Ipsilateral use yielded OR ¼ 2.0, 95% CI ¼ 1.2e3.4. In total OR ¼ 1.3, 95% CI ¼ 0.9e1.8 was found for meningioma increasing to OR ¼ 1.7, 95% CI ¼ 0.99e3.1 for ipsilateral use.

Only two studies have been published since then. Both were on acoustic neuroma^{48 49}. They were small and included no cases with a latency period of at least 10 years. Furthermore, most ORs were <1.0 in these two studies indicating serious methodological problems. The final results on this topic from the Interphone study led by the International Agency or Research on Cancer (IARC) are expected during 2008.

No other studies than from the Hardell group has published results for use of cordless phones (DECT)^{50 51}. Cordless phones are an important source of exposure to radiofrequency microwaves and they are usually used for a longer time period on daily basis as compared with mobile phones. Thus, to exclude such use, as was done in e.g. the Interphone studies, could lead to an underestimation of the risk for brain tumours from use of wireless phones.

⁴⁷ Hardell L, Carlberg M, So¨derqvist F, Hansson Mild K, Morgan LL. Long-term use of cellular phones and brain tumours: increased risk associated with use for 10 years. *Occup Environ Med* 2007;64: 626e32. doi:10.1136/oem.2006.029751.

⁴⁸ Klæboe L, Blaasaas KG, Tynes T. Use of mobile phones in Norway and risk of intracranial tumours. *Eur J Cancer Prev* 2007;16:158e64

⁴⁹ Schlehofer B, Schlafer K, Blettner M, Berg G, Bo¨hler F, Hettinger I, et al. Environmental risk factors for sporadic acoustic neuroma (Interphone Study Group, Germany). *Eur J Cancer* 2007;43(11):1741e7. doi:10.1016/j.ejca.2007.05.008

⁵⁰ Hardell L, Carlberg M, Hansson Mild K. Pooled analysis of two casecontrol studies on the use of cellular and cordless telephones and the risk of benign tumours diagnosed during 1997e2003. *Int J Oncol* 2006;28:509e18

⁵¹ Hardell L, Hansson Mild K, Carlberg M. Pooled analysis of two casecontrol studies on use of cellular and cordless telephones and the risk for malignant brain tumours diagnosed in 1997e2003. *Int Arch Occup Environ Health* 2006;79:630e9.

In summary our review yielded a consistent pattern of an increased risk for acoustic neuroma and glioma after 10 years mobile phone use. We conclude that current standard for exposure to microwaves during mobile phone use is not safe for long-term exposure and needs to be revised.

4.4. RF fields other than from mobile phones and epidemiological evidence for brain tumours

It is concluded that only few studies of long-term exposure to low levels of RF fields and brain tumours exist, all of which have methodological shortcomings including lack of quantitative exposure assessment. Given the crude exposure categories and the likelihood of a bias towards the null hypothesis of no association, the body of evidence is consistent with a moderately elevated risk. Occupational studies indicate that long-term exposure at workplaces may be associated with an elevated brain tumor risk.

Although in some occupations (especially in military jobs) current exposure guidelines may have sometimes been reached or exceeded, overall the evidence suggests that long-term exposure to levels generally lying below current guideline levels still carry the risk of increasing the incidence of brain tumours.

Despite a rather low population attributable risk (likely below 4%), still more than 1000 cases per year in the US can be attributed to RF exposure at workplaces alone.

4.5. Evidence for childhood cancers and leukemia

The only endpoint studied so far in sufficient detail is childhood leukemia. Brain and nervous system tumors were also studied in some detail but due to the diversity of these tumours no conclusions can be drawn. Childhood leukemia is the most frequent childhood malignancy that peaks in the age group of 2 to about 5 years. This peak seems to have been newly evolved in the early quarter of the

20th century and may be due to electrification⁵². This assumption is supported by the absence of this peak or it being much less pronounced in developing countries.

An overview of existing evidence from epidemiological studies indicates that there is a continuous increase of risk with increasing levels of average magnetic field exposure.

Risk estimates reach statistical significance at levels of 3×10^{-4} mG (0.3e0.4 microTesla or mT). The overall odds ratio in nine studies was 2.1, 95% confidence limit 1.3e3.3. A low number of children are exposed at these or higher levels.

The balance of evidence suggests that childhood leukaemia is associated with exposure to power-frequency ELF's either during pregnancy or early life. Considering only average MF flux densities the population attributable risk is low to moderate. However, there is a possibility that other exposure metrics are much stronger related to childhood leukaemia and may account for a substantial proportion of cases, perhaps up to 80% of all cases. The population attributable fraction ranges between 1 and 4%⁵³ assuming only exposures above 3×10^{-4} mG (0.3e0.4 mT) are relevant.

Other childhood cancers except leukaemia have not been studied in sufficient detail to allow conclusions about the existence and magnitude of the risk.

The International Commission for Non-ionizing Radiation Protection (ICNIRP) and Institute of Electric and Electronics Engineers, Inc. (IEEE) guideline levels are designed to protect from short-term immediate effects only, but not chronic exposures. Long-term effects such as cancer are evoked by exposure several orders of magnitudes below current guideline levels. The BioInitiative Report concludes that the evidence for increased risk of childhood leukaemia with

⁵² Milham S, Ossiander EM. Historical evidence that residential electrification caused the emergence of the childhood leukemia peak. *Med Hypotheses* 2001;56:290e5.

⁵³ Kheifets L, Afifi AA, Shimkhada R. Public health impact of extremely low frequency electromagnetic fields. *Environ Health Perspect* 2006;114(10):1532e7

chronic exposure to ELF is sufficient to warrant revision of ELF public safety limits⁵⁴.

4.6. Breast cancer

There is evidence from multiple areas of scientific investigations that ELF is related to breast cancer. Over the last two decades there have been numerous epidemiological studies on breast cancer in both men and women, although this relationship remains controversial. Many of these studies, however, report that ELF exposures are related to increased risk of breast cancer⁵⁵.

The evidence from studies on women in workplaces suggests that ELF is a risk factor for breast cancer for women with long-term exposures of 10 mG (1.0 mT) and higher.

Laboratory studies that examine human breast cancer cells have shown that ELF exposure between 6mG and 12 mG (0.6e1.2 mT) can interfere with protective effects of melatonin for the growth of these breast cancer cells. For a decade, there has been evidence that human breast cancer cells grow faster if exposed to ELF at low environmental levels. This is thought to be because ELF exposure can reduce melatonin levels in the body.

Laboratory studies of animals that have breast cancer tumours have been shown to have more tumours and larger tumours when exposed to ELF and a chemical tumour promoter at the same time. These studies taken together indicate that ELF is a likely risk factor for breast cancer, and that ELF levels of importance are no higher than many people are exposed to at home and at work. A

⁵⁴ Possible effects of Electromagnetic Fields (EMF) on Human Health. (19 July 2010) Scientific Committee On Emerging And Newly Identified Health Risks (SCENIHR)

⁵⁵ Heikkinen P, Kosma VM, Alhonen L, Huuskonen H, Komulainen H, Kumlin T, et al. Effects of mobile phone radiation on UV-induced skin tumourigenesis in ornithine decarboxylase transgenic and non-transgenic mice. *Int J Radiat Biol* 2003; 79:221-33.

reasonable suspicion of risk exists and is sufficient evidence on which to recommend new ELF limits; and to warrant preventative action⁵⁶.

Given the very high lifetime risks for developing breast cancer in women, and the critical importance of prevention, ELF exposures should be reduced for all people who are in high ELF environments for prolonged periods of time. Reducing ELF exposure would be particularly important for people who have breast cancer. The recovery environment should have low ELF levels given the evidence for poorer survival rates as shown for subjects with another malignant disease, childhood leukaemia patients in ELF fields over 2 mG or 3 mG (0.2 or 0.3 mT).

Preventative action for those who may be at higher risk for breast cancer is also warranted, particularly for those taking tamoxifen during their anti-cancer treatment, since in addition to reducing the effectiveness of melatonin, ELF exposure may also reduce the effectiveness of tamoxifen at these same low exposure levels. There is no excuse for ignoring the substantial body of evidence we already have that supports an association between breast cancer and ELF exposure; waiting for conclusive evidence is untenable given the enormous costs and societal and personal burdens caused by this disease.

4.7. Changes in the nervous system and brain function

Exposure to electromagnetic fields has been studied in connection with Alzheimer's disease, motor neuron disease and Parkinson's disease. There is evidence that high level of amyloid beta is a risk factor for Alzheimer's disease, and exposure to ELF can increase this substance in the brain. There is considerable evidence that melatonin can protect the brain against damage leading to Alzheimer's disease, and also strong evidence that exposure to ELF can reduce melatonin levels⁵⁷.

⁵⁶ Hepworth SJ, Schoemaker MJ, Muir KR, Swerdlow AJ, van Tongeren MJ, McKinney PA. Mobile phone use and risk of glioma in adults: case-control study. *BMJ* 2006; 332:883-7.

⁵⁷ Kula B, Sobczak A, Kuska R. (2000). Effects of static and ELF magnetic fields on free – radical processes in rat liver and kidney. *Electromagnetic Biology and Medicine* 19 (1), 99-105.

Thus it is hypothesized that one of the body's main protections against developing Alzheimer's disease (melatonin) is less available to the body when people are exposed to ELF. Prolonged exposure to ELF fields could alter calcium (Ca²⁺) levels in neurons and induce oxidative stress. Concern has also been raised that humans with epileptic disorders could be more susceptible to RF exposure.

Laboratory studies show that the nervous system of both humans and animals is sensitive to both ELF and RF. Measurable changes in brain function and behaviour occur at levels associated with new technologies including cell phone use. Exposing humans to cell phone radiation can change brainwave activity at levels as low as 0.1 watt per kilogram (W/Kg) specific absorption rate (SAR) in comparison to the US allowable level of 1.6 W/Kg (in 1 g of tissue) and ICNIRP allowable level of 2.0 W/Kg (in 10 g of tissue). Cell phone radiation can affect memory and learning. Changes in the way in which the brain and nervous system react depend very much on the specific exposures. Most studies only look at short-term effects, so the long-term consequences of exposures are not established, but existing scientific documentation of effects is sufficient to warrant preventative action with reduction in exposures, particularly for vulnerable groups such as children⁵⁸.

Factors that determine effects can depend on head shape and size, the location, size and shape of internal brain structures, thinness of the head and face, hydration of tissues, thickness of various tissues, dielectric constant of the tissues and so on. Age of the individual and state of health also appear to be important variables. There is large variability in the results of ELF and RF testing, which would be expected to be based on the large variability of factors that can influence test results. However, it is clearly demonstrated that under

⁵⁸ European Environmental Agency. Highlights: European Environmental Agency website by Dr. Jacqueline McGlade, Director. Statement of September 17, 2007. www.eea.europa.eu/themes/human

some conditions of exposure, the brain and nervous system functions of humans are altered.

The consequence of long-term or prolonged exposures has not been thoroughly studied in either adults or in children. The consequence of prolonged exposures to children, whose nervous systems continue to develop until late adolescence, is unknown at this time, but there are credible, published studies reporting bioeffects and adverse health impacts with exposures at very low levels (far below public safety standards). This could have serious implications to adult health and functioning in society if years of exposure of the young to both ELF and RF result in diminished capacity for thinking, judgment, memory, learning, and control over behavior.

4.8. Evidence for effects on gene and protein expression

The effects of RF EMF on global gene and protein expression have been investigated in different biological systems and most of the studies were focused on the mobile phone utilization frequency (800e2000 MHz) at a relatively low exposure density (average SAR near 2.0 W/Kg). Some studies reported negative results of RF EMF exposure on gene expression. Based on current available literature, it is justified to conclude that EMF exposure can change gene and/or protein expression in certain types of cells, even at intensities lower than ICNIRP recommended values. However, the biological consequences of most of the changed genes/proteins as based on early studies from proteomics and transcriptomics are still unclear, and need to be further explored. Thus, it is not the time point yet to assess the health impact of EMF based on the gene and protein expression data. The IEEE and WHO databases do not include the majority of ELF studies; they do include the majority of the RF studies.

Currently, the state of proteomics and transcriptomic is in its infancy, with only a few dozen studies reporting results, some positive and some negative. The EMF research community should pay equal attention to the negative reports as to the

positive ones. Not only the positive findings need to be replicated, the negative ones need to be critically assessed and replicated too.

4.9. Evidence for genotoxic effects e DNA damage

From this literature survey, about 50% of the studies reported effects. Not every study, however, would be expected to document effects, given the wide range of exposure conditions and varying sensitivity of assays. One can conclude that under certain conditions of exposure, radiofrequency radiation is genotoxic. Data available are mainly applicable only to cell phone radiation exposure. Other than the study by Phillips et al.⁵⁹, there are very few published studies of RF radiation at levels that one can experience in the vicinity of base stations and RF-transmission towers.

During cell phone use, a relatively constant mass of tissue in the brain is exposed to the radiation at relatively high intensity (peak SAR of 4e8 W/Kg). Several studies reported DNA damage at lower intensity than 4 W/Kg. The IEEE has revised its recommended standard for localized tissue exposure, changing it from 1.6 W/Kg over 1 g of tissue to 2 W/Kg over 10 g of tissue, although the Federal Communications Commission has not adopted this change. Since distribution of radiofrequency energy is non-homogenous inside tissue, this change allows a higher peak level of exposure. Furthermore, since critical genetic mutations in one single cell are sufficient to lead to cancer and there are millions of cells in a gram of tissue, it is inconceivable that the base of SAR standard was changed by IEEE from averaged over 1 gm of tissue to 10 gm.

Factors that may explain the failure of some studies to demonstrate effects, while others report clear and reproducible effects include (a) which DNA assay is used, (b) the exposure parameters of the experiment, and (c) which cell lines are used. Any effect of EMF has to depend on the energy absorbed by a biological entity

⁵⁹ European Environmental Agency. Highlights: European Environmental Agency website by Dr. Jacqueline McGlade, Director. Statement of September 17, 2007. www.eea.europa.eu/themes/human

and on how the energy is delivered in space and time. Frequency, intensity, exposure duration, and the number of exposure episodes can affect the response, and these factors can interact with each other to produce different effects.

The ‘comet assay’, has been used in most of the EMF studies to determine DNA damage. Different versions of the assay have been developed. These versions have different detection sensitivities and can be used to measure different aspects of DNA strand breaks. A comparison of data from experiments using different versions of the assay may be misleading, and may explain differing study results since some DNA comet assays are far more sensitive in detecting DNA damage than other assays.

A plausible biological mechanism to account for carcinogenesis is via free radical formation inside cells. Free radicals kill cells by damaging macromolecules, such as DNA, protein and membrane. Furthermore, free radicals play an essential role in the activation of certain signalling pathways. Several reports have indicated that EMFs enhance free radical activity in cells particularly via the Fenton reaction⁶⁰. The Fenton reaction is a catalytic process of iron to convert hydrogen peroxides, a product of oxidative respiration in the mitochondria, into hydroxyl free radical, which is a very potent and toxic free radical. Any exposure, including prolonged low-intensity ELF and RF exposures that result in increased free radical production may be considered a plausible biological mechanism for carcinogenesis.

4.10. Evidence for stress response

Studies of the stress response in different cells under various conditions have enabled us to characterize the molecular mechanisms by which cells respond to EMF and their effects on health risk. That information can now correct

⁶⁰ Lai H, Singh NP. Magnetic-field-induced DNA strand breaks in brain cells of the rat. *Environ Health Perspect* 2004;112(6):687e94

assumptions about biological effects of EMF, and establish a scientific basis for new safety standards⁶¹.

It is generally agreed that EMF safety standards should be based on science, yet recent EMF research has shown that a basic assumption used to determine EMF safety is not valid. The safety standard assumes that EMF causes biological damage only by heating, but cell damage occurs in the absence of heating and well below the safety limits. This has been shown in many studies, including the cellular stress response where cells synthesize stress proteins in reaction to potentially harmful stimuli in the environment, including EMF. The stress response to both the power-frequency (ELF) and radiofrequency/microwave (RF) ranges shows the inadequacy of the thermal SAR standard.

The stress response is a natural defense mechanism activated by molecular damage caused by environmental forces. The response involves activation of DNA, i.e., stimulating stress genes as well as genes that sense and repair damage to DNA and proteins. Scientific research has identified specific segments of DNA that respond to both ELF and RF. It has been possible to move these specific segments of DNA and transfer the sensitivity to EMF. At high EMF intensities, the interaction with DNA can lead to DNA strand breaks that could result in mutation, an initiating step in the development of cancer.⁶²

Scientific research has shown that ELF and RF fields interact with DNA to stimulate protein synthesis, and at higher intensities to cause DNA damage. The biological thresholds (field strength, duration) are well below current safety limits⁶³

⁶¹ Milani M, Balerini, M, Ferraro L, Zabeo M, Barberis M, Cannona M, Faleri M. (2001). Magnetic field effects on human lymphocytes. *Electromagnetic field effects on human lymphocytes. Electromagnetic Biology and Medicine* 20(1), 81-106

⁶² Phillips JL, Ivaschuk O, Ishida-Jones T, Jones RA, CampbellBeachler M, Haggren W. DNA damage in Molt-4 T-lymphoblastoid cells exposed to cellular telephone radiofrequency fields in vitro. *Bioelectrochem Bioenerg* 1998;45:103e10.

⁶³ Moriyama E., Salcman M., Broadwell R.D., 1991. Blood-brain barrier alteration after microwave-induced hyperthermia is purely a thermal effect: I. Temperature and power measurements. *Surg. Neurol.* ,35,177-182.

To be in line with EMF research, a biologically based standard must replace the thermal SAR standard, which is fundamentally flawed. EMF research also indicates a need for protection against the cumulative biological effects stimulated by EMF across the electromagnetic spectrum.

4.11. Key scientific evidence

Exposure to EMFs has been linked to a variety of adverse health outcomes. There are other effects not summarized here, see the BioInitiative Report.⁶⁴ Health endpoints that have been reported to be associated with ELF and/or RF include childhood leukaemia, adult brain tumours, childhood brain tumours, genotoxic effects (DNA damage and micronucleation), neurological effects and neurodegenerative diseases, immune system deregulation, allergic and inflammatory responses, breast cancer in men and women, miscarriage and some cardiovascular effects.

Effects are not specifically segregated for ELF or RF, since many overlapping exposures occur in daily life, and because this is an artificial division based on frequencies as defined in physics that have little bearing on the biological effects. Both ELF and RF, for example have been shown to cause cells to generate stress proteins, a universal sign of distress in plant, animal and human cells, and to cause DNA damage and neurological impacts at levels far below current safety standards.

⁶⁴ BioInitiative report: a rationale for a biologically-based public exposure standard for electromagnetic fields (ELF and RF). <http://www.bioinitiative.org>

CHAPTER FIVE

RECOMMENDATIONS AND CONCLUSIONS

5.0 Public health policy recommendations

There are many historical examples of scientifically based early warnings about potential health effects from environmental hazards and a long time period until precautionary and preventive measures were undertaken.⁶⁵ Vested interests may thereby counteract necessary public health actions.

The precautionary principle should be used when there is reasonable ground for concern. Based on the BioInitiative Report⁶⁶, this criterion is fulfilled regarding exposure to electromagnetic fields, both extremely low frequency electromagnetic and radiofrequency fields.

6. ELF limits should be set below those exposure levels that have been linked in childhood leukaemia studies to increased risk of disease, plus an additional safety factor. It is no longer acceptable to build new power lines and electrical facilities that place people in ELF environments that have been associated with an increased risk of adverse health effects, levels generally at 2 mG (0.2 mT) and above.

A new, lower planning limit for habitable space adjacent to all new or upgraded power lines and for all other new construction should be applied. A lower limit should also be used for existing habitable space for children and/or women who are pregnant. This recommendation is based on the assumption that a higher burden of protection is required for children who cannot protect themselves, and who are at risk for

⁶⁵ Hardell L, Walker M, Walhjalt B, Friedman LS, Richter ED. Secret ties to industry and conflicting interests in cancer research. *Am J Ind Med* 2007;50:227e33

⁶⁶ BioInitiative report: a rationale for a biologically-based public exposure standard for electromagnetic fields (ELF and RF). <http://www.bioinitiative.org>

childhood leukaemia at rates that are traditionally high enough to trigger regulatory action.

While it is not realistic to reconstruct all existing electrical distributions systems in the short-term, steps to reduce exposure from these existing systems need to be initiated, especially in places where children spend time, and should be encouraged.

7. A precautionary limit should be adopted for outdoor, cumulative RF exposure and for cumulative indoor RF fields with considerably lower limits than existing guidelines. It should reflect the current RF science and prudent public health response that would reasonably be set for pulsed RF (ambient) exposures where people live, work and go to school. This level of RF is experienced as whole-body exposure, and can be a chronic exposure where there is wireless coverage present for voice and data transmission for cell phones, pagers and personal digital assistants (PDAs) and other sources of radio- frequency radiation. Although this RF target level does not preclude further rollout of WI-FI technologies, wired alternatives to WI-FI should be implemented, particularly in schools and libraries so that children are not subjected to elevated RF levels until more is understood about possible health impacts.

This recommendation should be seen as an interim precautionary limit that is intended to guide preventative actions. More conservative limits may be needed in the future.

8. The current guideline for microwave exposure from mobile phones in Europe is 2 W/Kg for the brain. This is based on thermal effect using cataract development in animal eyes induced at 100 W/Kg with a safety factor of 50 for standard setting. There were also considerations about the relationship between the whole-body Specific absorption rate (SAR) SAR and local hot spots and local SAR in relation to whole-body SAR.

- Since use of mobile phones is associated with an increased risk for brain tumours (glioma, acoustic neuroma) after 10 years a new biologically based guideline should be applied. This new guideline should be based on non-thermal (low-intensity) effects from microwave exposure. It should be added that in toxicology normal practice is to add a safety limit of at least factor 100, which is factor 10 from animal to human beings and factor 10 for individual variability.⁶⁷
9. The same standard should be applied to cordless phones as for new guidelines for mobile phones based on biological effects. This is a reasonable suggestion to address the condition where occupied interior space is affected by cordless phones or other RF-emitting devices installed by the occupants. As with ELF fields also for RF fields different limits may be needed in the future as science progresses.
 10. There is the need for continuous education to consumers and the general public on the issue of effect of RF on the community. They need to be enlightened on the range of the electromagnetic frequencies i.e. low frequencies to high frequencies and the resultant effects of exposure to the frequencies. Mobile phones and base stations (BTS) fall under the low frequencies category and have no adverse effect on health, but X-RAYS on the other hand fall under the high frequency category and may impact negatively on human health. The public should be more concerned with exposure to these high frequencies such as X-rays and radioactive elements/materials.

⁶⁷ Scinicariello F, De Rosa CT. Genetic heterogeneity and its effect on susceptibility to environmental factors. Eur J Oncol 2007;12(3): 155e70.

5.1 Conclusions

Electricity - Studies of workers exposed to strong electric and magnetic fields (60 Hz) from power lines provide no consistent evidence that these fields are damaging to DNA or that they are capable of causing mutations or cancer.

RF - the most apparent biological effects of RF energy to living cells are due to heating. While it is not certain that RF radiation generally poses any risks to human health, some reasons exist for being concerned about human health effects from the cellular phones themselves. These concerns exist because the antennas of these phones deliver much of their RF energy to small portions of the user's head.

No evidence exists regarding any harmful effects resulting from exposure to typical levels of RF and EMF radiation. However, everyone should be aware that exposure to such radiation may not be completely safe at certain power levels and frequencies. It is always a good idea to avoid unnecessary radiation exposure whenever possible.

EMR exposure at the highest frequencies (X-Rays, Gamma rays) is a source of serious biological damage. Health effects from exposure to this form of radiation vary from no effect at all to death, and can cause diseases such as leukemia or bone, breast, and lung cancer.

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