Saudi Journal of Biological Sciences 28 (2021) 5585–5592

Contents lists available at ScienceDirect

Saudi Journal of Biological Sciences

journal homepage: www.sciencedirect.com

Review

Radiobiological effects and medical applications of non-ionizing radiation

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ARTICLE INFO

Article history:
Received 28 April 2021
Revised 26 May 2021
Accepted 27 May 2021
Available online 1 June 2021

Keywords:
Non-ionizing radiation
Optical radiation
Radiofrequency fields
Hazards
Medical applications

ABSTRACT

Radiation is used in medicine to diagnose and treat diseases but it can also cause harm to the body by burning or mutation. This depends on whether the radiation is ionizing or nonionizing. Despite its vast applications in surgery, dermatology and cosmetics, little is taught and thus known about non-ionizing radiation.

This review article discusses the fundamentals of non-ionizing electromagnetic radiations. The main aim is to extensively explain the different types of non-ionizing radiation. This will equip students and medical personnel with knowledge on different medical applications and expose them to a variety of specializations in medicine that utilize non-ionizing radiation. The article discusses the physics, hazard, means of protection and medical application of each type of radiation: ultraviolet radiation, light (both visible light and LASER), infrared radiation, microwaves and extremely low frequency radiation separately. It presents these terms in a simple manner that avoids rigors mathematics and physics, which makes them comprehensible for medical students.

The development of new diagnostic and therapeutic approaches could also lead to increased hazards to the body unless they are treated with precaution. If not adequately monitored, a significant health risk may be posed to potentially exposed employees. Hence proper dosage should be used for non-ionizing radiation. This is only possible through understanding of the risks/benefits of these radiations by studying the physics and radiobiological effects of each individual radiation.

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Peer review under responsibility of King Saud University.

Production and hosting by Elsevier

https://doi.org/10.1016/j.sjbs.2021.05.071

1. Introduction

The charged particles emit electromagnetic field in a form of energy. It travels through space like a wave with the power of oscillating electric and magnetic field. These waves are in phase, oscillating perpendicular as well as to the direction of the movement (Wojtczak and Piotrowski, 2020). The electromagnetic waves are created with a charged particle that creates electric field which can exert force on other charged particles resulting in excitation or ionization (Sinha and Amaratunga, 2018).

Non– ionizing radiations: the radiation energy is too low to trigger the ionization process in the medium which it passes (to trigger the emission of an electron from an atom). Non-ionization refers to the energy required to excite atoms or electrons in adequate amounts, but is not sufficient to expel electrons from their orbitals. Precautionary measures can raise concerns, intensify EMF-related perceptions of risk and reduce faith in the security of public health. Such impacts, challenging social assumptions, should be taken into account in precautionary action decisions. (Wiedemann and Schütz, 2005).

2. Excitation

Non-ionizing radiations occurs when a series of energy waves made up of oscillating electrical and magnetic fields travel at the speed of light. Excitation occurs because non-ionizing electromagnetic radiation only has sufficient energy for it, which is the transfer of an electron to a higher energy state, instead of generating charged ions while moving through matter. The non– ionizing radiation (NIR) spectrum two major areas are optical radiation and electromagnetic fields. Optical radiation focuses on visible light, ultraviolet radiation and infra-red radiation. These types can cause damage to the eyes and skin. Optical radiation falls into two groups: thermal and photochemical. (Youssef et al., 2011)

Single photons of ultraviolet radiation, despite having insufficient energy to ionize atoms, can damage tissue. This occurs when the bonds within DNA molecules are disrupted which can lead to a long-term cancer risk. This must be considered when it comes to permissible exposure. Visible light and IR only create harm by multi-photon interactions of high intensity. For both, effects produced are exactly the same, but lasers are able to produce higher irradiances and can heat tissue to a higher temperature sufficient which creates rapid physical change (Daddysman and Fecko, 2011).

Furthermore, electromagnetic fields are also categorized into radiofrequency fields: microwaves, high frequency, low frequency radio waves. There are several sources of non-ionizing radiation: those of natural origins, such as sunlight or and man-made ones produced for industrial purposes. Both of which can lead to harmful exposure and a danger to our health (International Commission on Non-Ionizing Radiation Protection. 2020). Non-ionizing radiation (NIR) is commonly used in health care in applications such as ultrasound imaging, laser surgery, and long-term UV light therapies, as well as MRI and transcranial magnetic stimulation as examples of more recently developed applications for depression therapy (Hansson Mild et al., 2019). The different types of nonionizing radiation are studied in depth in this review.

3. Types of nonionizing radiation and their clinical effects

3.1. Ultraviolet radiation (UVR)

A portion of the electromagnetic spectrum that has both nonionizing and ionizing properties is UVR, also called black light. It reaches us from the sun and has both the effects of disinfection and darkening (Maverakis et al., 2010). UV radiation comes from a variety of sources, the sun being the most important one. Manmade UV radiation are produced in welding, sun lamps, lasers (UV), germicidal lamps, and low/high pressure gas discharge lamps (Juzeniene et al., 2011). The biological effects of UV radiation depend on the wavelengths involved. The wavelength of the nonionizing UV spectrum is shorter than that of visible light but longer than an X-ray (100 nm [nm] to 400 nm). It is classified according to intensity: UV-A (315–400 nm), UV-B (280–315 nm) and UV-C (100280 nm) (Kim et al., 2016).

Hazards: UVR can cause biological damage by both photochemical and heating reactions. It has a high photon energy spectrum and is especially harmful since no immediate signs of excessive exposure are typically present. Whilst UV-C dissolves in the atmosphere in general has no hurtful impact, UV-A and UV-B on the other hand could have harmful effects on skin and eyes. UV contact responsible for 90 percent of early skin aging symptoms.

Similarly, radiation exposure to the eye may be caused by anything as simple as reflecting sunlight off water or even the flash from a camera. Overexposure to UV light may lead to serious risks including cataracts and macular degeneration (Duarte et al., 2015), (D'Orazio et al., 2013).

3.2. Protection: Skin/ Eye protection

1. **Dense fabric:** Ultraviolet light rays can be protected in many ways such as using denser and thicker fabric, and closer knit or weave. This prevents penetration of UV rays to the skin (Watson et al., 2016).
2. **Dark or bright colors:** dark colors absorb UV rays; hence the skin is exposed to lower levels of harmful radiation. However, there are also some bright colors (red) that can also task in UV rays.
3. **Synthetic material:** Synthetic fibers such as nylon or polyester absorb more UVR and are hence more protective than bleached cottons or semi-synthetic fabric such as rayon. (Sarkar, 2004).

4. **Less tension:** more stretchable fabrics allow UV rays to penetrate easily. Sporting clothes made up UPF (ultraviolet protection factor) shields from UV rays.
5. **Dry fabric:** The dampness content of a textile that can increase during wear decreases the ability of the fabric to protect the skin from UV rays.
6. **Newer condition:** The older and more worn-out the garment, the less able it becomes from shielding the skin against harmful rays. New clothes and accessories such as hats which cover the body are more protective.
7. **Sun protection creams:** Creams having a high sun-protection-factors are advised to use especially when people are exposed to high levels for example during out-door activities
8. **Eyes Protection:** sunglasses with 99–100 percent UV protection, as well as darker lenses, polarized lenses, or a mirror coating and wraparound glasses designed to keep light from entering around the frames and into one's eyes (van Kuijk 1991).

Medical application

Man-made UVRs are used in hospitals as *germicidal lamps* to kill bacteria and in skin tanning for cosmetic purposes or to treat skin disorders such as psoriasis (Sleijffers et al., 2004). UV, mediates the natural synthesis of vitamin D and endorphins in the skin, hence benefits human health. Various medical uses include UV and neonatal phototherapy, lasers for surgery and care, heat lamp physiotherapy (Sowa et al., 2013). Skin tanning is induced by oxidizing skin's melanin which results in a darker skin color. (Sivamani et al., 2009).

4. Light

Visible Light: is the small quantity to which the average human eye responds to the electromagnetic spectrum. We commonly refer to visible light as having wavelengths ranging from 400 to 750 nm. Actually, the retina of the eye responds to the lowest ultraviolet wavelengths, they are absorbed by cornea and lens and does not penetrate the retina. Vision is our most important source of external world knowledge. Eyes acquired 70% of the sensory input. The effect of light on human health and biodiversity is equally important (Lamphar and Kocifaj, 2013). Our eyes see the various apparent frequencies of the electromagnetic (EM) range as distinct colors. Good lighting is beneficial to better performance, and can help avert accidents associated with poor lighting settings. (Sliney 2016).

The lowest frequencies and longest wavelengths are required for red light, while violet light has the highest frequencies and shortest wavelengths. Blackbody radiation peaks in the visible portion of the spectrum from the sun, but is more powerful in the red than in the violet, rendering yellowish color of the Sun. The distinctions are not absolutely distinct amongst infrared, visible, and ultraviolet, neither stand between the seven colors of the rainbow.

Medical application of light includes

Ophthalmology, in which light is used to visualize the fundus of the eye. Many systemic diseases have ophthalmic manifestation with visible pathological feature affecting the fundus. Light and optical methods have had significant effects on modern medicine, with various lasers and optical instruments now being used to test health and treat illnesses in clinical practice. (Yun and Kwok, 2017).

Endoscopy which uses the phenomena of absolute inner reflection inside light pipes to explore the interior of a patient's body.

Microscopy which used particularly in microbiology and histology, to magnify microscopic bodies

Visible light in medicine covers

4.1. High energy visible light (HEV)

"Blue light" known as high energy visible light (HEV) or is visible light with wavelengths between ~381 nm and 500 nm (adjacent to UV on the EMR spectrum). It has high brightness levels and can thus cause lasting cell destruction in certain individuals. Lengthy exposure to HEV increases loss of central vision. We can be exposed to "blue light" through computers, televisions and cell phones etc. but we can use Blue-blocker lenses as to protect ourselves. They do not decrease the light but instead modify the look of blue and green colors to make them less damaging. Blue light is close in the range to UV, hence blue blockers with UV protection is recommended.

4.2. LASER

'LASER' acronym stands for Light Amplification by Stimulated Emission of Radiation. Lasers emit different types of electromagnetic optical Helium-neon, neodymium YAG, and ruby visible lasers, and the Nitrogen UV laser are popular lasers that include CO_2 IR lasers.

The three mechanisms of lasing are: energy absorption, stimulated emission and amplification as shown in Fig. 1.

Properties of LASER are monochromatic, directional and coherent. This concentrating phenomenon makes it possible to make sharp cuts and precise burns that improve medical use. (Patil and Dhami, 2008). Lasers are classified from Class 1 to Class 4 according to its potential hazards; where *Class 1* Signifies laser or laser devices which pose no threat under usual working circumstances, incapable of producing damage; and *Class 4* It refers to lasers and laser structures that not only generate a danger from straight or specular reflections, but can also generate major skin and fire dangers (Bargman, 2010).

Hazards of LASER: The term LASER includes a range of wavelengths: infra-red, Visible, UVR and X-ray LASER. In the past decades, the use of lasers in medical practice has seen great growth and very sophisticated devices are frequently designed and implemented. These devices can, however, also pose a significant threat. Developing a risk management perspective on laser protection is crucial. (Smalley, 2011).

In general, laser hazards are classified into beam hazards which cause eye and skin damage, and non-beam hazards which occur from the laser system itself or its contact within the surgical setting with materials. These include Laser plume threats, fire hazards, and electrical hazards inherent in a laser device that is a high-voltage. (Dudelzak and Goldberg, 2011). In regards to the eye acute exposure of certain power of wavelengths can cause burns to cornea or retina or both, (Birtel, et al., 2017). Excessive levels of chronic exposure can produce cataracts as well as damage the retina. An example of LASER injury is retinal injury causing blind spot in the fovea. Symptoms associated with LASER injury includes burning pain, photophobia and difficulty to see "green and blue" colors. The real harm occurs when no pain is detected until an irreversible damage occurs. This is usually associated with Nd-Yag Lasers. (Yolton et al., 1999). On the skin, burns may occur when there are high amounts of optical radiation. LASER with ultraviolet wavelengths (290–320 nm) can cause carcinogenesis. Many lasers need dangerous or poisonous substances to work, and which can also damage the skin and eye if not used correctly. The high voltages which are required for the majority of lasers to work which can also prove to be lethal.

Furthermore, laser dye includes flammable solvents. Ignition can be triggered by high voltage spikes or flash lamps. Flammable and poisonous organic solvents with additives such as cyclooctatetraene (COT) are used by the latest dye lasers (Zachary and Gustavsson, 2012).

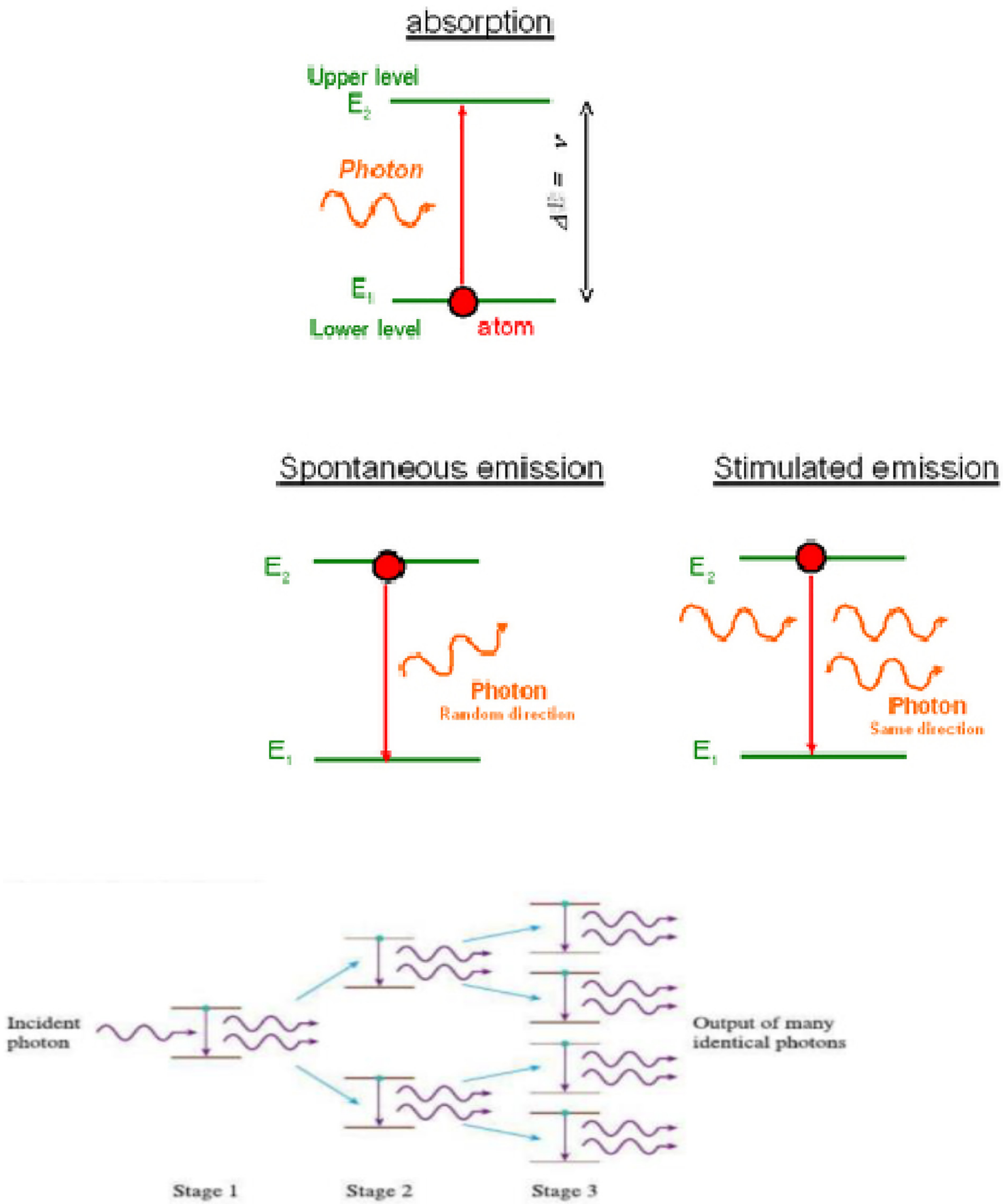

Fig. 1. Lasing Mechanism.

5. LASER in medicine

Laser is intensively used in ophthalmology and ophthalmic surgery due to its high intensity that allows fine cuts as well as coagulation post operation. Some applications include:

1. **Vision correction:** The reshaping of the corneal curvature. The Laser in situ Keratomileusis is the most widely used laser vision correction technique (LASIK). The top layer of the cornea is surgically peeled back and multiple bursts of precisely regulated ultraviolet radiation emitted by an excimer laser ablate the underlying tissue. 90% of the patients get corrected from nearsightedness, farsightedness, and astigmatism. The flap of the cornea is replaced; the procedure is painless and heals quickly (Lim and Lim 2019).
2. **Retinal holes, tears and detachments:** LASER is used to create burns around the retinal tears and prevent the tear causing retinal detachment from the fundus (Moo-Young, 1985).

3. **Diabetic Retinopathy:** This is a noticeable disorder involving leaking vessels and bleeding or hemorrhage. Due to the low oxygen stress, new vessels develop; the retina is pulled and torn. Several burns are used across the fovea to reduce the need for fresh vessels. At the cost of peripheral viewing, the central vision is saved (Yun and Adelman, 2015).
4. **Cataract Surgery:** The LASER is used to create an opening for the removal of the cataract lens in the posterior capsule. For the following three phases in cataract surgery, FDA has approved femtosecond lasers: corneal incision creation, anterior capsulotomy, and fragmentation of the lens. It is also used for astigmatic correction to generate limbal relaxing incisions (Chen et al. 2014).
5. **Posterior Capsulotomy:** One of the common problems of cataract surgery cases is PCO or Posterior lens capsule opacification. During the surgery a laser is used to extract the cloudy central portion behind the lens implant from the posterior capsule. The laser aims slightly posterior to the capsule in the vitreous to prevent damage to the intraocular lens implant. The most common delayed complication of cataract surgery is PCO. An alternative laser choice, Neodymium Nd:YAG laser capsulotomy has proved to be a successful to surgical discission to prevent complications such as endophthalmitis and vitreous failure (Karahan et al 2014).
6. **Glaucoma treatment with LASER**

Over the past 5 decades there's has been an increase in the use of LASER when tackling and treating glaucoma. The following are some examples of LASERS designed for this use:

- **LASER iridoltomy**: (angle-closure glaucoma) A hole in the iris is built to avoid pressure elevation and prevent the eye from ballooning (de Silva et al., 2007).
- **LASER gonioplasty**: using photocoagulation, iris is contracted exposing the trabecular mesh work (Weiss et al., 1992).
- **LASER trabeculoplasty:** For open-angle glaucoma, the trabecular meshwork is punctured to increase the aqueous flow and thereby decrease the intraocular pressure (IOP) (Garg and Gazzard, 2018).
- **LASER surgery**: LASER is used to cut through tissue and then close blood vessels thermally to decrease bleeding**.** Studies indicate that the use of lasers have dramatically improved and reduced scar thickness, neuropathic pain and the need for surgical excision etc. LASER is also used in other surgeries including:
- **Photocoagulation:** heating causing destabilization of protein (similar to egg boiling). Used for: mass reduction or devastation. Temperature above 50 ^{0}C and below 100 °C.
- **Photo-vaporization:** used in skin rejuvenation; Using high power densities to heat the tissues rapidly beyond 1000C, boiling the water that makes up 70% of the tissue and gradually evaporating the tissue.

5.1. LASER interaction with the skin

The effective interaction of LASER with the skin depends on absorption of energy which in turn results in heat production and elevation of the temperature. In the skin, the absorption of laser light is reliant on the contact with water, melanin, and hemoglobin; with water being the element that absorbs most of the energy. Absorbed LASER energy creates photochemical effects reliant on the water content of the tissues. Vaporization of the tissue water, also known as ablation occurs at 100 °C. Denaturation of proteins occur at temperatures below 100 °C but above 60 °C. At temperatures in excess of 200 °C, the tissue is dehydrated and then burnt, causing a detrimental effect called carbonization, (Verma, 2012).

5.2. LASER applications in cosmetics

For cosmetic purposes, there are two types of lasers used: ablative lasers which vaporize the top layers of damaged skin and non-ablative lasers that work deeper in the skin without eradicating or otherwise harming the top layers. An example of this would be using lasers to treat lines and wrinkles which use a mixture of skin rising and skin-tightening techniques can be used or both. Most enhancing laser techniques offer at least some level of superficial tightening because they produce a precise injury of the skin, which boosts collagen production.

Lasers have also proven to be useful when treating pigmented lesions that cause hyperpigmentation issues such as sun spots, age spots, and melisma.

Good results of LASER applications are achieved when treating vascular lesions that include a variety of blemishes ranging from birthmarks, spider veins on the legs, broken blood vessels on the face and spider nevi. Non-ablative lasers have also shown significant progress with superficial acne scarring.

One of the most popular cosmetic procedures at local salons is laser hair removal. This can become an issue when using lasers as the results are dependent on the pigment present in both the skin and hair of the patient.

5.3. LASER in dentistry

LASER use in dentistry are categorized as soft tissue and hard tissue procedures. Soft tissue techniques include preventative techniques such as wound healing, aesthetic gingival re-contouring and crown lengthening with minimal pain, discomfort, and bleeding associated with the conventional procedures. Hard tissue procedures include: cavity preparation, nerve repair and regeneration, impacted wisdom teeth and treating hypersensitivity in teeth. Low level laser therapy helps in nerve repair and regeneration while reducing inflammatory reactions.

https://www.123dentist.com/laser-dentistry-what-is-laser-dentistry/

6. Infrared radiation (IR)

IR are situated between microwaves and visible light. It has a range of wavelengths, with the nearest wavelength to visible light being near infrared and the "far infrared" closer to the microwave region. Near infrared waves are short and not hot and undetectable, which makes them especially harmful for sensitive tissues, such as skin and eyes. (Zheng et al., 2010). Infrared radiation (IR) heat is absorbed by the skin and eyes. Furnaces, heat lamps, and IR lasers are among the sources of IR radiation (Vatansever and Hamblin, 2012).

Hazards: Skin's response to IR exposure is to give a warning signal in the form of pain. Since IR is not visible to the eye it is important to always protect the eye by wearing items with IR filters. Prolonged exposure to IR can include permanent damage to the cornea and retina through burns (Tsai and Hamblin, 2017).

6.1. Protection

Black clothing: Heat energy meets the same conservation principles as light energy. If most light wavelengths are reflected by a certain material, most heat energy would be reflected as well. Therefore, colors that reflect most wavelengths of light appear to be cooler than those that reflect less, because of the existence of visible light. This concept will help in understanding the principles of different colors to stay warmer or cooler. Researchers has suggested the heavy black robes worn by Bedouins in desert thick black color fabric which absorbs more heat but does not affect the skin due to its thickness. Thin black clothing transmits the heat to the skin, cooling mechanism does not take place as sweat evaporation is not possible hence latent heat of vaporization does not occur (Liu and Zhang, 2015).

6.2. Infra-red applications in medicine

Diagnostic IR: Abnormal body temperature is a natural predictor of illness. Infrared thermography (IRT) for body temperature monitoring is a quick, passive, non-contact and non-invasive alternative to traditional clinical thermometers. Depth-resolved visualization of tissue for measurement of temperature variation. Such approaches have helped to diagnose many medical problems, including skin/breast cancer, arthritis, allergies, burns, and others (Gurjarpadhye et al., 2015).

Thermal imaging cameras have played a major role in the last five decades to obtain correlations between thermal physiology and skin temperature. IRT is now widely used to detect symptoms of COVID-19 indicated by high temperature. It is also used in the diagnosis for the treatment of breast cancer and vascular disorders. As well as to treat issues on various fields such as neonatal physiology, gynecology, dermatology, cardiology, kidney transplantation, screening of fever etc. The data acquisition from IR cameras and processing procedures is likely to fuel further research in these fields (Lahiri et al., 2012). Current efforts are based on the automated analysis of the distribution of temperatures in the areas of interest and their statistical breakdown for abnormality detection. This will help to develop the field of medical IRT.

The therapeutic effects of heat: Infrared radiation can encourage the circulation of local blood and reduce stress in the muscles. The relief of muscle pain and stress, treatment of autoimmune diseases or wound-healing conditions, are examples of typical medical uses of infrared radiation (Park et al., 2018). It causes molecules to vibrate as infrared radiation strikes biological tissue, creating heat and causing the temperature to rise. The absorption potential of water for the different wavelengths of incident infrared radiation plays a key role in assessing the penetration depth and effects of radiation, since human tissue is primarily made up of water. It can penetrate up to 1.5 in. (4 cm) under the skin (Vatansever and Hamblin, 2012). Excess temperatures are harmful, there are adverse effects with increased temperature and time exposure exceeds critical limits causing burns which results in disturbances in the heat balance of the entire organism. The eyes are sensitive to thermal effects. Appropriate safety goggles may protect the eyes from unnecessary infrared radiation exposure (Rahmani et al., 2016).

Health benefits of infrared light: 'Infrared light has been correlated with many advantages. Healing of wounds and ulcers and tissue repairment, improving hair growth, controlling psoriasis, pain relief, improving skin appearance as well as reducing the side effects of cancer treatments such as oral mucositis are amongst the therapeutic benefits of IR' (El Mobadder et al., 2018). IR is also used by dentist and rheumatologist to reduce pain and inflammation. In sports medicine, IR therapy is commonly used to treat a wide variety of chronic and acute musculoskeletal injuries suffered by athletes (Foley et al., 2016).

7. Microwave radiation (MW)

Microwave radiation (MW) fall into the electromagnetic spectrum with wavelengths between 1 mm and 1 m (or the equivalent frequency range from 300 GHz to 300 MHz). They are used in a variety of fields from communications to broadcasting to heating or defrosting of food in the kitchen. Frequencies ranging from 80 to 800 are used for TV and FM radio broadcasting antennas. Microwaves are often produced from mobile phones and their base stations and microwave links. Also, it comes from cordless phones, blue tooth devices, wireless local area networks and many other applications.

7.1. Hazards of microwave radiation

Microwave radiations are usually specified as thermal or non-thermal based on their biological effects. Thermal effects are contacts that are induced by biological sample heating and can be duplicated using traditional heating methods. The contact that the electromagnetic field of the incoming microwave radiation and the biological subject is caused by non-thermal or specific effects. Microwave EMF exposures produce a variety of neuropsychiatric effects (Pall, 2016). If the body has high exposure to MW with high temperatures there will be damage to the issues which will lead to health issues for the individual (Zhi et al., 2017). An area of vulnerability is the central nervous system which has shown a significant change when the body is exposed to microwave radiation. It can cause sleep disorders as well as memory impairment, with some studies suggesting that prolonged exposure to mobile phone devices (which emit MW) leading to increases chances of developing a brain tumor (Kan et al, 2008). Exposure to MW through radio emitter and mobile phones means it can be absorbed by the body through the skin which can damage tissues (Myung et al., 2009), (Kim et al., 2019).

MW can damage tissue through heating at sufficiently high intensities. The depths of travel of the microwave depends on the frequency of the microwaves as well as the type of the tissue that is affected. These effects are not instantly apparent as lower frequencies reach deeper into the tissue and as there are less nerve endings in deeper-located areas of the body (Mehrotra et al., 2019; Kan et al., 2008; Khurana et al. 2009); Myuang et al., 2009).

7.2. MW effects on the reproductive organs

The testicles are particularly susceptible to temperature elevation, making them more susceptible to microwave radiation exposure. Research on mammals such as dogs, rabbit has exhibited that severe damage to the testicles with a reduction of sperm cells which are able to mature (Wang et al., 2006). 'The decrease in testicular function due to the heating effect appears to be transient and reversible at10 mW/cm^2. Neurological effects were also found in offspring who had exposure to Wi-Fi radio frequencies (Othman et al., 2017). Furthermore, the effect of exposing pregnant rats to 9.417 GHz microwaves, resulted in their offspring (both male and female) displaying an increase in anxiety related behavior and more surprisingly, the males displayed impaired memory and learning. (Zhang et al 2015).

Microwave applications in medicine

Microwave medical diagnosis

The inclusion of non-ionizing EM waves for sensing and imaging in medical diagnosis in the range of microwave frequency is becoming more common as it is inexpensive and poses a lower health risk compared to the imaging technologies described above. The principle of medical microwave diagnosis is to observe the scattering of the signal created by the dielectric difference. There is a comparison of dielectric properties between healthy and malignant tissues in this process. A microwave sensor that has been modified for tracking medical conditions such as lower extremity injuries and craniosynostosis is shown in the figure below. The figure below shows a microwave sensor that was adapted for the monitoring of medical conditions such as lower extremity injuries and craniosynostosis. (Craniosynostosis is a birth defect in which the bones in the skull of a baby join together too early. This occurs before the brain of the baby is fully developed. The skull may become more mis-formed as the brain of the baby develops.

7.3. Microwave medical therapy

Microwave energy for the thermal ablation of tissue is commonly used in medicine. Microwave energy can be used to produce '*localized dielectric heating*' (diathermy), resulting in precise tissue destruction. Without the unnecessary searing and damage to the nerve that is associated with RF ablation, microwave ablation also provides tissue desiccation (Hao et al., 2015). To generate heat, microwave ablation utilizes dielectric hysteresis. Tissue loss occurs when tissues from a selected electromagnetic field, usually at 900–2500 MHz, are heated to lethal temperatures. Microwave power enters into the body via an interstitial antenna connecting energy from the generator power source to the tissue. As the tissue absorbs the radiation it heats up due to the radiating nature of the antenna. This heating mechanism varies greatly from the ablation of radiofrequency (RF), which produces heat as electrical stream penetrates through the ionic tissue medium. An advantage of microwave technology is its flexibility which. Due this, there is a wide range of medical treatments that can benefit from the range of available frequencies.

Higher frequencies can be used to treat a variety of health issues including skin cancer, uterine fibroids, numerous small liver metastases and corneal ablation (vision correction). Higher frequency treatments in the 5.8 GHz-10 GHz range are capable of producing shallow energy penetration and are thus suitable for surface treatment or anything requiring very precise ablation. Microwaves in highly vascular organs such as the liver (Swift et al., 2003) and spleen (Jiang et al., 2016) may also be used to coagulate bleeding.

8. Extremely low frequency radiation (ELF)

Extremely Low Frequency at 60 Hz is normally used by communication industries for power lines, electrical wiring, and electrical equipment. 'ELF induction furnaces, high-voltage power lines and power plants are common sources of extreme exposure (Torres-Duran et al., 2007).

Hazards: Recent epidemiological studies have indicated that human health is impaired by exposure electromagnetic fields with extremely low frequencies. This causes certain forms of cancer, depression, and miscarriage among people living or working in environments exposed to such fields (Singh and Kapoor, 2014; Kim et al., 2019). ELF exposure is known to increase free radical concentrations and traceability and can influence the recombination of radical couples. Several studies have reported that exposure to ELF in several tissues of the body, results in oxidative stress (Kıvrak et al., 2017). Protective measures for the body against EMF exposure includes taking antioxidants such as vitamin E, MEL, and FA to avoid the possible adverse effects of exposure to EMF.

Medical applications

ELF are now effectively used in medicine inn diagnostics, e.g. Magnetic resonance imaging, scanner and microwave imaging (Hartwig et al., 2009).

They also provides non– invasive method to treat injury, Gauss or micro- Tesla instrument which is a pulsed electromagnetic fields with low frequency and intensity range, increases oxygenation to blood, improve circulation and cell metabolism, improve function pain and fatigue from fibromyalgia (Legros et al., 2015; Paolucci et al., 2020).

They are commonly used in neurology, psychiatry (treatment of depression), rheumatology, orthopedics (to treat spinal injury) and dermatology both at diagnostic and therapeutic levels (D'Angelo et al., 2015; Mattsson and Simkó, 2019). (Kumar et al., 2017). It also promotes cell proliferation (Song et al., 2018) and has supporting role of in generating immune-modulatory responses, neuromodulation and possible benefits of neuroprotection. (Guerriero and Ricevuti, 2016).

9. Conclusions

This review literature of non– ionizing Electromagnetic radiations deals with the biological effects in terms of hazards and medical applications. Various types of non– ionizing electromagnetic waves in the spectrum include: ultraviolet (UV), visible light, infrared (IR), microwave (MW), radio frequency (RF), and extremely low frequency (ELF) of different wavelengths. Our paper deals with sources of each type of non– ionizing electromagnetic waves. Secondly, it discusses the hazardous effects on human health arising from prolonged exposure of these radiations and means of protection. Finally, we present the short overview on medical application of all non– ionizing radiations.

The development of new diagnostic and therapeutic approaches could also lead to increased hazards to the body unless they are treated with precaution. If not adequately monitored, a significant health risk may be posed to potentially exposed employees. Hence proper dosage should be used for non-ionizing radiation. This is only possible through understanding of the risks/benefits of these radiations by studying the physics and radiobiological effects of each individual radiation.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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