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NON-IONIZING RADIATION AND HEALTH PROTECTION PROBLEMS

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The term non-ionizing radiation (NIR) generally refers to all those types of radiation which when interacting with matter cannot impart enough energy to produce ionization. It is now conventional to take as the dividing line between ionizing and non-ionizing radiation a photon energy of 12 eV, corresponding to a wavelength of 10^{-7} m (100 nm). Non-ionizing radiation thus includes all electromagnetic radiation with a wavelength equal to or greater than 10^{-7} m, that is : ultraviolet radiation, visible light, infrared radiation, microwaves, etc... up to the longest radiowaves. For health protection purposes, the field of NIR usually extends to electrostatic and magnetostatic fields and, though they are quite different in nature, also to ultrasonic waves because they raise quite similar health protection problems.

The health significance of exposure to NIR will depend on the physical characteristics of the radiation involved.

Wavelength and frequency are two closely related properties which determine the characteristics of any particular type of electromagnetic radiation and which can be used interchangeably to describe it. The frequency

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as well as the photon energy are increasing when the wavelength is decreasing. The penetration into living matter of electromagnetic radiation depends upon the energy of the photon, it passes through a minimum in the visible and near infrared and ultraviolet region. Thus from infrared wavelengths up to the longest radiowaves, in a general way, the depth of penetration will increase with increasing wavelength and decreasing frequency. However it is also influenced by the nature of the interacting tissue. When electromagnetic radiation passes from one medium to another, it can be reflected, refracted, transmitted or absorbed depending on the constituents and structure of the biological material and on the wavelength (or frequency) of the radiation. Diffusion and resonance phenomena will interfere with the simple laws of energy absorption and conversion into heat.

For protection purposes, the determination of the energy absorbed (absorbed dose) and of its distribution within living systems, whatever the radiation concerned, is still one of the chief problems to be solved. Therefore, although thermal effects are often prevailing, no appropriate dose - effect relationships could be established in most cases and more particularly as far as non-thermal effects are concerned.

Following these few general considerations, we shall briefly review the problems associated with the different types of NIR.

OPTICAL RADIATION AND LASERS

Optical radiation covers the ultraviolet, visible and infrared part of the electromagnetic spectrum. Most of its health effects have been known for many years. But optical radiation involves a more particular hazard when emitted as a coherent, monochromatic, very narrow and intense beam of electromagnetic radiation by laser devices ; this will be considered separately.

Ultraviolet radiation (UV)

Exposure to UV radiation occurs both from natural and artificial sources and involves the spectral region ranging from 2.10^{-7} to 4.10^{-7} m. The main source of UV exposure both for workers and for the general public

remains the sun. Occupational health hazards furthermore arise in industry (electrical arcs, mercury vapor lamps ...), in biological laboratories and in hospitals (UV sterilization and medical uses). Public exposure results from the home use of UV lamps mainly for cosmetic purposes. Medical exposure is increasing due to the expanded used of photo-therapeutic methods.

The effects of UV radiation on man may be beneficial or detrimental and depend on a number of circumstances. UV is an essential factor for normal mineral metabolism and lack in UV exposure may result in vitamin D deficiency. The harmful effects may be acute or chronic and involve primarily the skin and the eyes. Besides the well-known increase in skin pigmentation (suntan), acute effects on skin consist of solar erythema (sunburn) and, if severe enough, in damage similar to a first or second degree heat burn. Chronic exposure entails degeneration and aging of the skin, it may produce premalignant skin changes and finally result in skin cancer induction. Acute effects on the eye (photokeratitis, photoconjunctivitis) are generally reversible, while chronic effects consist in the development of cataracts and cancer of the conjunctivis. Furthermore the interaction of UV radiation and a number of chemical and pharmaceutical substances results in increased photosensitivity.

More information is still needed to establish scientifically acceptable protection standards covering both acute and long term effects for workers and for members of the public. Some occupational exposure standards have been proposed, the most comprehensive of which is that recommended by the American Conference of Governmental Industrial Hygienists (ACGIH) with different limits according to UV wavelength and exposure time.

Visible radiation

Visible light is generally safe but hazards can arise from certain high intensity light sources such as bright sun projector bulbs, spotlights and floodlights which can cause skin effects and impairment of vision.

Infrared radiation (IR)

Occupational health hazards arise in industry near high temperature sources (metallurgy, glass-works). Exposure of the public results

chiefly from the expanding use of IR heating devices. Medical exposure is increasing with the development of thermotherapeutic methods.

Exposure to IR produces a temperature rise and can result in burns affecting the skin or the eyes or in a heat syndrome.

No protection standards exist up to now but ACGIH (1978) proposes some exposure limiting values for light and near IR.

Lasers

Since their introduction some 15 years ago, the development of lasers has been phenomenal. Occupational exposure represents for the moment the chief potential health problem because of the high powers involved in scientific and industrial applications. But attention should be paid to the expanding sources of public exposure as low-power lasers are ever more used in teaching, show-business and devices for home use. In medicine, diagnostic and therapeutic laser techniques are developing in various fields.

The associated hazards vary greatly with the wavelength used - ranging form the far UV to the far IR - the mode of operation and the power output. The most vulnerable organ is the eye, but exposure to high intensity radiation can lead to severe burns of the skin and possible damage to underlying organs.

Very few countries introduced standards regulating laser safety. Recommendations on exposure limitation and performance standards for laser devices are in preparation by the International Electrotechnical Commission.

MICROWAVES AND RADIOFREQUENCIES (MW and RF)

Microwaves (involving the 300 GHz - 300 MHz frequency range) are widely and increasingly used in telecommunications (television links and certain color TV systems), telenavigation, radar installations, medicine, as well as in a wide range of industries (food, metal, chemical, wood, etc... industries) and consumer products (microwave ovens).

One category of biological effects of microwaves consistsin conse-

quences of dielectric heating (whole body or local hyperthermia). Another category, the effects on the nervous, endocrine, and hematopoietic systems may be ascribed to interference with bioelectrical phenomena, interference with cell membrane function and biophysics of intermolecular reactions in living systems (e.g. long-term energy storage in macromolecules). Teratogenic and genetic effects of MW exposure were reported and chromosome aberrations may be induced.

In the RF range, beginning with very high frequency (300 MHz) and ending with very low frequency (100 kHz), broadcasting and telecommunication systems, industrial and home-use appliances create an ever increasing intensity of electromagnetic fields almost everywhere. It should be added, that depending on frequency and modulation, continuous or intermittent exposure, biological effects and the underlying biophysical mechanisms may vary widely.

Exposure limits and equipment performance standards have already been introduced by a number of countries. However, from one country to another there are wide differences in the values adopted, although a trend to reduce the higher values associated with particular frequencies may presently be observed.

ULTRASONIC RADIATION

Ultrasound generating devices are used in medical practice and of particular concern is the use of ultrasonics as a diagnostic aid during pregnancy. Many industrial applications of ultrasound exist. Various testing and cleaning appliances are in wide use. Ultrasound is also generated incidentally by high-speed machinery. The biological effects of ultrasound are even less understood than those of other NIR ranges. This is partly because of limitations in dosimetry particularly of pulsed ultrasound. Lack of knowledge about propagation of ultrasound in the human body makes evaluating dose-effect relationship difficult, even in the case of such effects as tissue destruction or heating. Performance standards for ultrasound devices exist in some countries but no exposure standards have been developed.

ACTION OF IRPA IN THE FIELD OF NIR

With the rapidly expanding use of non-ionizing radiation producing devices and the increasing concern about their possible health hazards, many of those engaged in radiation protection became ever more involved in the field of NIR because of their experience in the field of ionizing radiation and of their scientific and technical background. This question having been brought up by several affiliated Societies, IRPA in 1973 set up a Working Group later transformed into a Study Group to review the situation in the field of protection against NIR, to study carefully the technical problems raised and to look at the steps taken in this field by other international organizations.

As a result of its review, the Study Group, besides its reports to the Executive Council dealing with the general situation in this field, issued a technical report summarizing the basic health criteria and standards used for the different NIR - "Overviews on Non-Ionizing Radiation" - which was distributed at the 1977 IRPA Congress in Paris.

The main conclusions of the Study Group's review were the following :

"Considering the rapidly expanding worldwide use of NIR producing devices, it is important to assess realistically the potential hazards of NIR exposure and to establish exposure limits so that the worker or the general public will be adequately protected without unduly restricting the beneficial applications of these energies. It is regrettable that the lack of an agreed-upon philosophy and the use of very different concepts, quantities and units often make it difficult to compare the data obtained in different studies. In some countries, protection standards have already been issued for particular types of NIR or for certain occupational situations, but owing to differences in the underlying concepts, there are wide variations in the values adopted. Because of the universal character of electromagnetic pollution as well as the increasing international trade in electronic products, international agreements on exposure limits and guidelines for equipment performance standards are urgently needed. Internationally acceptable protection standards, however, can be established only if consensus is reached on the different quantities, concepts and basic principles of protection. The complexity of the problems necessitates wide interdiscipli-

nary cooperation on an international basis."

Although some international organizations had already included NIR in their field of interest, their activities up to then were more devoted to the development of research on the biological effects of NIR (WHO, URSI, International Commission of Photobiology) or of product standards for the construction of safe devices (IEC). Others such as ILO, CEC had expressed their interest in some guidelines concerning limitation of exposure to NIR. It thus appeared that to realize international agreement upon criteria, fundamental principles and a consistent system of exposure limitation for protection against NIR, a non-governmental international body was badly missing.

When formally approached by the IRPA about this problem, the ICRP, although it recognized that adequate control should be established over a number of sources of NIR, considered that this subject was lying outside its field of work.

Having carefully considered the above mentioned points and the work performed by the different international organizations active in this field, the IRPA during its 4th General Assembly in 1977 decided to set up an International NIR-Committee as follows :

" The General Assembly amends the Constitution of IRPA in order that IRPA may apply its objectives and purposes also in the field of non-ionizing radiation protection.

The General Assembly directs the Executive Council to extend the work of the Study Group by establishing an International NIR-Committee formed around the current membership of the Group (consisting of *Dr. H. Jammet* as Chairman and *Drs. P. Czerski, M. Faber, Z.V. Gordon, J.C. Villforth, G.M. Wilkening* as members), with the objective of developing background documents and international accepted recommendations.

The General Assembly expresses the wish of IRPA to collaborate formally with the WHO on criteria for non-ionizing radiation protection, and, as far as appropriate, to explore with other international organizations and agencies ways and means for furthering non-ionizing radiation protection activities.

The Chairman of the International NIR-Committee shall undertake all steps necessary to implement the tasks formulated under Sections 3 and 4 supra, he shall report on the work of the Committee at each Meeting of the Executive Council, and he shall present a report on the activities of the Committee at the International Meetings of IRPA."

THE IRPA / INTERNATIONAL NIR-COMMITTEE (IRPA / INIRC)

Composition

In a first time, it was found reasonable that the IRPA/INIRC be composed of 12 members. These are chosen primarily on the basis of their recognized activity in the different fields of NIR and of their expertise within appropriate disciplines (health physics, biology, physics, medicine and engineering), keeping in mind the need for adequate representation of the different scientific trends. Presently, the INIRC membership has been extended to nine, pending the answer of three other invited experts.

Scope of activities

The objective imparted to the Committee being to develop background documents and internationally accepted recommendations, the scope of its activities was defined as follows :

- collation of information on exposure levels ;
- recommendation of appropriate quantities and units with respect to the different types of NIR ;
- analysis of the biological effects of NIR and development of protection criteria ;
- recommendation of a system of exposure limitation ; primary, secondary and derived standards ; reference levels ; guidelines for the protection of workers and members of the public.

Large differences in the physical, biological and technical problems associated with parts of the NIR spectrum require these topics to be considered separately for each type of NIR.

Relations with other international organizations

Following the wish expressed by the IRPA General Assembly, the Committee developed working relationships with the WHO, the ILO and the URSI.

Practical modalities of cooperation with the WHO were defined during a joint consultation in November 1977. It was agreed that the WHO / Environmental Health Division and the IRPA / INIRC would cooperate in the preparation of health criteria documents for the different types of NIR within the frame of UNEP's environmental health criteria programme. These joint publications are intended to provide background information which will serve as a basis to IRPA / INIRC for setting up appropriate exposure limitations. Joint work is already in progress.

ILO which was represented at the WHO / IRPA - INIRC joint consultation expressed the wish to cooperate with IRPA in the development of occupational protection standards.

According to an agreement between IRPA and URSI, the Committee cooperates with URSI Committee A's Working Group on Measurements related to the interaction of electromagnetic fields with biological systems in the promotion of International Symposia. After Airlie (1977), Helsinki (1978), the INIRC cooperates in the organization of an International Symposium on Electromagnetic Waves and Biology which will be held from 30th June to 4th July 1978 in Jouy-en-Josas near Paris.

Contacts have also been taken with the ICRU and the Commission of the European Communities.

Current work and future working programme

Development of protection standards requires a realistic assessment of the possible biological effects and the exposure-response relationship as well as appropriate information on the exposure conditions and the people at risk. Therefore, it is essential to achieve first a thorough review of all available data, which generally will lead to the preparation of a so-called basic criteria document. This will then be an important basis for determining fundamental exposure limits and recommending a consistent system of exposure limitation for workers and the general public. Once such protection standards are established guidance is generally needed for their practical application in various circumstances.

These different steps form the basis of the Committee's present

and future working programme. Considering the amount of work necessitated by the collection of background data including information on exposure sources and levels, physical, biological and technical data and a review of existing emission and protection standards, the Committee found it advisable to cooperate with the WHO / Environmental Health Division which was starting work in this field owing to a financial support from UNEP. A scheme of cooperation in the preparation of joint health criteria documents on NIR was agreed upon. As a result some joint working groups were established to deal with specific topics and several joint meetings were held in 1978 and 1979. It is anticipated that the joint health criteria documents will be developed and published approximately according to the following time schedule :

- ultraviolet : the document is in its final stage of preparation and is anticipated to be published in 1979 ;

- microwave and radiofrequency radiation : the document will be completed in 1979 and may be published in early 1980 ;

- lasers and visible light : will be combined in a single document, the work on which could be started beginning 1979 with a first draft being ready towards the end of 1980 ;

- ultrasound : the work on a criteria document could be started in the second half of 1979 and it is hoped that a first draft could be ready towards the end of 1980 ;

- extremely low frequency (ELF) radiation : the work will start after completion of the microwave and RF criteria document with a first draft anticipated for the end of 1980 or the beginning of 1981.

Furthermore, ILO will cooperate in collecting information on occupational exposure data.

However, the main objective of the IRPA / INIRC is to develop appropriate and internationally agreed-upon protection standards in the field of NIR.

Therefore, in a first time, INIRC has to consider the problems of :
- harmonizing quantities and units to be used for the different NIR ; and
- developing basic concepts of protection against NIR.

These basic principles together with the background material collected in the health criteria documents as well as the information on occupational exposure will then serve as a basis to the Committee for the development of appropriate exposure limits.

Thereafter, it has been considered that guidance for operational protection against the different NIR and for appropriate education and training of workers could possibly be developed in some codes of practice or manuals which would be prepared in cooperation with WHO and ILO.

CONCLUSION

Despite the rapidly expanding worldwide use of devices generating all types of NIR, our knowledge concerning their possible impact on human health is still poor. Much scientific work remains to be done to clarify the fundamental biophysical mechanisms of interaction of NIR with living systems, to determine the absorbed energy distribution within the body and to develop appropriate methods of measurement of incident radiation, to improve our knowledge with respect to biological effects and more particularly dose-effect relationships.

The establishment of appropriate protection standards requires adequate evaluation of information gained from animal experimentation, from observations on exposed individuals and, whenever possible, from epidemiological surveys of exposed people. But the basic criteria used to interpret such data vary from one country to another, thus leading to the adoption of very different exposure limits. Efforts are presently being developed within the scientific community to compare the basic approaches and bring them closer together through the agreement of joint research programmes, between eastern and western countries for instance. Meanwhile, however, an increasing number of countries is promulgating regulatory measures for limiting exposure to NIR of occupationally exposed individuals and of the general population. Harmonization of basic concepts and internationally acceptable protection standards are therefore urgently needed. IRPA is probably the only international, non-governmental scientific organization able to promote wide international and interdisciplinary cooperation in the field of health protection against NIR. Therefore, after

having carefully considered the situation, IRPA felt that it was its responsibility to produce guidance on basic protection criteria and standards and created the International NIR-Committee with the objective of developing background documents and internationally accepted recommendations.