Health Hazards Due to Electromagnetic Radiation in The Workplace

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Abstract

The conveniences and satisfaction derived in the use of EM radiation is being threatened by claims of adverse effects on human health by radiation coming from this device. This radiation belongs to the type called ionizing and non-ionizing radiation the health hazard of which remains debatable. Research has not been carried out on possible effect this device might have on human health and no experimental proof, based on data obtained within Nigeria, exist to substantiate any claim. Safety standards exist for radiation from cell phone but these are not reassuring. This paper investigates any possible effect of EM radiation on human heart rate and then come out with conclusion based on experimental proof as well as the controlling actions. In the wireless devices, there has been a massive increase in radiofrequency (RF) exposure from wireless devices as well as reports of hypersensitivity and diseases related to electromagnetic field and RF exposure. Multiple studies correlate RF exposure with diseases such as cancer, neurological disease, reproductive disorders, immune dysfunction, and electromagnetic hypersensitivity. Aim of this paper is to create social awareness of possible radiation hazards and precaution needed for protection.

Keywords: Health Hazards, Human Pulse Rate, Ionization, Radio Frequency, RF/MW Radiation.

I. INTRODUCTION

EM radiations contain waves of different frequencies. Numerous sources emitting these radiations results in exposure of general population and causing ionizing and non-ionizing effects due to EM radiation. Radiation that carries less energy can only excite the water molecule. It is therefore called non-ionizing radiation. Radiation that carries more energy than 1216 kJ/mol can remove an electron from a water molecule, and is therefore called ionizing radiation. Two things can happen when radiation is absorbed by matter: excitation or ionization.

- **Excitation** occurs when the radiation excites the motion of the atoms or molecules, or excites an electron from an occupied orbital into an empty, higher-energy orbital.

- **Ionization** take place when the radiation carries enough energy to eliminate an electron from an atom or molecule.

“Radiofrequency (or RF) Radiation” refers to electromagnetic fields with frequencies between 300kHz and 300MHz, while “Microwave (or MW) Radiation” covers fields from 300MHz to 300GHz. Since they have similar characteristics, RF and MW radiation are usually treated together. As well, the lower-frequency boundary of RF radiation is often extended to 10 kHz, or even to 3 kHz, in order to include emissions from commonly used devices. RF radiation is produced by devices such as radio and TV transmitters, induction heaters, and dielectric heaters (also known as RF sealers). MW radiation is produced by microwave ovens, parabolic (dish) antennas, radar devices, and diathermy applicators. This guideline gives advice on preventing overexposure to RF/MW radiation in the workplace and sets out Occupational Exposure Limits.[1] However, this guideline cannot cover all possible situations. The requirements set out in the Occupational Health and Safety Act must be complied with, and they should be referred to when this guideline is used.
II. HEALTH HAZARDS DUE TO IONIZING EFFECTS

When ionizing radiation passes through living tissue, electrons are removed from neutral water molecules to produce $H_2O^+$ ions. Between three and four water molecules are ionized for every $1.6 \times 10^{-17}$ joules of energy absorbed in the form of ionizing radiation.

$$H_2O \Rightarrow H_2O^+ + e^-$$

The $H_2O^+$ ion should not be confused with the $H_3O^+$ ion produced when acids dissolve in water. The $H_2O^+$ ion contains an unpaired valence-shell electron. These free radicals are extremely reactive. The radicals formed once ionizing radiation passes through water are among the strongest oxidizing agents that can occur in aqueous solution.[2] At the molecular level, these oxidizing agents destroy biologically active molecules by either removing electrons or removing hydrogen atoms. This often results in damage of the membrane, nucleus, chromosomes, or mitochondria of the cell that either inhibits cell division, results in cell death, or produces a malignant cell.

A. Biological Effects of Ionizing Radiation

Ionizing radiation is more dangerous compared to non-ionizing. A dose of 300 joules of x-ray or $\gamma$-ray radiation is fatal for the average human, even though this radiation increases the temperature of the human body by only 0.001°C. $\alpha$-particle radiation is even more dangerous, a dose equivalent to only 15 joules is fatal for the average human body. Whereas it takes almost seven moles of photons of visible light to produce a fatal dose of non-ionizing radiation, absorption of only $7 \times 10^{-10}$ moles of the $\alpha$-particles emitted by $^{238}\text{U}$ is fatal.

B. Measuring parameters for ionizing radiation

- To measure the activity of the source in units of disintegrations per second or curies, is the easiest measurement method.
- To measure the radiation to which an object is exposed in units of roentgens by measuring the amount of ionization produced when this radiation passes through a sample of air.
- To measure the radiation absorbed by the object in units of radiation absorbed doses or "rads." This is the most useful quantity, but it is the hardest to obtain.

One radiation absorbed dose, corresponds to the absorption of $10^{-5}$ joules of energy per gram of body weight. Because this is equivalent to 0.01 J/kg, one rad produces an increase in body temperature of about $2 \times 10^{-6}$°C. It seems the rad to be a negligibly small unit of measurement. The destructive power of the radicals produced when water is ionized is very large; however, that cells are inactivated at a dose of 100 rads, and a dose of 400 to 450 rads is fatal for the average human.

C. Sources of Radiation

External sources of radiation include cosmic rays from the sun and $\alpha$-particles or $\gamma$-rays emitted from rocks and soil. Internal sources of radiation include nuclides that enter the body when we breathe ($^{14}\text{C}$, $^{85}\text{Kr}$, $^{220}\text{Rn}$, and $^{222}\text{Rn}$) and through the food chain ($^3\text{H}$, $^{14}\text{C}$, $^{40}\text{K}$, $^{85}\text{Sr}$, $^{131}\text{I}$, and $^{137}\text{Cs}$). People who live in the Rocky Mountains, for example, receive twice as much background radiation as the national average because there is less atmosphere to filter out the cosmic rays from the sun. The dose of radiation from medical x-rays has decreased in recent years because of improvement in the sensitivity of the photographic film.
used for x-rays. X-rays emitted by television sets, and inhaled tobacco smoke. The most recent survey says most of the radiation emit from the mining and milling of uranium, the fabrication of reactor fuels, the storage of radioactive wastes, and the operation of nuclear reactors.

### III. MEASUREMENT STANDARDS

The human body can’t sense ionizing radiation except it is in very high dose, but the effects of ionization can be used to characterize the radiation. Parameters of interest include disintegration rate, particle flux, particle type, beam energy, dose rate and cumulative dose received by a target. Particle type is measured by differential measurements in the presence of electrical fields, magnetic fields, or varying amounts of shielding. Dose values may represent absorbed, equivalent, effective or committed dose. Radiation measuring instruments are commonly calibrated to provide readings of more sophisticated quantities than what is actually measured. For example, most dosimeter gives instantaneous readings of equivalent dose. Such calibrations make assumptions about the radiation type, beam energy, field uniformity, and range based on the expected use of the instrument. These assumptions are not universally applicable, and may produce very erroneous readings in some situations.

### IV. USES OF MICROWAVE IONIZING RADIATION

Ionizing radiation has many industrial, military, and medical uses. Its utility must be balanced with its hazards, a compromise that has shifted over time. For example, at one time, assistants in shoe shops used X-rays to check a child's shoe size, but this practice was halted when the risks of ionizing radiation were better understood.

Neutron radiation is necessary to the working of nuclear reactors and nuclear weapons. The penetrating power of x-ray, gamma, beta, and positron radiation is used for medical imaging, nondestructive testing, and a variety of industrial gauges. Radioactive tracers are used in medical and industrial applications, and biological and radiation chemistry. Alpha radiation is used in static eliminators and smoke detectors. The sterilizing effects of ionizing radiation are useful for cleaning medical instruments, food irradiation, and the sterile insect technique. Measurements of Carbon-14, can be used to date the remains of long-dead.

### V. HEALTH HAZARDS DUE TO NON-IONIZING EFFECTS

The nature and the degree of the health effects of overexposure to RF/MW fields depend on the frequency and intensity of the fields, the duration of exposure, the distance from the source, any shielding that may be used, and other factors. The main effect of exposure to RF/MW fields is heating of body tissues as energy from the fields is absorbed by the body. Prolonged exposure to strong RF/MW fields may increase the body temperature, producing symptoms similar to those of physical activity. In extreme cases, or when exposed to other sources of heat at the same time, the body’s cooling system may be unable to cope with the heat load, leading to heat exhaustion and heat stroke. Localized heating, or “hotspots,” may lead to heat damage and burns to internal tissues. Hot spots can be caused by non-uniform fields, by reflection and refraction of RF/MW fields inside the body, or by the interaction of the fields with metallic implants, for example, cardiac pacemakers or aneurism clips. There is a higher risk of heat damage with organs which have poor temperature control, such as the lens of the eye and the testes. Other hazards include contact shocks and RF burns. These can result from the electric currents which flow between a conducting object and a person who comes into contact with it while they are exposed to RF fields. (These effects should not be confused with shocks from static electricity). Some laboratory studies have reported biological effects from RF/MW radiation at field levels which are too low to cause tissue heating. To date, these non-thermal effects are not known to result in health hazards in workers. Although we are constantly exposed to weak RF fields from radio and television broadcasting, no health risks have been identified from this low-level exposure.

### VI. EXPOSURE LIMITS

Exposure limits for RF/MW radiation are designed to keep the RF/MW energy absorbed by the body well below the lowest levels associated with demonstrated adverse effects, and to reduce the likelihood of contact shocks and burns. Since the RF/MW energy absorbed by the body varies with the frequency of the fields, and since the rate of energy absorption is difficult to measure directly, the exposure limits are expressed in terms of frequency-dependent, root-mean-square (RMS) electric and magnetic field strengths, or in power density units (W/m²). Power density measures the amount of radiating energy crossing a given area in a given period of time. Occupational exposure of the whole body to RF/MW fields should not exceed the values in Table I

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Electric field strength; RMS (V/m)</th>
<th>Magnetic field strength; RMS (A/m)</th>
<th>Power Density (W/m²)</th>
<th>Averaging time (min.)</th>
</tr>
</thead>
</table>

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<table>
<thead>
<tr>
<th>Frequency (MHz)</th>
<th>Induced Current (RMS) (mA)</th>
<th>RMS contact current(mA)</th>
<th>Average Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Through Both Feet</td>
<td>Through Each Foot</td>
<td>Hand grip and Through Each Foot</td>
<td></td>
</tr>
<tr>
<td>0.003-0.1</td>
<td>2000f</td>
<td>1000f</td>
<td>1000f</td>
</tr>
<tr>
<td>0.1-110</td>
<td>200</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

VII. HAZARD DUE TO GSM RADIATION

Parts of the radio waves emitted by a mobile telephone handset are absorbed by the body. The radio waves emitted by a GSM handset can have a peak power of 2 watts, and a US analogue phone had a maximum transmit power of 3.6 watts. The rate at which energy is absorbed by the human body is measured by the Specific Absorption Rate (SAR), and its maximum levels for modern handsets have been set by governmental regulating agencies in many countries. In the USA, SAR limit of 1.6 W/kg, averaged over a volume of 1 gram of tissue, for the head. And In Europe, the limit is 2 W/kg, averaged over a volume of 10 grams of tissue.[3]

A. THERMAL EFFECT:
One well-understood effect of microwave radiation is dielectric heating. In the case of a person using a cell phone, most of the heating effect will occur at the surface of the head, causing its temperature to increase by a fraction of a degree. In this case, the level of temperature increase is an order of magnitude less than that obtained during the exposure of the head to direct sunlight. The brain’s blood is capable of disposing of excess heat by increasing local blood flow. However, the cornea of the eye does not have this temperature regulation mechanism and exposure of 2–3 hours duration has been reported to produce cataracts in rabbits’ eyes at SAR values from 100–140W/kg, which produced ventricular temperatures of 41°C.[3]

B. NON THERMAL EFFECT:
The German biophysicist Roland Glaser has said that there are some thermo receptor molecules in cells, and they activate a cascade of second and third messenger systems, gene expression mechanisms and produces heat shock proteins in order to protect the cell against metabolic cell stress produced by heat.

Studies have concluded that cell phones and cell sites are risk factors of the following:

1. Neurological effects including sleep disturbance learning difficulties, depression and suicides.
2. Reproductive effects, cardiac arrhythmia heart attack and heart disease.
3. Virus and infectious disease.

Radiation from the GSM antenna also caused biological effects likes:
- Sleep disruption
- Headache
- Concentration
- Forget full memory
- Depression
A. Cognitive effects:
Radiofrequency radiation (RFR) radiated by standard GSM cell phones on the cognitive functions of humans. Right-handed subjects open to RFR on the left side of their head on average had considerably longer response times when compared to exposure to the right side and sham-exposure. Longer time of exposure to RFR may increase the effects on performance. Several users of mobile phones also reported short-term memory loss. The cognitive functions are heavily affected by longer exposure.\[14\]

B. The Blood-Brain Barrier:
A few studies have stated that exposure to rodents to very low level fields might alter the permeability of the blood-brain barrier and cause leakage of molecules from the blood into the cerebrospinal fluid.\[5\] Such responses could produce severe and letting adverse consequences, and changes in permeability also occur in brain trauma and during hyperthermia. AGNIIR (2003) concluded that well-conducted studies have not reported any effects on the blood-brain barrier unless exposures increased core body temperature.\[34\]

C. Genotoxic effect:
In genetics, genotoxicity describes the property of chemical agents that damages the genetic information within a cell causing mutations. In this like EMF is damage DNA directly and damage can be evaluated experimentally by the so-called comet assay, which identifies whether base damage and single-strand breaks in the DNA molecule inside the cell nucleus have occurred (neutral comet test), which is repairable damage or double-strand breaks have occurred (alkaline comet test), which is repairable damage. IARC (International Agency for Research on Cancer) arrived the conclusion that there is so far inadequate evidence for a low-level RF interaction causing genotoxicity as well as potentiation of other mutagens. Therefore, since oncogenesis depends strictly on its occurrence at cellular level, there is no plausible mechanism for cancer causation at or below international safety levels.\[14\]

D. Electromagnetic Hypersensitivity Syndrome
Electromagnetic energy outside of the visible spectrum and the infrared is not, under normal circumstances, detectable by human beings, since we don't have specialized receptors to transceiver directly its specific frequencies. The pathological phenomenon in this respect consists of individuals who, being sensitive or not, report a number of distressing subjective symptoms during and after using a cell phone and other radiofrequency-emitting devices, or when they are near an RF antenna site. These symptoms are quite nonspecific and are present in many diseases, such as cold and flu-like symptoms (headache, nausea, fatigue, muscle aches, malaise, etc.). The most common health complaints were sleep disorders (43%) and headaches (34%), which were generally attributed to power lines and mobile phone handsets. Additionally, 53.5% were bothered about adverse health effects from EMF, without attributing their own health symptoms to them. \[4\] The phenomenon is real, and the quality of life of these individuals suffers greatly with debilitating symptoms, to the point that work and recreation becomes difficult. Electroencephalogram and event-related potential studies (Electrophysiology and Sleep).

Several electrophysiological studies on the effect of acute RF fields on the human EEG and ERP have been performed, with somewhat mixed results. This study showed a decrease in rapid eye movement sleep latency and increased electroencephalogram spectral power in the 11.5-12.25 Hz frequency range during the initial part of sleep following exposure. Which showed that RF from cell phones induced mild relaxation, and a quicker induction to REM sleep (which is associated to dreaming in humans) in the first period of sleep, no detrimental effects on sleep health could be demonstrated. The effects of RF on brain oscillatory responses may be subtle, variable and difficult to replicate for unknown reasons.\[14\]

Other symptoms and diseases
- Cataract
- reproductive risk
- cardiovascular disease

E. Cancer:
Many epidemiological studies have addressed probable links between exposure to RF and excess threat of cancer. However, due to differences in the design and execution of these studies, their outcomes are hard to interpret. Many national and international peer review groups have determined that there is no solid evidence of relations among RF exposure and excess threat of cancer. WHO has also concluded that there is no substantial scientific proof that exposure to RF reduces the life period of humans, or that RF is an inducer or promoter of cancer. However, additional studies are required. \[14\][15]
F. Behavioral changes:
Behavior, in common, reflects adaptive brain-behavior patterns. It becomes vital in the research of effects of radiofrequency radiation, specifically in reference to behavioral thermal parameter, the conscious attempt to uphold a constant body temperature. Behavioral responses are not essentially from the specific variations in the central nervous system, but may be a direct or indirect effect of microwaves on another body part. This makes the extrapolation of data from animals to humans especially difficult. It has been shown that if the metabolic rate of a rat is exceeded by radioactivity, behavior is disrupted. Variations in body temperature bring about both autonomic and behavioral responses. The behavioral responses arise from thermal stress that cause actions to lessen the thermal discomfort (i.e. the organism moves to a more thermoneutral atmosphere). [15][14]

VIII. HAZARD BY MICROWAVE OVENS

An experiment conducted at home for a high school science fair has verified the danger of microwave ovens not only to humans but even plants and other organic matter. The microwaved water given to a plant caused the plant to wither and die within days; however, another identical plant given water that was boiled on conventional stave grew normally during the same time period.

Microwaved prepared meats cause the formation of d-Nitrosodienthanolamines, a well-known carcinogen. Microwaving can also cause some amino acids in foods such as milk and cereal grains to be converted into carcinogens. Even very short exposure for cooked, frozen or raw vegetables to microwaves. Broccoli showed a 97% loss of its vitamin C, when cooked in a microwave oven.

WI-FI

WI-FI is most likely much safer than using a cell-phone. Overall, the average person’s cumulative exposure to microwave radiation from Wi-Fi is much, much less than exposure from other radio frequency devise. These signals are very low power, typically 0.1 Watt. Thus, the fields that are induced by WI-FI transmissions are well below those that could cause problems to humans.

However, long use of Wi-Fi can result in subtle damage in human tissue and cell death. One recent study published in the journals Fertility and sterility, found that man using wireless internet on laptops had a 25% reduction in stream also showed 9% DNA fragmentation.

IX. CONTROLLING OF EM RADIATION

A. Protection from radiation for ionizing radiation:
There are three standard ways to limit exposure:
- Time: For people who are exposed to radiation in addition to natural background radiation, limiting or minimizing the exposure time will reduce the dose from the radiation source.
- Distance: Radiation intensity decreases sharply with distance, according to an inverse-square law (in an absolute vacuum)
- Shielding: Air or skin can be sufficient to substantially attenuate low-energy alpha and beta radiation. Barriers of lead, concrete, or water give effective protection from more energetic particles such as gamma rays and neutrons. Some radioactive materials are stored or handled underwater or by remote control in rooms constructed of thick concrete or lined with lead. There are special plastic shields that stop beta particles, and air will stop most alpha particles. The effectiveness of a material in shielding radiation is determined by its half-value thickness, the thickness of material that reduces the radiation by half. This value is a function of the material itself and of the type and energy of ionizing radiation.[7] Some generally accepted thicknesses of attenuating material are 5 mm of aluminum for most beta particles, and 3 inches of lead for gamma radiation.
- Containment is a combination of shielding and distance: Radioactive materials are confined in the smallest possible space and kept out of the environment. Radioactive isotopes for medical use, for example, are dispensed in closed handling facilities, while nuclear reactors operate within closed systems with multiple barriers that keep the radioactive materials contained. Rooms have a reduced air pressure so that any leaks occur into the room and not out of it.[6] An example of containment is an effective fallout shelter, which in a nuclear war, reduces human exposure at least 1,000 times.

Other civil defense measures can help reduce exposure of populations by reducing ingestion of isotopes and occupational exposure during war time and nuclear reactor accidents. [8] One available measure is the use of potassium iodide (KI) tablets, which effectively blocks the uptake of radioactive iodine (one of the major radioisotope products of nuclear fission) into the human thyroid gland.
B. Protection from radiation for non-ionizing radiation:

1) Engineering Controls
   - Sources of RF/MW radiation should be correctly shielded to minimize stray radiation.
   - Devices which can produce severe thermal damages (e.g., industrial MW ovens) should have interlocked doors.
   - Devices which produce great levels of stray RF radiation (e.g., induction heaters and dielectric heaters) should be operated remotely whenever possible. [17]

2) Administrative Controls
   - Exposure of workers to RF/MW Radiation should not go beyond the recommended exposure limits. [17]

C. Recommendation:
To date, research does not suggest any consistent evidence of adverse effects from exposure to EM fields at levels below those that cause tissue heating. Some recommendations to minimize the possible health hazards due to exposure of EM radiations due to cell phones are:
   - The EM radiation is reduced by 75 percent by moving the cell phone 5cm away from your head while talking.
   - Turn off the cell phone at night so that the sleep quality does not get disturbed by EM radiations.
   - While carrying a cell phone, always position it such that the keypad faces towards you. This way antenna faces away from you.
   - Consider using laptops computers to make calls or send instant messages.
   - Avoid using wired headsets. Headsets including ear buds acts as antenna, channelling EM radiations directly to the ear canal and the brain.
   - Use air-tube headsets with ferrite beads which do not work as antenna. Ferrite beads suppress EM radiations and dissipate as heat.
   - Avoid making calls when travelling fast because it increases output power as these attempts to handoff.
   - When purchasing a cell phone, get one with low SAR.
   - Avoid using cell phone in a metal enclosure because it acts as Faraday cage, trapping it back upon you and others.
   - Use speaker phone as much as possible. EM radiation decreases in direct proportion to the distance of the source.
   - Make calls when and where signal is strong. When signal is weak, cell phone automatically increases the power output, exposing to greater EM radiation.
   - Keep the talking brief to avoid disturbance in electrical activity of brain and developing brain cancer.
   - Use hands-free kit to decrease the radiations to the head.
   - Do not use telephone in car without an external antenna.
   - Use regular phones in place of cordless phones at offices and home.
   - Pregnant women should avoid using cell phone because low levels of non-ionizing
   - Radiations are likely to cause behavioral changes in children after birth.
   - Keep children away from cell phones. EM field penetrate through the brain of children, increasing the risk or cancer and affects the central nervous system.
   - Use a Bluetooth headset which emits 1/1000th EM radiation of a normal cell phone.
   - Use a cell phone radiation protection device which has a patented shield technology that superimposes a low-frequency noise-field onto the radio frequency to make it harmless to the body.

X. CONCLUSIONS
There are many biological effects on living organisms due to the exposure of the EM radiations. Many researchers conducted over last some decades have provided a base for the understanding of these effects. Studies and experiments have shown that there is a profound effect on biological process due to the exposure to low intensity radiation. The non-thermal effects of EM radiation exposure are now a days the important measurements criteria showing the effects of biological interactions with the EM fields. The cause of stress and trauma to biological systems is essentially due to the absorption of EM radiations. When the incident radiations emitted at the resonance frequency of the biological material the greatest amount of energy will be absorbed.

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