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Nonionizing Radiation

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Introduction

In the past 75 years, there has been a remarkable increase in the number of man-made sources and applications of nonionizing radiation. These include a myriad of uses of laser and radio-frequency radiation in industrial, scientific, military, consumer, and medical applications. During much of the same period, research has focused on the possible health effects associated with nonionizing radiation (NIR), both man-made and naturally occurring. The body of information generated in those studies demonstrate that not only can overexposure to nonionizing radiation produce a number of serious health effects, but that there are thresholds between safe exposures and over exposures. Hence, it is possible to use nonionizing radiation for beneficial applications in the occupational environment without subjecting workers to harmful exposures. To achieve this goal, however, it is necessary to recognize and evaluate sources of nonionizing radiation in the workplace and provide expertise in appropriate controls to the worker. This is the role of the occupational hygienist.

The intent of this chapter is to assist the occupational hygienist in anticipating, recognizing, evaluating and controlling nonionizing radiation. Other useful references on nonionizing radiation are available.[1-4]

Electromagnetic Radiation

Because all nonionizing radiation is electromagnetic radiation (or electric and magnetic fields), it is necessary to have a basic understanding of electromagnetic radiation before delving into the nonionizing radiation spectral regions in more detail.

Electromagnetic radiation is the propagation, or transfer, of energy through space and matter by time-varying electric and magnetic fields, as shown in Figure 21.1. In the case of electromagnetic energy, the fields are composed of vector quantities. A vector field is any physical quantity that takes on different values of magnitude and direction at different points in space.

As depicted in Figure 21.1, the electric and magnetic fields are in time phase and space quadrature. Space quadrature means the electric and magnetic vector fields are mutually orthogonal. Time phase means that the waves have reached the same stage in their periodic oscillation with respect to time.

Electric fields are produced by electric charges, while magnetic fields are produced by moving charges, or a current.

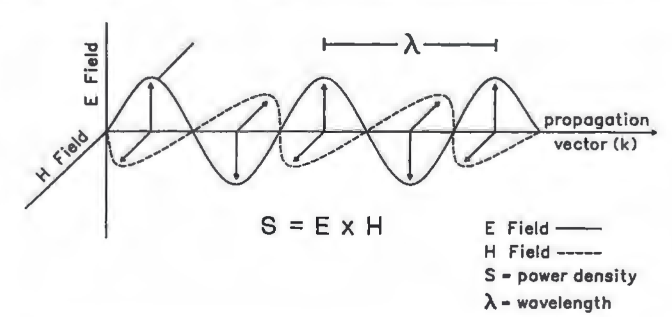

Figure 21.1 — The waves represent the electric and magnetic fields. The electric field vector (solid line) is vibrating up and down in the plane of the paper, while the magnetic field vector (dashed line) is vibrating in and out of the plane of the paper. The direction the radiation is moving is defined by a third vector — the propagation vector, k. Electromagnetic fields are transverse to the direction of propagation and contained within the envelope formed by the axis of propagation and the sinusoidal waves.

Information and Training

Employees should be provided with information concerning NIR sources in their workplaces, potential exposures, and operating procedures. Some organizations recommend that individuals who have a high likelihood of being exposed at or above the applicable exposure limits should receive education and training commensurate with the level of risk. For example, U.S. Department of Defense Instruction 6055.11 requires RF safety training for "personnel who routinely work directly with equipment that emits RF levels in excess" of the exposure limits.[770] Also, ANSI Z136.1 requires laser safety training of users who are at greatest risk of overexposure (i.e., users of Class 3b and Class 4 lasers). It may be prudent, however, to provide brief information sessions to individuals who have low-level exposures or where there is a low risk of exposure.

Informational and training requirements are often reviewed during the prepurchase review meeting. DOE recommends that workers be trained "prior to assignment to a job involving potential exposure to NIR and at least annually thereafter."[771]

NIR safety training should provide the exposed individuals with an understanding of the sources and exposure levels in their workplaces. This information will help place the potential exposures in perspective. Other information that might be in the training program includes company information (policy, operating procedures, medical surveillance, intracompany contacts, etc.) and information on instrumentation, as appropriate.

Hazard Communication

Although OSHA did not extend the hazard communication law to physical agents, the concept of effective risk communication is also integral to programs dealing with physical agents. As a minimum, the nonionizing radiation safety program should familiarize exposed workers with the potential hazards of nonionizing radiation. To maximize effectiveness, the program will also proactively share information about exposure levels and the resulting risks with the workers. Such an approach helps simplify and explain otherwise complex and often confusing issues dealing with real and purported biologic effects of nonionizing radiation. Documentation of the results of any hazard evaluations should be shared with employees who use the source, and their supervisors.

The conclusions of accident investigations should be made available to employees, including the outcome of field evaluations and clinical examinations.

Self-Checks and Audits

Periodic self-checks are often performed by individuals responsible for significant sources of nonionizing radiation. These include checks of hardware and administrative controls. Periodic audits may be used by the competent person to evaluate the effectiveness of the self-check program.

Summary

Nonionizing radiation includes UV, visible, IR, RF, and ELF spectral regions and laser radiation. Sources of NIR are both naturally occurring and man-made. Because the number of man-made sources of NIR is increasing, and a larger number of these may generate more than one type of NIR, the potential for exposure to NIR is increasing.

Overexposure to NIR electromagnetic radiation and fields may cause a variety of biological and health effects. These span the spectrum from benign effects, such as constriction of the pupillary opening on exposure to light, to serious diseases, such as UV-induced skin cancer. In general, most effects are nonstochastic, with the intensity of the response varying with the magnitude of the dose or dose rate. Some stochastic effects (e.g., skin cancer) arise from UV exposure, and effects windows have been reported in in-vitro studies of ELF fields.

Exposure guidelines have been recommended from 180 nm in the UV-C spectral region through the ELF and sub-ELF region to fields generated by direct current (non-time-varying electric and magnetic fields). The guidelines for each spectral region are discrete, whereas the limits for laser radiation cover all optical radiation (UV, visible, and IR). The UV and RF guidelines are examples of envelope guidelines, and the RF and ELF guidelines (including sub-RF) are derived from the basic limits, SAR and current density, respectively. The guidelines are dynamic, and are revised when there is consensus concerning the available scientific evidence.

Broad-band field survey instruments are available for most NIR regions, except for some infrared and microwave wavelengths. Dosimeters or personal exposure monitors are available in the UV and ELF spectral regions, although NIR dosimetry is still a developing area at this time. Numerical modeling to predict potential exposure is useful for some sources, especially when the radiation is in the shape of a beam, as it is in lasers and some collimated microwaves.

Engineering and administrative/procedural control measures apply throughout the NIR spectrum. Shielding is an effective engineering control throughout, but is more complicated for low-frequency magnetic fields. Distance is also useful throughout, since the intensity of NIR decreases with radial distance from the source. Personal protective equipment is most useful for optical radiation.

A nonionizing radiation protection program needs management support, the involvement of a competent technical staff, and workers who are aware of the potential hazards of NIR sources with which they work. Successful implementation of such a program will minimize the risk of NIR-related health effects, meet regulatory requirements, help control insurance costs, and reduce the impact of possible negative publicity.

References

1. **Wilkening, G.M.:** Nonionizing Radiation. In *Patty's Industrial Hygiene and Toxicology General Principles*, 4th Ed. New York: John Wiley & Sons, 1991. pp. 657-742.
2. **Murray, W.E., R.T. Hitchcock, R.M. Patterson, and S.M. Michaelson:** Nonionizing Electromagnetic Energies. In *Patty's Industrial Hygiene & Toxicology*, Vol. 3, Part B, 3rd. Ed. New York: John Wiley & Sons, 1995. pp. 623-727.
3. **Miller, G.:** Nonionizing Radiation. In *Fundamentals of Industrial Hygiene*, 4th Ed. Itasca, IL: National Safety Council, 1995. pp. 273-317.
4. **Patterson, R.M., and R.T. Hitchcock:** Nonionizing Radiation and Fields. In *Health and Safety Beyond the Workplace*. New York: John Wiley & Sons, 1990. pp. 143-176.
5. **International Radiation Protection Association:** Review of Concepts, Quantities, Units and Terminology for Non- Ionizing Radiation Protection. *Health Phys. 49*:1329-1362 (1985).
6. **Sutter, E.:** Quantities and Units of Optical Radiation and their Measurement. In *Dosimetry of Laser Radiation in Medicine and Biology* (SPIE Vol. IS 5). Bellingham, WA: SPIE Optical Engineering Press, 1989. pp. 38-79.
7. **National Council on Radiation Protection and Measurements (NCRP):** *Radiofrequency Electromagnetic Fields — Properties, Quantities and Units, Biophysical Interaction, and Measurements.* Washington, D.C.: NCRP, 1981.
8. **World Health Organization:** *Extremely Low Frequency (ELF) Fields* (Environmental Health Criteria 35). Geneva: WHO, 1984.
9. **Sliney, D., and M. Wolbarsht:** *Safety with Lasers and Other Optical Sources.* New York: Plenum Press, 1980.
10. **World Health Organization:** *Lasers and Optical Radiation* (Environmental Health Criteria 23). Geneva: WHO, 1982. pp. 42-45.
11. **Sutter, E.:** Extended Sources—Concepts and Potential Hazards. *Optics Laser Technol.* 27:5-13 (1995).
12. **Everett, M.A., R.M. Sayre, and R.L. Olsen:** Physiologic Response of Human Skin to Ultraviolet Light. In *The Biological Effects of Ultraviolet Radiation (With Emphasis on the Skin).* New York: Pergamon Press, 1969. pp. 181-186.
13. **McKinlay, A.F., and B.L. Diffey:** A Reference Action Spectrum for Ultraviolet Induced Erythema in Human Skin. *CIE J. 66*:17-22 (1987).
14. **Diffey, B.L.:** Observed and Predicted Minimal Erythema Doses: A Comparative Study. *Photochem. Photobiol. 60*:380-382 (1994).
15. **Parrish, J.A., K.F. Jaenicke, and R.R. Anderson:** Erythema and Melanogenesis of Normal Human Skin. *Photochem. Photobiol. 36*: 187-191 (1982).
16. **Matelsky, I.:** Non-ionizing Radiations. In *Industrial Hygiene Highlights, Vol I.* Pittsburgh: Industrial Hygiene Foundation of America, Inc, 1968. pp. 140-179.
17. **Epstein, J.H.:** Photomedicine. In *The Science of Photobiology*, 2nd Ed. New York and London: Plenum Press, 1989. pp. 155-192.
18. **U.S. Food and Drug Administration:** *Medications that Increase Sensitivity to Light: A 1990 Listing* by J.I. Levine (DHHS [FDA] Pub. No. 91–8280). Rockville, MD: U.S. Department of Health and Human Services, 1990.
19. **Hawk, J.L.M.:** Photosensitizing Agents in the United Kingdom. *Clin. Exptl. Dermatol. 9*:300-302 (1984).

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