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Public health impact and mitigation of exposure to non-ionizing radiation

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Abstract: Electro Magnetic Radiation (EMR) is of two types, non-ionization radiation that is below the ultraviolet wavelength range of sunlight spectrum, and radiation from fission products of some nuclides in soil and ionization radiation obtained from UV wavelength to higher wavelength of sunlight spectrum and also from nuclear bomb explosion and nuclear power plant accidents etc. This article explains the non-ionization EMR radiation to which human body is exposed daily. Non-ionization radiations are of two types, man-made and natural. Natural radiations are low levels of radiation to which human body is daily exposed and get acclimatized to it to certain extent. Natural radiations include radon gas emitted from rocks, soil, groundwater and visible light as well as invisible non-ionization EMR of sunlight spectrum including infrared (IR), microwave (MW), radio frequency (RF), very low frequency (VLF) and extremely low frequency (ELF), and thermal radiation from hot objects. The man-made sources of non-ionization EMR are electronic gadgets like mobile, mobile tower, wifi, cordless phones, television waves, laptops, computer etc. Exposure to man-made sources of non-ionization EMR is increasing with the increase in use of electronic gadgets. Public health impacts are reported above threshold radiation level. There are easy ways to minimize the impact, including simple preventive measures as given by Department of Telecommunication (DoT), Government of India, technological solutions, and use of shield material. Standards and guidelines have been developed by DoT, GoI, 10 times stricter than International Standards, for EMR from mobiles and mobile towers, for distance between mobile towers and buildings, and for manufacturer of electronic gadgets by U.S. EPA and many countries including India.

Keywords: Non-ionization electromagnetic radiations, Sources, Health effects, Standards, Guidelines, Prevention

I. Introduction

People at large are aware of ionizing radiation and its public health impacts due to world famous health impacts of atom bomb attack on Hiroshima and Nagasaki and accidents in nuclear power plants. However, most people are ignorant about invisible non-ionizing electromagnetic radiation (NI-EMR) that are present everywhere and to which everyone is exposed in their daily life. Natural sources of NI-EMR (Natural background NI-EMR) are non-ionizing solar radiation, terrestrial radiation from radio-nuclides present in earth's crust such as radium-224, uranium-238, thorium-232, potassium-40, carbon-14 etc. as well as some species of animals and plants which accumulate specific radioactive material for ex. oysters accumulate 65Zn, fish accumulate 55Fe, marine animals deposit 90Sr. Man-made sources of NI-EMR are microwaves, ultrasound, laptops, and computers to list a few (Table I). These radiations have inherent weak radioactivity. There are many myths and misconception about the EMR, creating psychological stress among people with respect to their health impacts. Lot of research has been carried out on non-ionizing radiation and its effect on public health all over the world, including India. The issues pertaining to the nature, source, doses from natural and man-made sources, safe dose, standards and guidelines for safety and preventive management are discussed in this article.

Table I: Natural and man-made sources of radiation exposure [1]

Natural sources	Terrestrial sources – (Primordial radionuclides) soil, stone, sand, water, air, natural gases
	Extra terrestrial sources – (Cosmogenic radionuclides) cosmic rays, Non-ionizing radiation of solar spectrum.
Man-made sources	Medical and dental X-rays, occupational exposures, nuclear exposures, radioactive fallouts, nuclear reactor waste, miscellaneous (Air travel., TV, Luminous dials, luminous markers, isotope tagged products etc.

II. Radionuclides Cause Of Radiation

Radioactive forms of elements are called radionuclides. Some occur naturally in the environment, while others are man-made. Radiation is given out when radioactive decay occurs, during which a radioisotopes

transforms into another radioisotope. Some radionuclides have half-lives of mere seconds, but others have half-lives of millions of years. The twelve radionuclides encountered in medical, commercial and military activities are americium-241, cesium-137, cobalt-60, iodine, plutonium, radium, radon, strontium-90, technetium-99, thorium, tritium, and uranium [2].

III. Definition of Non-Ionizing Radiation

NI-EMR consists of a series of energy waves composed of oscillating electric and magnetic fields traveling at the speed of light. NI-EMR in sunlight spectrum includes electromagnetic waves at the longer wave length of the spectrum below ultraviolet (UV), including visible light, infrared (IR), microwave (MW), radio frequency (RF), very low frequency (VLF) and extremely low frequency (ELF) (Fig. 1). Lasers commonly operate in the UV, visible, and IR frequencies. Alternatively, it has been suggested that radiation with particle or photon energies less than 10 electron volts may be called non-ionizable radiation, which is the energy needed to ionize water molecule. The part of sunlight spectrum from far UV to higher electromagnetic radiation (X-rays, gamma-rays, and all particle radiation from radioactive decay) is ionization radiation.

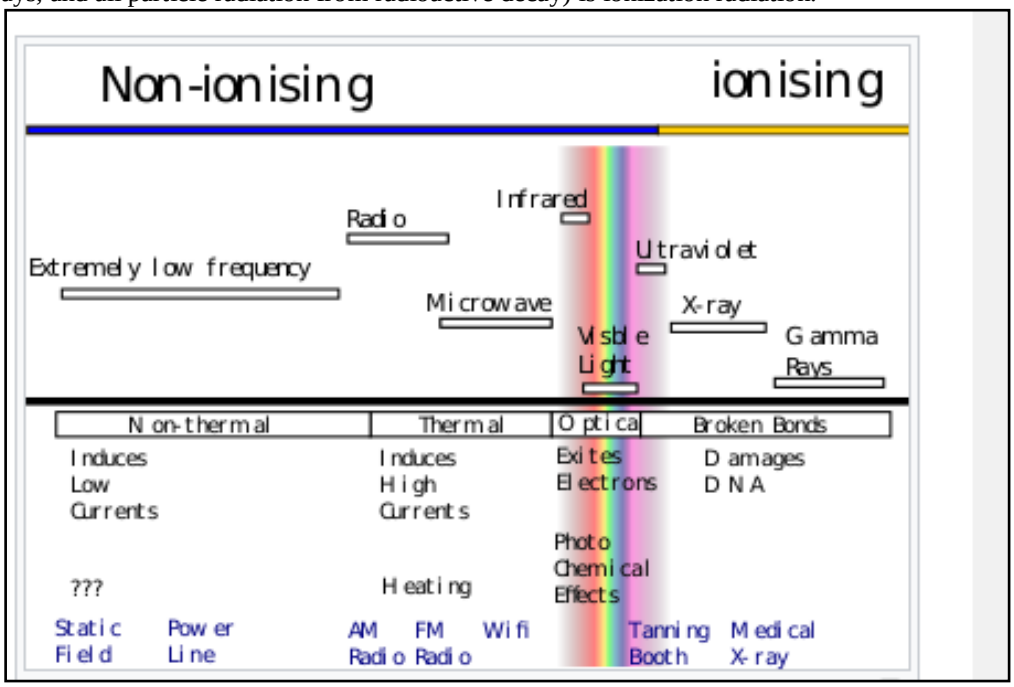

Figure 1: Different types of non-ionizing and ionizing radiations [3]

NI-EMRs have sufficient energy only for excitation of atoms or molecules i.e., the movement of an electron to a higher energy state, causing them to vibrate faster; however, it does not carry enough energy per quantum (photon energy) to ionize atoms or molecules (like ionization radiation), that is to completely remove an electron from an atom or molecule. In microwave oven, the radiation causes water molecules in the cooking medium to vibrate faster and thus raising its temperature. They may damage eyes which may be caused by reflections from coastal sand, snow (snow blindness), and directly looking towards sun during eclipse. They injure the cells of skin and blood capillaries producing blisters and reddening called sunburns.

IV. Types of Ni-Emr and their Applications

Microwaves are electromagnetic waves ranging from as long as one meter to as short as one millimeter (frequencies between 300 MHz (0.3 GHz) and 300 GHz). Microwaves are applied in cell phone, telephones, radars, airport scanners, microwave ovens, earth remote sensing satellite, radio and satellite.

Visible light occurs in narrow range (about 400 to 700 nm or up to 380 – 750 nm) in sunlight spectrum and is visible to eyes.

Infrared (IR) EMR wavelength ranges from 0.7 to 300 micrometers. The energy content of bright sunlight is over 1 kilowatt per sq m at sea level, which consists of 527 watts of IR radiation, 445 watts of visible light and 32 watts is ultraviolet radiation.

Radio Waves EMR wavelengths are longer than infrared light. Natural radio waves are also formed by lightning and by astronomical objects. Man-made radio waves are used for fixed and mobile radio communication, broadcasting, radar and other navigation systems. Other applications are satellite

communication, computer networks and innumerable other applications. Different frequencies of radio waves have different propagation characteristics in the earth's atmosphere, long waves may cover a part of earth very consistently, shorter waves can reflect off the ionosphere and travel around the world, and much shorter wavelengths bend or reflect very little and travel on a line of sight.

Very low frequency (VLF) (3 to 30 kHz) is called as myriameter band as the wavelengths range from ten to one myriameter. There is not much band width in this band of the radio spectrum, only very simplest signals are used, such as for radio navigation.

Extremely low frequency (ELF) is the range of radiation frequencies from 300 Hz to 3 kHz, considered to be in ULF range.

Electromagnetic fields (EMF) are created by electric current, higher the voltage; the stronger will be the resultant magnetic field. Magnetic fields are created at right angles to an electric current and to the direction of propagation. EMF are commonly found around high voltage power lines, neighbourhood transmission lines, grounding systems that protect residents from lightning, electric shock due to faulty gadgets, operation of common electrical appliances like microwave ovens, aquariums, electric ranges, table fans, electric space heaters, computer monitors, electric clocks, clock radios, heated waterbeds, electric blankets, hair dryers, cellular phones, video display terminals (VDTs).

Thermal radiation is radiated in the form of electromagnetic waves by the objects having thermal energy. Infrared radiations from household heater, infra-red light lamps, or kitchen oven are examples of thermal radiation. Part of electromagnetic spectrum of thermal radiation may be ionizing, if the object is hot enough.

V. The UV Spectrum

The UV spectrum (3.1 eV (400 nm)-10 eV) are non-ionizing but can produce photochemical reactions producing free radicals that induce cellular damage and can be carcinogenic by heat and other effects. These reactions are very similar to those caused by ionizing radiation. Thus, the entire UV spectrum is considered to be equivalent to ionization radiation.

VI. Background Ni-Emr in Troposphere

Background NI-EMR in human environment is coming from sunlight, medical procedures (diagnostic X-rays, nuclear medicine, and radiation therapy), mobile, laptop/computer, consumer products such as tobacco (thorium), terrestrial (rock, soil, groundwater), combustible fuels (gas, coal, etc.), ophthalmic glass, televisions, luminous watches and dials (tritium), public places, smoke detectors (americium), road construction materials, electron tubes, fluorescent lamp starters, lantern mantles (thorium). Occupational exposure is from fuel cycle, radiography and X-ray machines. Electric power lines, electric wiring and electrical equipments also emit electric and magnetic field (EMF) radiation but of extremely low frequency. However, high voltage power lines produce intense radiation (U.S. Department of Labor). In occupational environment, highest exposure includes ELF induction furnaces. Other sources are heat sealers, microwave towers, radio and TV broadcast antennas.

In any city in India, the top one meter of soil from 0.1 acre field contains 11,200 kg of potassium, 1.28 kg of which is of potassium-40 (K-40), a radioactive isotope of potassium, 3.6 kg of thorium and one kg of uranium. These values may be higher or lower depending on the type of soil. Uranium and thorium decay through several radio-nuclides to lead (Pb), a stable element. Normally, the presence of radioactive nuclides does not pose any significant risk [2]. Parts of Kerala and Tamil Nadu are high background radiation areas because of the presence of large quantities of monazite in the soil. Thorium content in monazite ranges from 8-10.5 per cent [4].

In the Indian subcontinent, the regions of Maharashtra and south Gujarat are covered by the Deccan lava basalt with very low radioactivity; the Gangetic alluvial regions covering parts of Uttar Pradesh, Bihar and West Bengal have somewhat higher radioactivity; the granite region of Andhra Pradesh exhibits quite high levels of the primordial radioactivity. In the coastal areas of Kerala and Tamil Nadu, thorium rich monazite sands result in dose rates as high as 32,500 µSv per year in some locations [5].

The whole world is naturally radioactive. The naturally-occurring radionuclides of interest are uranium, thorium, actinium series elements 40K and 14C. These radionuclides are of main concern due to their relative long half-lives and are principal sources of exposure of natural radiation. Since these radionuclides are not uniformly distributed over the earth, the knowledge of radionuclides distribution and radiation levels in the environment is important for assessing the effects of radiation exposure to human beings. Natural radioactivity is widespread in the earth's environment and it exists in various geological formations in soils, rocks, plants, water and air [4]. Some of the radionuclides from these sources may be transferred to human beings through food chain or inhalation [5].

VII. Ndoor Radiation Levels

Most individuals spend 90% of their time indoors, so they receive low levels of background NI-EMR in indoor environment through inhalation of radionuclides. Building materials like sandstone, concrete, brick, natural stone, gypsum and granite do not generally contain radioactive material. However, some building materials at some specific places may contain radioactive elements like potassium (K-40), rubidium (Rb-87), cosmogenic nuclides and the two series of radioactive elements arising from the decay of uranium-238 and thorium-232, which are the long lived radionuclides that have remained on earth since its origin and.

These naturally occurring radioactive elements in rocks, soil and groundwater break down or decay into the radioactive materials. The radon gas (radon-222) formed by decay product of uranium-238 and thoron gas (radon-220) produced during the decay series of thorium-232 seep out of the earth and cause indoor exposure [6] through cracks and holes in the foundation of the buildings or private well water, construction joints, gaps in suspended floors, gaps around service pipes, cavities inside walls, and the water supply. These may cause some increase in radiation levels. Radon is a gas without having smell, taste or appearance and is more likely to get into indoor environment. The water supply from groundwater may contain radon, while radon from surface water sources is of no concern, as radon is mostly released into air from these sources before it enters the home. Usually the air pressure in homes and buildings is lower than the pressure outside in the soil around or underneath the foundation. This pressure difference will create suction, and radon will come in through cracks due to suction. Elevated levels of indoor radon may pose a risk to human health.

There is wealth of scientific data (occupational miner data) on the relationship between radon exposure and the development of lung cancer. The report of the National Academy of Science's Biological Effects of Ionizing Radiation (BEIR VI) in U/S.A. [7] confirms that radon is the second-leading cause of lung cancer and is serious public health concern. However, this may be due to exposure to higher than threshold level of radiation, as described further in this article. However, to investigate epidemiological effects, 10,000 to 30,000 cases may be required as in case of study of lung cancer risk of cigarette smoking, this is labourious and so complicated due to other factors also like, mobility of people, change in housing stock, inaccurate history etc. Epidemiological studies are still not conclusive.

Fig. 2 shows average contribution from various sources of radiation to which an individual is exposed during his lifetime. This figure indicates that radon gas is the largest contributor to the collective exposition to natural radiation of the population in the world. [8]. The inhalation of short-lived decay products of radon (222Rn) accounts on average about 55% of the effective equivalent dose on the human being.

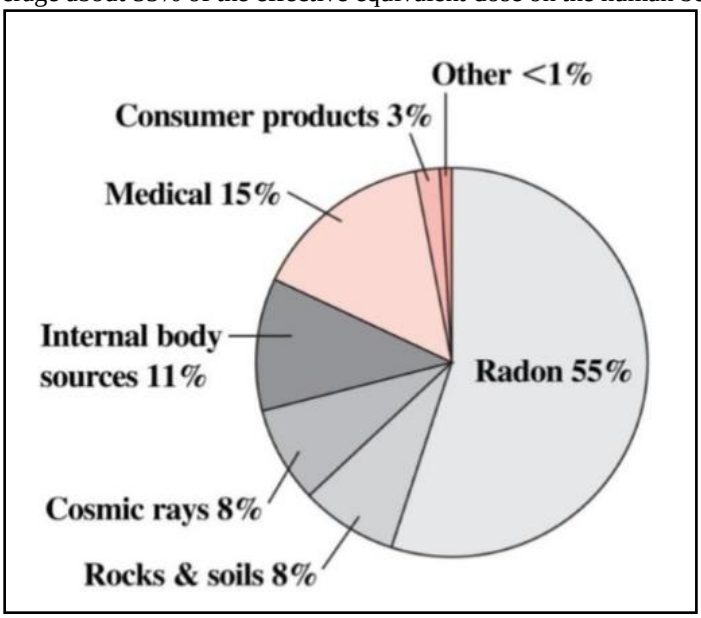

Figure 2: Average contribution towards radiation exposure from various sources [8]

VIII. Exposure Pathways of Radiation

All the persons are constantly exposed by two types of sources i.e. natural and artificial sources of radiations. The exposure pathway to natural sources of radiation are (a) Sources of Terrestrial origin (b) External source of extraterrestrial origin (cosmic rays, solar spectrum), and (c) Internal exposure from nuclides taken into the body through ingestion of food materials.

The terrestrial component of radiation mainly originates from the primordial radionuclides (238U, 235U, 226Ra, 232Th, and 40K) that were existed on the earth's crust since its formation. The dose from terrestrial sources varies in different parts of the world depending upon the concentrations of uranium and thorium in their soils.

External or Direct exposure is when the radioactive source is outside the body. Cosmic rays coming from the outer space contribute an estimated 8% of the average radiation dose to the population. The primary cosmic rays (high energy protons, the nuclei and electrons moving almost at the speed of light) on reaching upper atmosphere interacts with the atmosphere to produce number of radioactive nuclei, called cosmogenic radionuclides, giving out secondary radiation that rains down, including x-rays, muons, protons, alpha particles, pions, electrons, and neutrons. X-rays and gamma rays pass through the body and deposit energy as they go.

Internal exposure is due to accumulation of radioactive material in the body tissues through eating, drinking, breathing or injection (medical treatment). These include minute quantity of uranium, thorium and isotopes of potassium (40K), strontium (90Sr) and carbon (14C). Alpha and beta particles pose a serious health threat if significant quantities are inhaled or ingested. Outside the body, alpha particles are too long to pass through the skin or a thin layer of clothes. Therefore the effect depends upon the extent of exposed part of body. Radiation effects depend upon the type of radiation received (alpha, beta, gamma, x-ray), energy content of radiation, external or internal exposure, ingestion and inhalation of radiation, and accumulation (for long or short time) of radionuclide in the body.

Internal radiation is thought to inflict about 0.25 mSv/y on the body as a whole. In addition, smokers are exposed to radiation from the radio nuclide 210Po, which is also found in tobacco; the resulting dose to the bronchial epithelium can be as high as 20 mrem (0.2 mSv) per year [9, 10].

IX. Impacts and Health Effects of Non Ionizing Radiation

The sunlight that reaches earth is largely composed of non-ionizing radiation, since the ionizing far-ultraviolet rays have been filtered out by the gases in the atmosphere, particularly oxygen. The remaining ultra violate radiation from the sun is in the non-ionizing band, and causes molecular damage like sunburn by photochemical and free-radical-production that do not ionize.

Human immunity system is affected by sun's harmful UV radiation due to Ozone Layer depletion. The effects are skin cancer, melanoma, non-melanoma skin cancer, premature aging and other skin damage, cataract and other eye damage, and immune suppression. Around up to 90 percent of the visible skin changes commonly attributed to aging are caused by the sun. With proper protection from UV radiation, most premature aging of the skin can be avoided. Unprotected exposure to UV radiation is the most preventable risk factor for skin cancer [11].

Different types of non-ionizing radiations have different biological effects [12, 13]. These radiations may induce photochemical reactions, or accelerate radical reaction, such as photochemical aging of varnishes [14], or the breakdown of flavouring compounds in beer to produce the "lightstruck flavor" [15].

Study of the high background radiation areas (HBRA) in India with 3.8 milligray per year (as against one milligray normal background value) during 1990-99 by the researchers from the Regional Cancer Centre and Bhabha Atomic Research Centre did not show any health effect attributed to radiation [2]. All these limits are for the amount of radiation exposure in addition to background radiation and medical radiation.

The biological damage caused by the radiation is determined by the intensity of radiation and duration of the exposure. It depends on the amount of energy deposited by the radiation in the biological system. For example, alpha particles (protons) do much more damage per unit energy deposited than do beta particles (electrons). At low doses, such as what we receive every day from background radiation (<1 mrem), the cells repair the damage rapidly. At higher doses (up to 100 rem), the cells might not be able to repair the damage, and the cells may either be changed permanently or die. Cells changed permanently may go on to produce abnormal cells when they divide and may become cancerous. At even higher doses, the cells cannot be replaced fast enough and tissues fail to function. An example of this would be "radiation sickness." This is a condition that results after high doses is given to the whole body (>100 rem) [16].

The surface area of bird is relatively larger than their body weight in comparison to human body so they absorb more radiation. Also the fluid content in the body of the bird is less due to small body weight so it gets heated up very fast. Magnetic field from the towers disturbs birds' navigation skills; hence when birds are exposed to EMR, they disorient and begin to fly in all directions. A large number of birds die each year from collisions with telecommunication masts [1].

Visible light radiation frequencies of the electromagnetic spectrum are recognized by eyes as different colours. Good lighting has encouraging effect on work efficiency as against poor lighting conditions. Excessive visible radiation is damaging for eyes and skin.

Ultraviolet radiation (UV) has a high photon energy range and is hazardous, but shows no immediate symptoms.

Lasers typically emit optical (UV, visible light, IR) radiations and may pose hazard for eye and skin. Common lasers include CO2 IR laser, helium – neon, neodymium YAG and ruby visible lasers, and the Nitrogen UV laser.

Non-ionizing radiation is found in a wide range of occupational settings and can pose a considerable health risk to potentially exposed workers if not properly controlled. EMR intensity is gradually increasing with more use of electricity, leading to hidden threats to health.

X. Unit of Radiation Dose to Human Body

10.1 Absorbed Dose

Gray is a unit for absorbed dose; when the radiation energy imparted to a kg of tissue, it is one joule (1). It is called a gray as SI unit. Since gray is very large, milligray (one thousandth of a gray), and microgray (one millionth of a gray), are commonly used

1 Gy = 1J / kg =100 rad. ---------- (1)

The RAD (radioactivity absorbed dose), is the corresponding traditional unit which is 0.01 J deposited per kg.

1.2 Dose Equivalent

For radiation protection purpose, the absorbed dose is weighted to take account of the effectiveness of different types of radiation and the radio sensitivity of various organs and tissues. The biological damage produced on a given organism is called the dose equivalent, measured in Sievert (Sv) (2).

1Sv = 100 rem = 105 mrem ---------- (2)

The Rem (Roentgen equivalent man) is the traditional unit of equivalent dose. Because the Rem is a relatively large unit, typical equivalent dose is measured in milliRem (mrem). A milliRem (mrem) is $1/1000^{th}$ of a Rem or in microsievert (μSv) 10^{-6} Sv (1 mrem = 10 μSv). A Rem is a unit of ionizing radiation equal to the amount that produces the same damage to humans as one roentgen of high-voltage x-rays. The name is derived from "Rontgen equivalent man". Wilhelm Roentgen discovered ionizing radiation in 1895 at about the same time that Pierre and Marie Curie discovered radium.

10.3 Working Level Month (WLM)

It is the unit of time integrated radiation exposure measurement. A WLM results from the exposure to a concentration of decay products in air of 1 WL for an average working month of 170 hrs at a breathing rate of 1.2 m3.h-1. Residence in a house at 1 Bq/m3 results in approximately 0.005 WLM/y of exposure. For example, if average age of a resident is 70 years and radon concentration taken as 46 Bq/m3, then the exposure = 0.005 WLM / y x46x70 y = 16 WLM

XI. Total Radiation Doses to Human

Cosmic rays and terrestrial radiation contribute mainly to total background radiation, and both are variable at different places. Terrestrial radiation depends upon the presence and amount of radionuclides in different types of soils. Cosmic rays come from outer space and their intensity at a place depends on the altitude. Cosmic rays alone contribute 0.28 milligray at the first three cities (Mumbai, Chennai, Kolkata) as they are at sea level; the column of air helps to reduce their intensity. At high altitudes, the reduction from the column of air is less. The cosmic ray contribution are higher at 0.31 milligray and 0.44 milligray respectively at Delhi and Bengaluru as these cities are at altitudes of 216 m and 921 m. Air passengers receive 5 microgray per hour from cosmic rays [4]. The total annual external dose from sources in soil and cosmic rays in Mumbai, Kolkata, Chennai, Delhi and Bengaluru is 0.484, 0.81, 0.79, 0.70 and 0.825 milligray respectively [17].

The estimated annual effective dose and percent contribution from different natural sources to Indian population and the world population is given in Table II. Radon and thoron contribute highest (51.9% to 53.7%) followed by terrestrial (16.5% to 19.6%) and external exposure (cosmic radiation) (15.4% to 15.5%). Annual effective dose for Indian people is 2.299 mSv/y and for World population is 2.455 mSv/y. The average exposure in the United States, from natural sources of radiation (mostly cosmic and radon), is 300 millirem per year (3.00 mSv/y) at sea level. Radiation exposure is slightly higher at higher elevations.

Table II: Estimated annual effective dose (mSv/y) and percentage contribution (%) from different natural sources to Indian population and its comparison with global value reported by UNSCEAR, 2000 [18]

Sources of Radiation	India		World	
	Annual effective dose (mSv/y)	Percent contribution (%)	Annual effective dose (mSv/y)	Percent contribution (%)
External exposure: Cosmic	0.355	15.4	0.380	15.5

radiation				
Terrestrial	0.379	16.5	0.480	19.6
Internal exposure: cosmogenic nuclide (inhalation)	0.015	0.65	0.010	0.41
Radon and thoron (inhalation)	1.235	53.7	1.275	51.9
Terrestrial (ingestion)	0.315	13.7	0.310	12.6
Total	2.299	100.0	2.455	100.0

Average value of population dose in India in high background radiation areas (HBRA) is 3.8 milligray or mSv per year. One milligray is the average value for areas of normal background radiation. All these limits are for the amount of radiation exposure in addition to background radiation and medical radiation. The units of milligray and millisievert are the same in these instances.

Levels of exposure to radioactivity also depend upon a person's weight. A diagnostic tracer of one microcurie of radioactive calcium 45, given orally, would result in an exposure of 3.7 millirems for a 100-pound person, and half of that, 1.85 millirems, for a 200-pound person. When therapeutic radiation treatment is given by administering radioactive material through mouth or by injection, results in high, much localized doses to a small part of the body, which absorbs most of the radioactivity. Radioactivity remains in the target organ for a longer period of time, and not in whole body.

XII. Chronic Health Effects of Radiation

In general, the amount and duration of radiation exposure affects the severity or type of health effect. There are two broad categories of health effects, chronic (long-term) and acute (short-term). Chronic exposure is continuous or intermittent exposure to low level of radiation over a long period of time. During chronic exposure, there is delay in appearance of observed health effects. These effects are cancer and other health problems like benign tumors, cataracts, and potentially harmful genetic changes. The effects are also dependent on age, sex, and factors such as tobacco use. Current science maintains that there is risk of cancer from any exposure to radiation. U.S. protection radiation standards are based on the premise that any radiation dose carries some risk, and that risk increases directly with dose as per "linear no-threshold model (LNT)".

Pregnant women and children are more sensitive to radiation exposure, as the cells in them divide rapidly, providing more opportunity to radiation to disrupt process and cause cell damage. EPA accounts for these differences in sensitivity due to age and sex when revising radiation protection standards.

XIII. Acute Health Effects of Radiation

Acute health effects occur when large parts of body are exposed to a large amount of radiation, which can occur at once or from multiple exposures in a short period of time. Examples of acute exposure are rare such as accidentally handling a strong industrial radiation source or extreme exposure due to nuclear explosions or accidents in nuclear power plants. The large radiation exposure, more than 75 rad (equivalent to x-ray dose of 75000 mrem, in comparison to adult chest x-ray dose of 4 mrem), in a short time causes acute health effects like radiation sickness. Exposure between 5 to 10 rad results in no acute health effects, but increase the risk of getting cancer in future [19].

XIV. Health Impact of Cell Phones and Radio Emitters

In India, the telecom subscribers are 892 million including 861.7 million wireless segment subscribers. To cater to the cell phone and wireless communication devices, 736 K mobile towers with about 10 service providers in each of 22 Licensing Service Areas are present. Public are comprehensive about possible health hazards and impact on biota and environment due to EMF radiation from mobile towers/handsets.

Radio emitters and cell phones emit microwave radiation (MW) and radiofrequency (RF) radiation. The skin of human body absorbs the MW at its surface, while RF radiation may be absorbed throughout the body. At high enough intensities, both will damage tissue through heating effect. However, EPA has not changed its standards regarding radiation exposure, and no protective guidelines were changed during this administration.

Every antenna on cell phone tower radiates electro-magnetic radiation (power). One cell phone tower is being used by a number of operators; more the number of antennas, more is the power intensity in the nearby area. The power level near towers is higher and reduces as we move away. EMR may cause cellular and psychological changes in human beings due to thermal effects that are generated due to absorption of microwave radiation. EMR can also cause non thermal effects which are caused by radio frequency fields at levels too low to produce significant heating and are due to movement of calcium and other ions across cell

membranes. Such exposure is known to be responsible for fatigue, nausea, irritability, headaches, loss of appetite and other psychological disorders.

Serious public concern is observed over health effects of EMF radiation from mobile BTS Antennae and mobile. WHO established the International EMF Project in 1996 to assess the scientific evidence of possible health effects of EMF in the frequency range from 0 to 300 GHz. WHO has referred approximately 25,000 articles published in past 30 years. The conclusion of WHO and large number of studies carried out by U.S. Food and Drug Administration (USFDA) and other reputed organizations have found no scientific evidence to establish a link between ailments like cancer and infertility and radio frequency (RF) radiation [20] from base stations and wireless networks [21, 22] and no adverse short or long term health effects occur from the RF signals produced by base stations. Mobile phone tower radiation is lakhs of times weaker than X-rays or UV rays, even visible light.

Cell phone technology utilizes electromagnetic radiation in the microwave range (450 – 3800 MHz). It is now clear that there is no risk of brain concern or any head tumors in case of mobile users {23, 24] and that radiofrequency energy does not cause DNA damage that can lead to cancer. It is only consistently observed biological effect in humans is tissue heating. In animal studies, it has not been found to cause cancer or to enhance the cancer-causing effects of known chemical carcinogens [27, 28]. Evidence does not support the hypothesis that mobile phones radiation has an effect on the permeability of the blood-brain barrier (United States National Cancer Institute).

XV. Prevention from Radiation in Indoor Environment

Generally the level of radiation from the building material is very low and may not cause harm to human health. In certain cases, radioactive gas may be released from building materials; In that case, get tested the level of radon released from building materials take preventive measures accordingly. Radon testing kits are online available in India at a low rate of around Rs. 500/-.

If the radon levels are observed exceeding 4 picocuries per litre in air (pCi/L), then a qualified radon mitigation contractor is selected, and an appropriate radon reduction method is determined. Some radon reduction systems reduce the radon levels in the home by up to 99 percent.

Several methods are available to lower radon levels entering / entered the home. Soil suction is one of the methods to flush out the radon from below the house and venting it through a pipe or pipes to the air above the house. Radon reduction system needs occasional maintenance, by looking at the warning device on a regular basis, or to test the home at least every two years to be sure radon levels remain low.

U.S. EPA [23] has given comprehensive information on the indoor radiation and its measurement and preventive measures. The mission of EPA's Radiation Protection Program is to protect human health and the environment from unnecessary exposure to radiation [25].

XVI. Protective Shielding as Protection Measure

Various protective shielding materials are now available for online purchase at reasonable rates. Some of the protective gadgets are listed below.

- Mobile sticker chip for Mobile devices and laptops
- Digital LCD electromagnetic radiation detector
- EMF Meter dosimeter tester
- EMF protection pendant
- Wireless Tower Protection device
- Radiation free headset;
- Shielding the bed with a Faraday bed canopy
- Shielding the windows
- Shielding paints (to keep on outer walls to protect from tower radiation
- Cheaper EMF shielding by aluminium foil which can be stick to wall suing wall paper paste.
- Magnetic Shielding to protect critical electronic components

XVII. Guidelines and Standards

17.1 Worker's Right Related to Radiation Exposure (U.S. Department of Labor)

Workers have a right to a safe and healthful workplace. The OSHA law also prohibits employers from retaliating against employees for exercising their rights under the law. Workers can file a complaint to if employer is not following OSHA standards, or that there are serious hazards.

17.2 Preventive Measures for Laser

Laser Classes for safety purpose are defined as given below.
Class I : Safe – no label needed; do not disassemble Class I systems.
Class II : Visible lasers; Aversion response provides protection; prevent staring into beam.
Class IIIa : Visible lasers; limit eye exposure from focusing lenses.
Class IIIb : No eye exposure
Class IV : No eye or skin exposure; hazard from diffuse reflections; potential fire hazard.

17.3 International Safety Standards and Licensing

The regulatory bodies adopt safety standards in relation to limits on exposure levels below a certain value. The International Commission on Non-Ionizing Radiation Protection (ICNIRP) has given guidelines which have been adopted in more than 80 countries. For radio stations, ICNIRP proposes two safety levels: one for occupational exposure, another one for the general population. Currently there are efforts underway to harmonize the different standards in existence (26).

Mobile telephone service providers are, in many regions, required to obtain construction licenses, provide certification of antenna emission levels and assure compliance to ICNIRP standards and/or to other environmental legislation. Many governmental bodies also require that competing telecommunication companies try to achieve sharing of towers so as to decrease environmental and cosmetic impact. This issue is an influential factor of rejection of installation of new antennas and towers in communities.

In U.S.A., the current federal occupational limit of exposure per year for an adult, working near radiation, is as low as reasonably achievable; however, not to exceed 5,000 millirems [16], in addition to the 300+ millirems of natural sources of radiation and any medical radiation. Radiation workers wear badges made of photographic film which indicate the exposure to radiation, and readings are taken monthly. A federal advisory committee recommends that the lifetime exposure be limited to a person's age multiplied by 1,000 millirems (example: for a 65-year-old person, 65,000 millirems). The maximum limit of permissible exposure for a person under 18, working near radiation, is <500 millirem in addition to 300+ millirem background exposure. For foetus, the permissible limit is 500 millirems or <50 millirems per month. U.S. Food and Drug Administration (FDA) sets standards for electronic devices that emit non-ionizing or ionizing radiation [26].

In conclusion, one milligray is the average value for areas of normal background radiation; the limit of exposure per year for an adult, working near radiation, should be as low as reasonably achievable; however, not to exceed 5,000 millirems, and for persons under 18 working near radiation is <500 millirem (+300 millirem background exposure) and for foetus, it is <50millirems per month (U.S.A.)

XVIII. Indian Safety Standards and Guidelines

Department of Telecommunication (DoT), Government of India has been noticing global developments since 2008 and has already adopted stricter norms for safety from EMF radiation emitted from mobile towers and mobile handsets. Government of India has been taking due precautions by issuing various guidelines and norms, after considering the international standards / norms prescribed by International Commission on Non Ionizing Radiation Protection (ICNIRP) as recommended by World Health Organization.

Government of India adopted the International Commission for Non Ionizing Radiation Protection (ICNIRP) Guidelines. Then, license conditions of operators were amended on 4th November 2008, with directions to comply with ICNIRP prescribed radiation norms and to report compliance through self certification of their BTS to the respective Telecom Enforcement Resource & Monitoring (TERM) Units of Licensor (DoT).

18.1 Revised Indian Radiation Norms

Government of India introduced toughest electromagnetic field radiation standards after 1st September 2012. The limiting reference levels of electromagnetic radiation from mobile towers (Table III) were reduced to 1/10th of the limit prescribed by the ICNIRP with effect from 1st September 2012, based on the recommendations of an Inter Ministerial Committee constituted by DoT in the year 2010. DoT has a country-wide network of over 30 specialist enforcement and monitoring units called TERM cells to make rigid checks and enforce severe penalty in cases of non-compliance.

Table III: Standard for radiation norms for mobile towers

Frequency	ICNIRP Radiation Norms	Revised DoT Norms effective from 1st September 2012
900 MHz	4.5 watt /sq m	0.45 watt/ sq m
1800 MHz	9.0 watt / sq m	0.90 watt / sq m
2100 MHz	10.5 watt / sq m	1.05 watt / sq m

18.2 Revised Norms for SAR Level for Mobile Handsets

Adoption of Specific Absorption Rate (SAR) of 1.6 watt / kg (averaged over 1 gm of tissue) also implemented from 1st September 2012 (Table IV).

Table IV: SAR levels for mobiles

Frequency (10 MHz to 10 GHz)	ICNIRP SAR Limit	Revised SAR Limit effective from 1st September 2012
General Public exposure	2 watt/kg (averaged over 10 gm tissue)	1.6 watt/kg (averaged over 1 gm tissue)

- Mobile handsets with existing designs, compliant with 2.0 Watt/Kg averaged over a mass of 10 gram tissue, not to continue to co-exist after 31st August 2013.
- From 1st September 2013, only the mobile handsets with revised SAR value of 1.6 Watt/Kg shall be permitted for manufacturing or to import in India for domestic market.
- It will be mandatory for manufacturers to display the SAR – level on each mobile handset like IMEI (International Mobile Equipment Identity) display from 01.09.2013.
- SAR Test Laboratory has been set up in the Telecom – Engineering Centre DoT for testing of SAR value of Mobile handsets imported/ manufactured in India.
- India has become one of the very few countries in the world having toughest EMF radiation standards for mobile towers and handsets after 1st September 2012.
- Telecom enforcement Resource & Monitoring (TERM) Cells of DOT have been entrusted with the job of conducting audit on the self certification furnished by the Service Providers. TERM Cell shall carry out test audit up to 10% of the BTS site on random basis and on all cases where there is a public complaint.
- Telecom Engineering Centre (TEC) has revised the Test Procedure for measurement of EMF for verification of EMF compliance for BTS towers in accordance with new standards effective from 1st September 2012.
- For non-compliance of EMF standards, penalty of Rs. 5 lakh is liable to be levied per BTS per Service Provider of Mobile Handsets.

18.3 Guidelines for Setting up of Telecom Towers

- Before installation of tower, the licensee company obtains siting clearance from DoT to ensure that no interference with other wireless users, no aviation hazards and no obstruction to any other existing microwave links.
- Telecom service providers have to obtain the necessary permission from the concerned local authorities/ Municipal Corporation before installation of tower.
- Ensure that no nearby buildings right in front of the antenna with height comparable to the lowest antenna on tower at a distance threshold as specified.
- Operators through actual peak traffic time measurements need to establish that exclusion zone (Table V) does not cover areas with public exposure.

Table V: Guidelines for distance from the antenna to the building/structure

Number of Multiple antennas with same orientation	Building/Structure distance from the antenna (safe distance) (in meters)
1	20
2	35
4	45
6	55

18.4 Guidelines for Wall Mounted/Pole mounted Antenna

- Pole mounted Antenna height ≥ 5 meter above ground / road level on flyovers.
- No Residential place / office directly in front of the wall mounted antenna at a height comparable to the antenna in the exclusion zone.
- No restriction for installation of tower on / near specific buildings such as schools / hospitals / playground etc. as new tougher standards based on precautionary principles apply equally to all locations with human presence.

XIX. Proactive Steps Taken by Dot

- Broad guidelines issued by DoT for issuing clearances for installation of Mobile Towers.
- Precautionary Guidelines issued for Mobile Users advising them to take precautions while using/ purchasing the mobile handsets.
- These guidelines are available at DoT website

19.1 Public Awareness Programme by DoT

DoT has issued an informative guide on "Mobile Communications – Radio Waves and Safety". The document covers a basic introduction to radio waves, various terminologies, Do's & Don'ts related to mobile phone usage, clarification of various myths regarding deployment, use of radio waves / safety standards and frequently asked questions relating to mobile phones and human health. Advertisement for ensuring safety from radiations of mobile towers & handsets has been issued by DoT which has been published in national & regional newspapers.

19.2 DoT Precautionary Guidelines for Mobile users

i. Keep distance – Hold the cell phone away from body to the extent possible.
ii. Use a headset (wired or Bluetooth) to keep the handset away from your head.
iii. Do not press the phone against your head. Radio Frequency (RF) energy is inversely proportional to the square of the distance from the source.
iv. Limit the length of mobile calls.
v. Use text as compared to voice wherever possible.
vi. If the radio signal is weak, a mobile phone will increase its transmission power. Find a strong signal and avoid movement, use your phone where reception is good.
vii. Let the call connect before putting the handset on your ear or start speaking and listening – a mobile phone first makes the communication at higher power and then reduces power to an adequate level. More power is radiated during call connecting time.
viii. If you have a choice, use a landline (wired) phone, not a mobile phone.
ix. People having active medical implants should preferably keep the cell phone at least 15 cm away from the implant.
x. While purchasing a mobile handset, check the SAR value of the mobile if its model number and make is known.

Department of Telecom, Govt. of India has given clarification on various myths about mobile handsets and Mobile base stations among the people (Table VI).

Table VI: Various myths and facts about mobile handsets & mobile base station

Myth	Fact
Mobile phone use cause headache.	Headaches are not related to mobile phone use and there is no scientific evidence.
It is safer using a mobile phone in a car as the car shields from the radiation.	The RF radiation is increased by mobile phones when used in a car to overcome the shielding.
Mobile phones cause brain cancer to the people who use it.	There is no scientific evidence that mobile phone can cause brain cancer.
Mobile base stations are dangerous and one should have distance from it.	It is the antenna from which we should keep distance and not from tower and that too if we are positioned facing antenna at comparable height. At the ground level, the intensity of RF radiation from base station is much less.
Nobody is investigating the health effects of Radio Frequency (RF) radiation.	The World Health Organization, many national and international organizations and independent expert groups are coordinating to investigate health effects of RF radiation.

XX. Conclusion

There is no convincing scientific evidence of causing adverse health effects due to exposure to EMF radiations from a mobile tower, which are below the safe limits prescribed by ICNIRP and recommended by

WHO. Government of India has introduced toughest electromagnetic field radiation standards for mobile towers and for mobile SAR. Further, Government of India has taken adequate steps to ensure that Telecommunications Service Providers strictly adhere to these prescribed norms. The guidelines and other information are available on the website of Department of Telecommunications, Government of India.

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