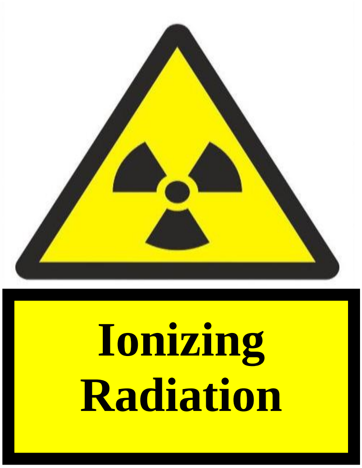
Ministry of Health of the Republic of Moldova
„Nicolae Testemiţanu” State Medicine and Pharmacy University
Hygiene, Discipline of Department of Preventive Medicine

Ion BAHNAREL   Aliona TIHON

Ionizing and non-ionizing radiation



CHIȘINĂU, 2022

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The paper was discussed and approved at the Meeting of Central Methodic Concilium of the „Nicolae Testemitanu" State University of Medicine and Pharmacy

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Discipline of Hygiene

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These guidelines are intended for practical laboratory works on general hygiene. The guidelines were compiled by

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The guidelines for practical classes correspond to the syllabus of the student curricula of the faculties of Medicine, Pharmacy and Dentistry.

DESCRIEREA

ABREVIATION LIST

ADN	**-** desoxyribonucleic acid
ALARA	**-** As Low As Reasonably Achievable
dB	**-** decibel
Gy	**-** unit of measurement for absorbed radiation
Eel	**-** value of electron energy
Evibr	**-** vibration energy
Erot	**-** rotation energy
Hz-hertzi	**-** unit of measurement for frequency
NFRP 2000	**-** National Norm for Radioprotection 2000
Sv	**- u**nit for effective dose
TLD	**-** thermo-luminescent detectors
UV	**-** ultraviolet radiation
α	**-** α radiation
β	**-** β radiation
γ	**-** γ radiation

CONTENTS

Purpose of the paper:

Acquire the notions of ionizing and non-ionizing radiation, their effects, measures to protect against the use of radiation and know the hygienic estimation of the level of radiation of the population and the development of prophylactic measures.

The objectives of the methodical elaboration are:

• increasing the level of knowledge of students, residents, master students from USMF „Nicolae Testemitanu" on the general notions about ionizing, non-ionizing radiation and their effects on health;

• raising public awareness of the health benefits and risks associated with ionizing and non-ionizing radiation;

• training and development of correct skills to promote health by mastering the basic principles of radiation protection.

The methodical elaboration is structured in four parts:

• relevant legislation;
• general notions of ionizing and non-ionizing radiation;
• the effects of ionizing and non-ionizing radiation on health;
• basic principles and prophylaxis measures.

Practical skills:

• Dividing patients into categories for radiological medical examinations;
• Classification of critical organs;
• Radiation protection principles.

Conclusions

The existence of exposure of the population to ionizing and non-ionizing radiation sources, which is the key issue in public health, should be taken into account. It is important to know the sources of radiation, which present a real risk, manifested by radio-induced malignancies which indicate that the global levels of exposure of the population to radiation continue to increase, which argues for the knowledge and periodic reassessment of doses.

„Life on earth developed in the presence
of background radiation.
It's nothing new, man-made."
ERIC J. HALL

INTRODUCTION

Man lives on Earth, continuously subjected to the action of multiple environmental agents, including ionizing radiation. Most of the radiation is of natural origin to which man has added in the last hundred years and the artificial ones due to his own activity. The discovery of nuclear energy is considered one of the greatest achievements of the twentieth century, but the use of radiation in multiple economic fields today also means the expansion of health problems caused by this radiation, from occupational to general population, with other words, a public health issue.

Ionizing radiation sources are currently used in virtually all fields of science and technology, in energy, industry, agriculture, construction, etc. Unfortunately, ionizing radiation sources are used not only for peaceful purposes, but also in the production of nuclear and thermonuclear weapons. Regardless of the scope of use, sources of ionizing radiation present a potential risk if the requirements and rules of radiation protection and nuclear safety are not complied with.

In medicine, the sources of ionizing radiation have found an extremely wide spread in the diagnosis, treatment and prophylaxis of diseases.

In addition, the use of non-ionizing radiation in all areas of life has increased significantly in recent years. At the same time, more and more scientific data on the impact of non-ionizing radiation on health continues to accumulate.

This methodical elaboration is addressed to the population, students, residents, master students from USMF „Nicolae Testemitanu", with the aim of protecting public health and preventing diseases associated with ionizing radiation. It contains important public health advisory information on ionizing and non-ionizing radiation, its effects on health and radiation protection principles. Methodical elaboration does not replace the legislation in force.

MAIN REGULATORY ACTS IN THE FIELD:

- Law no. 111/1996 on the safe conduct of nuclear activities, republished, with subsequent amendments;
- Fundamental Norms of Radiation Protection, Hygienic Requirements and Rules no. 06.5.3.34 of February 27, 2001. In: Official Gazette No. 40-41 Art. No: 111, 05.04.2001 Chisinau;
- Council Directive 2013/59 / Euratom laying down basic safety rules for protection against the dangers arising from exposure to ionizing radiation and repealing Directives 89/618 Euratom, 90/641 Euratom, 96/29 / Euratom, 97 / 43 / Euratom and 2003/122 Euratom.

I. GENERAL NOTIONS REGARDING IONIZING RADIATION

1.1. Radiation classification, radiation sources.

Radiation is a fact of life. It is present in nature and can be produced artificially. Radiation of natural origin exists in the whole environment, while radiation of artificial origin has been used for only a few decades. Natural and artificial radiation are neither different in type nor in effect.

Radiation is inherently harmful to humans and therefore the population must be protected from unnecessary or excessive exposure. However, the use of ionizing radiation contributes to the good of man, they are important in the development of medicine, science, as well as in industry, agriculture, etc.

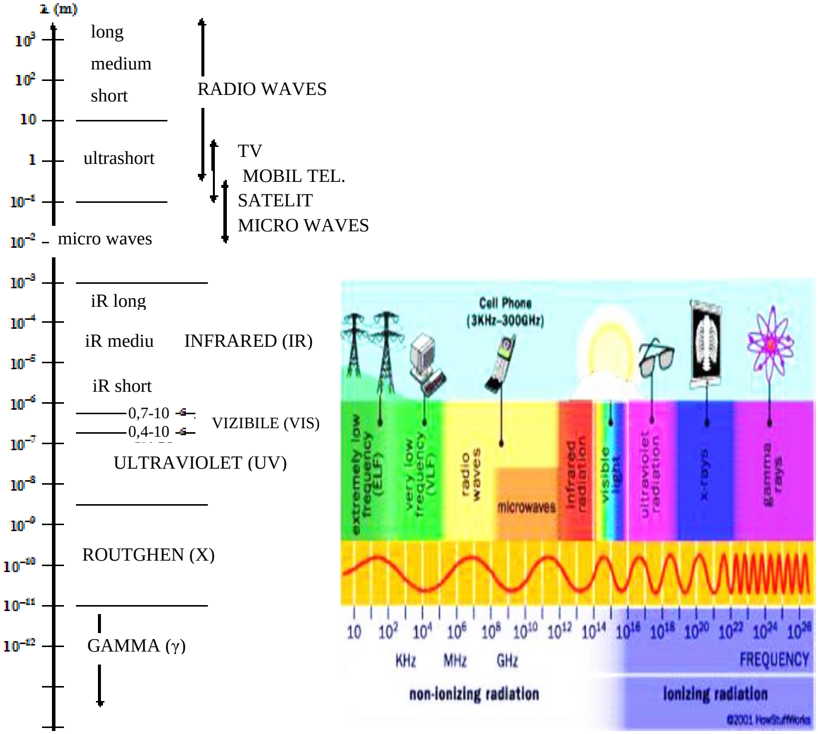
The most worrying effects of radiation are malignancies caused to exposed people, as well as defects inherited from their descendants. The probability of any effect caused by ionizing radiation is related to the dose of radiation received. The risk associated with any exposure must be weighed against the benefits of the procedures that caused the exposure.

On average, natural radiation causes the greatest exposure to humans. Much of this cannot be avoided, although some control can be exercised. The tightness of control, the balance between risk and benefit is an issue that society needs to appreciate.

Radiation is the energy emitted by a source and transmitted through space in the form of waves or particles.

From the point of view of radiation protection, radiation is divided into 2 categories: non-ionizing and ionizing, to emphasize the danger to human health. Electromagnetic radiation: light, ultraviolet and infrared radiation, radio waves, microwaves, ultrasound belong to non-ionizing radiation.

When radiation hits an atom, it transfers some of its energy to it. If the energy transferred by the radiation is high enough, ionization occurs - the process of removing an electron from the atom that leaves behind 2 electrically charged particles - an electron and a positive ion. The presence of large numbers of such electrically charged particles can cause damage to living tissues. Radiation that can transfer enough energy to do this is called ionizing radiation, and those with a lower energy level are called non-ionizing radiation. Although certain types of non-ionizing radiation can be harmful in high doses, ionizing radiation is usually much more dangerous. When people talk about radiation, they usually refer to ionizing radiation. In everyday life we encounter different types of radiation, both non-ionizing - such as light, radio waves, microwaves, and ionizing such as X-rays, gamma, etc.



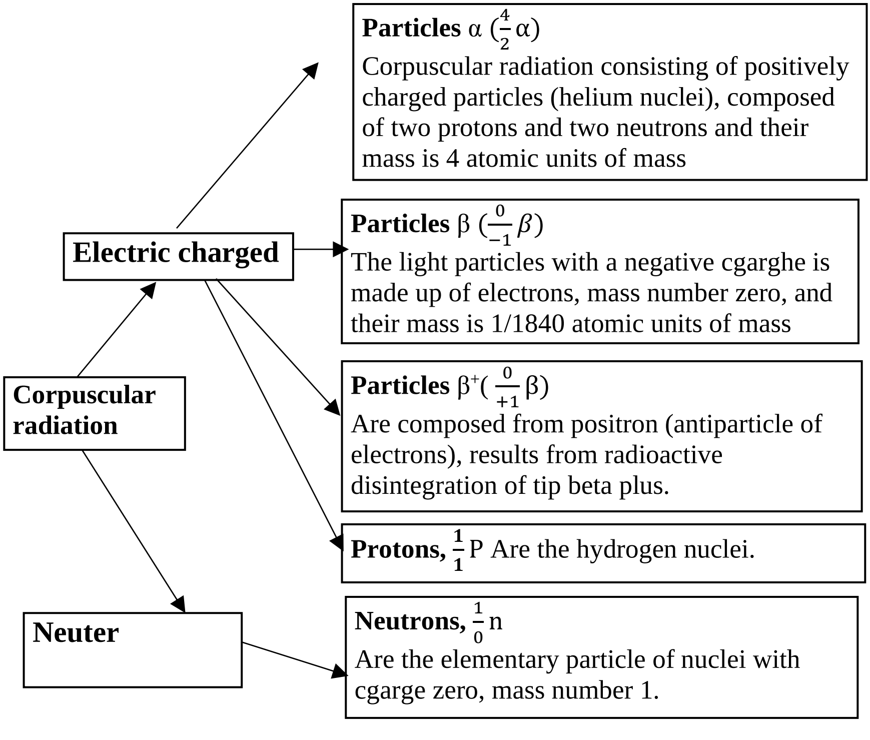
Picture 1. **Electromagnetic spectrum.**

<u>By their nature, radiation falls into two categories:</u>

- *electromagnetic radiation*: radio, TV, radar, microwave, infrared, light, ultraviolet, X-ray, gamma, cosmic waves. Electromagnetic radiation is emitted and absorbed in nature in the form of quanta (photons). Photons are particles without rest mass, each carrying an amount of energy that can be calculated with the expression E = hn, where h = Planck's constant (6,625.10–34 Js), and n = radiation frequency. Their mass of motion, m, is related to energy by Einstein's formula: E = mc2, c being the speed of light in a vacuum. Currently, their energy is expressed in electron-Volts: 1eV = 1,6.10–19 J.

The spectrum of electromagnetic radiation is extremely wide. Depending on their wavelengths in vacuum (l = c / n), it can be represented as in *Picture 1*.

- *corpuscular radiation*: electrons, protons, neutrons, alpha, beta. Corpuscular radiation is composed of particles of substance with a certain kinetic energy. They can be subdivided according to the load and mass of the energy-carrying particles, according to the diagram below *(Picture 2)*.



Picture 2. **Classification of corpuscular radiation.**

Depending on the energy transported, the radiation can be:

- non-ionizing radiation: radio, TV, radar, microwave, infrared, bright, ultraviolet waves;
- ionizing radiation: particles or electromagnetic waves with a maximum wavelength of 100 nanometers (a frequency of at least 3 × 1015 Hertz) capable of producing ions, directly or indirectly - X-rays, gamma, cosmic radiation.

1.2. The source of ionizing radiation, natural and artificial sources of radiation.

Ionizing radiation occurs when there is a source of radiation. Ionizing radiation sources are grouped into two broad categories:

- ***natural sources*** - radioactive materials exist naturally in the environment;
- ***artificial sources*** - artificially produced radioactive materials or radiation generators - devices capable of generating ionizing radiation, such as X-rays, neutrons, electrons or other charged particles.

Natural sources.

Most radiation originates in the natural environment and is the natural background for radiation. Thus, man is permanently exposed to the following natural ionizing radiation:

- ***cosmic radiation*** - high energy particles (heavy nuclei, alpha particles, protons and electrons) and gamma radiation from outer space, which bombard the Earth continuously. The amount (or dose) of cosmic radiation received is influenced by the altitude, atmospheric conditions and magnetic field of the Earth;
- ***terrestrial radiation*** - is due to radioactive substances (uranium, thorium and potassium), which exist in rocks and soil. The dose of radiation from terrestrial sources varies greatly on the surface of the globe due to the inhomogeneous

distribution of natural radioactive elements in the earth's crust undisturbed;

- r***adon*** - radioactive element in gaseous state, existing in the environment, which has a major contribution to the natural terrestrial radiation background;
- ***natural radiation inside the body*** **-** radionuclides that reach the body through inhalation (radon), ingestion (potassium-40) or through the skin.

It is important to note that man himself creates additional natural radioactivity through socio-economic activity - mining, construction materials.

Artificial sources

Exposure to radiation from artificial sources is the result of:

- medical exposure - includes exposure of people undergoing diagnostic examinations, interventional procedures and radiation therapy. The use of radiation in medicine is the most important artificial source of radiation exposure of the population;
- exposure to other sources created by human activity such as testing nuclear weapons in the atmosphere, producing electricity, industrial use of radiation, transportation and storage of nuclear materials, etc.

The average annual effective dose due to the natural background of radiation is about 2.4 mSv per year (global average) and it represents about 80% of the total average effective dose received by man. The difference comes from artificial sources of ionizing radiation.

1.3. Types of ionizing radiation and their penetrating power

Different sources emit different types of ionizing radiation:

• ***Alpha (α) radiation***, in fact the helium atom, interacts with many atoms over a very short distance. They give rise to ions and consume all their energy over that short distance. Most alpha particles will consume all their energy when passing through a simple sheet of paper. The main effect on health associated with alpha particles occurs when alpha-emitting materials are ingested or inhaled, and the energy of alpha particles affects internal tissues, such as the lungs.

Alpha (α) radiation - corpuscular radiation consisting of positively charged particles (helium nuclei), composed of two protons and two neutrons, emitted by natural isotopes (such as uranium, thorium and radium) and artificial (such as cesium, plutonium and americium). It has the following features:

• are not penetrating, can only penetrate the outer layer of the skin (epidermis),

• the distance in the air is 3-4 cm,

• can be shielded by a sheet of paper, • presents a severe risk on internal irradiation (by the penetration of alpha-emitting radionuclides into the body).

• ***Beta (β) radiation*** is made up of electrons - light particles with a negative charge. They travel a little further in the air and can pass through the paper, but cannot penetrate the skin through the human body. The effects on health associated with beta particles are mainly manifested when beta-emitting materials are ingested or inhaled.

Beta (β) radiation - electron or positron beams with the following properties:

• the penetration power is higher than the alpha particles, having the ability to penetrate the skin,

• can be shielded by plastic, thin aluminium foil

• presents a medium risk on internal and external irradiation.

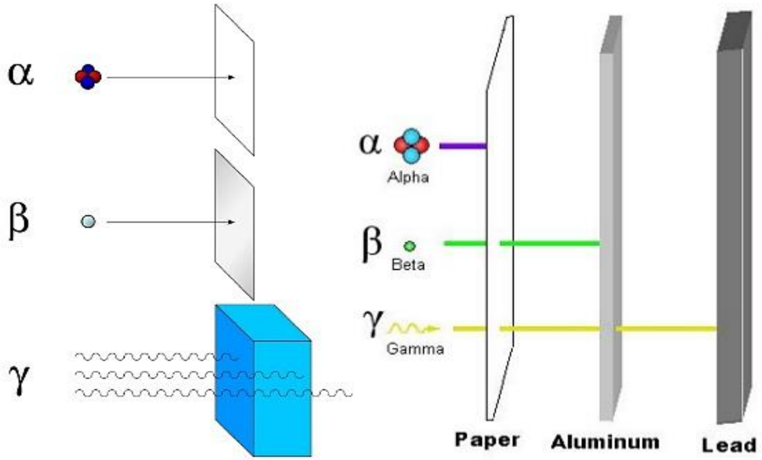
• ***Gamma radiation (γ)*** is in the form of electromagnetic waves or photons emitted from the nucleus of an atom. They can completely penetrate the human body, and can only be stopped by a concrete wall or a 15 cm thick lead plate. Gamma radiation is stopped by: water, concrete, and especially dense materials, such as lead, used as protection against exposure to this type of radiation. The effects on health associated with gamma particles are manifested mainly when gamma-emitting materials are outside the human body (*Picture 3*).

Gamma (γ) radiation is high-energy electromagnetic radiation or photons emitted from the nucleus of an atom.

• are penetrating, have the ability to cross the body completely,

• can be shielded by materials with high Z (Pb),

• presents a significant radiological risk on internal and external irradiation.



Picture 3. **Penetration of matter at α, β, γ radiation.**

Application in medicine

Because they are ionizing radiation, gamma rays can kill living cells. Thus, they are used to treat malignant tumours with radiotherapy. For deep treatment in the body, high-energy photons are sent to reach only the target tumorous, without severely affecting the surrounding tissue. Although X-rays are also ionizing radiation, due to their lower energy compared to gamma rays, they may not reach deep enough in the body and may cause damage to the surrounding tissues that have absorbed them. They can also be used to make incisions in surgery.

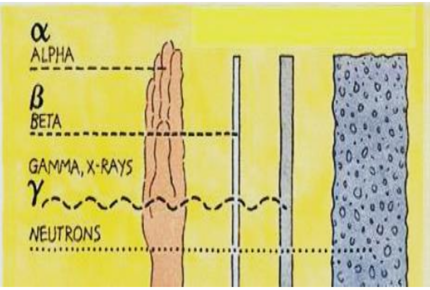
• ***X-rays*** are low energy gamma radiation. In the case of the human body, they can penetrate the muscle tissues, but they cannot penetrate the bones, hence their usefulness in medicine (radio-graphs).

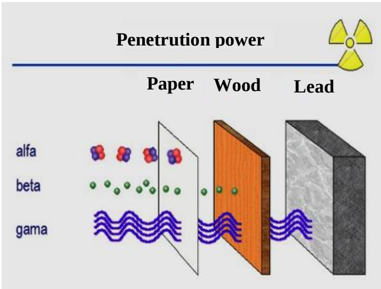
X-rays are ionizing electromagnetic radiation located in the spectral range between gamma and ultraviolet radiation. The difference between gamma radiation and X-rays is where they come from. Specifically, X-rays are produced outside the nucleus (at the level of the electron shell), and gamma radiation is produced inside the nucleus. X-rays, which generally have lower energies, have a lower tissue penetration capacity compared to gamma radiation (*Picture 4*).

Neutrons are non-charged nuclear particles that:

• they are very penetrating, they can cover long distances in the air, very thick materials with hydrogen content (concrete, water or paraffin) are needed for shielding;

• present a high radiological risk on the body.





***Picture 4.* Power of penetration of ionizing radiation depending on the material.**

1.4. Interaction of ionizing radiation with the substance.

When radiation passes through a substance, energy is released to the atoms with which it interacts.

The main process of interaction of ionizing radiation with the substance is the **ionization** of the atom, ie the removal of an electron from the atom. The electron-free atom becomes positively charged electrically, that is, positively ion. The electron snatched from the atom, which takes over the energy given off by the radiation, can in turn ionize other atoms or molecules.

There are cases in which when the interaction of radiation with the atom, the electron is not taken out of the atom but, taking over an amount of energy, passes to a higher energy level. This process is called atomic excitation. By de-excitation, the atom emits the excess energy in the form of radiation and returns to the steady state.

The energy required to excite an atom is less than the energy required to ionize it (W excitation <W ionization).

The ionization of the substance is:

- **direct** in case of electrically charged particles (alpha, beta radiation)

- **indirect** in the case of gamma radiation, X-rays and neutrons.

The interaction of ionizing radiation with the substance it passes through is of interest from two points of view:

- detection of ionizing radiation;

- the biological effects they produce.

1.5. Detection of ionizing radiation.

Ionizing radiation cannot be perceived by the human senses, but can be detected with the help of ionizing radiation detectors, devices used to obtain information about the intensity of radiation in a certain place in space at a given time. They are connected to measuring devices (electronic counter, ammeter, voltmeter) and thus quantitative measurements can be made.

The detection of ionizing radiation is based on the following phenomena produced by their interaction with the substance:

• electrical (ionization of the media traversed);

• optical (scintillation, luminescence);

• chemical (influencing the kinetics of the reactions, their radio catalysis);

• photochemical (impression of photographic emulsions).

1.6. Types of radiation detectors

• *ionization chambers, proportional meters and Geiger-Mueller meters* - the operation of which is based on the measurement of the electrical charge resulting from the ionization of a gas;

• *semiconductor detectors* - are also based on the ionization phenomenon that takes place, however, inside a semiconductor;

• *scintillation detectors* - are based on the emission of light radiation following the interaction of ionizing radiation with a substance that can be in solid form (sodium iodide crystal) or liquid (organic solvents in which scintillating substances are added);

• *photographic films* - use the chemical effect of blackening the photographic film as a result of the ionization of silver halide microcrystals in the film emulsion; the amount of blackening produced by the resulting metallic silver is proportional to the amount of radiation received by the emulsion;

• *thermo luminescent detectors* (TLD) - use the thermo luminescent properties of solid crystals through which the energy absorbed by them after irradiation is released in the form of light when heated above a certain temperature;

• *chemical dosimeters* - use the chemical reactions of substances produced after irradiation.

1.7. Exposure to ionizing radiation.

- ***The external exposure*** of the body is due to a source of radiation from outside it.
- ***Internal exposure*** is caused by a source of radiation inside the body that has penetrated by inhalation, ingestion, injection or due to absorption through the skin.

Both types of exposures can be produced by closed or open radiation sources. Only in the case of open radiation sources can we talk about contamination.

Contamination of the human body is caused by:

- ***external contamination*** which consists in accidental deposition on the skin, on the clothes of the radionuclides fixed or absorbed in the dust particles from the human environment;
- ***internal contamination*** is achieved by accidental penetration of radionuclides by:

• ***inhalation of contaminated aerosols*** that occur after tests or nuclear accidents;

• ***digestive ingestion*** consisting of consumption of food and water contaminated by various radioactive deposits in the environment or transfer through the food chain;

• ***skin absorption***; much less important in the case of intact skin and more significant in the case of skin lesions.

Radionuclides entering the human body are detected by:

• blood, urine (Iodine 131, Cs 134 and Cs 137),

• feces (Sr 90),

• bone tissue.

Radionuclides in the blood pass into the tissues, and the rest is eliminated through feces, urine and even sweat. Depending on the metabolism of the tissues in which they attach, radionuclides can be eliminated, recirculated in the blood and fixed again in the tissues depending on their tropism.

Examples: Strontium 90 attaches to the bones and is very difficult to remove; Cs-137 is fixed in soft organs, muscles, is metabolized strongly, eliminating quite easily; I-131 mainly attaches to the thyroid and can cause serious effects such as thyroid cancer over time. It is known that radioactive iodine was the major component released in the Chernobyl accident in April 1986, which accumulated in the body of the population, especially children living in heavily contaminated areas and led to the development of a large number of thyroid cancers in children (Table 1).

Table 1.

Accumulation of radionuclides in target organs.

Radionuclides	**Target organ, affected tissue**
I-131	Thyroid
Sr-90	Hematopoietic marrow, bones
Cs-137	Muscles, soft organs
H-3 (tritium)	Body fluids
C-14	Fatty tissues

II. NON-IONIZING RADIATION.

2.1. Definitions of non-ionizing radiation:

• ***non-ionizing radiation*** - static, electrical and magnetic and time-varying magnetic fields, magnetic, as well as electromagnetic, as well as radiation from artificial sources with frequencies from 0 Hz to $1{,}7\times10^{15}$ Hz;

• ***optical radiation*** **-** radiation from artificial sources in the frequency range from $3\cdot10^{11}$ Hz la $1{,}7\cdot10^{15}$ Hz corresponding to wavelengths from 180 nm to 1 mm;

• ***coherent radiation*** **-** optical radiation created by stimulated emission with a clearly defined phase and frequency; the radiation emitted by a laser is consistent; incoherent radiation is optical radiation that occurs through spontaneous radiation emission;

• ***laser*** **-** any device that can be modified to create or amplify electromagnetic radiation in the wavelength range of optical radiation through a controlled stimulated emission process;

• ***maximum permissible values of non-ionizing radiation*** **-** limit values based directly on proven health effects and information on their biological effects; if they are not exceeded, it is guaranteed that the employee or another person exposed to non-ionizing radiation is protected from all known biophysical and indirect effects of an electromagnetic field;

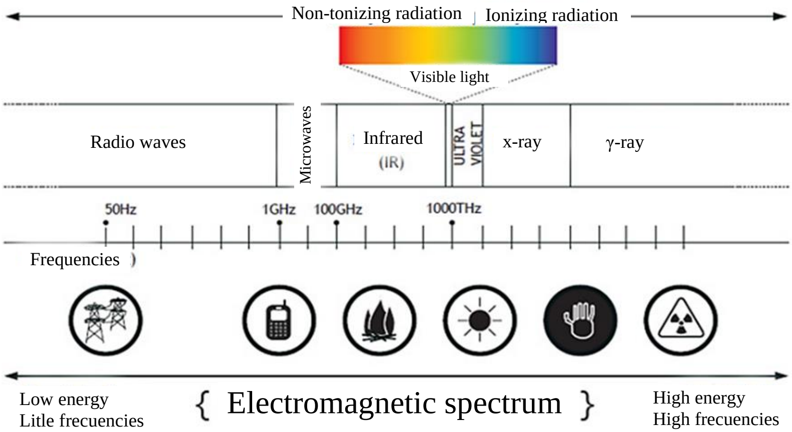
• ***reference values*** **-** size values of non-ionizing radiation parameters measured directly in the frequency range from 0 Hz to $3\cdot10^{11}$ Hz, which are the electric field strength, magnetic induction, radiation flux density and contact current, which are used to make it easier to prove that the maximum allowed values have not been exceeded.

• ***maximum permissible values of non-ionizing radiation*** (hereinafter referred to as „maximum permissible values" in the frequency range 0 Hz to $1{,}7.10^{15}$ Hz for employees and individuals in a common environment (hereinafter referred to as „other person"), in which the exposure assessment, the minimum size of the health protection information and the minimum size of the employees' health protection measures must be verified.

2.2. The effects of non-ionizing radiation.

The radiation we call non-ionizing is electromagnetic radiation with a wavelength in the range of 150 nm and centimeter waves.

Non-ionizing radiation occupies the first part of the electromagnetic spectrum (*Picture 5*).



***Picture 5.* Electromagnetic spectrum of non-ionizing radiation.**

The electromagnetic spectrum of non-ionizing radiation includes:

- static electric and magnetic fields (0 hertz);
- time and time varying electric and magnetic fields (up to 100 kHz, low frequency fields);
- electromagnetic fields (radio frequency, 100 kilohertz - 300 GHz);
- infrared radiation (300 GHz - 400 terahertz or depending on the wavelength, between 1 mm - 750 nm;
- visible (bright) radiation between 790 - 400 terahertz or between 380 nm - 760 nm);
- ultraviolet radiation (400 nm - 100 nm).

The ultraviolet spectrum is divided into 3 spectral bands:

- ultraviolet C (100-280 nm),
- ultraviolet B (280-315 nm)
- ultraviolet A (315-400 nm).

Ultraviolet radiation, with higher frequencies, is followed by very high energy radiation - ionizing radiation. Specific for non-ionizing radiation is the fact that they do not have enough energy to break the bonds between molecules or break an electron in the atom by interacting with living matter.

Electromagnetic radiation is a form of space propagation of the energy of an electric field E and a magnetic field B, whose vectors oscillate with the same period T, or frequency n, in a plane perpendicular to each other and which are perpendicular to the direction of propagation of wave with speed „v".

Any electromagnetic radiation can be considered simultaneously both the wave and the corpuscle (photon). Depending on the frequency of the waves, there is mainly one or the other aspect. At low frequencies (radio waves, TV, microwave) the undulating character predominates, and for high frequency radiation (infrared, visible, ultraviolet) the corpuscular character begins to manifest itself.

To explain the interaction of electromagnetic radiation with the substance (photoelectric effect, photochemical reactions, scattering), it is necessary to consider the corpuscular character (photon flux), the main physical phenomenon resulting from this interaction being energy absorption.

From the category of non-ionizing radiation, we will examine:

- ultraviolet radiation with l between 150-400 nm,
- visible radiation with l between 400-800 nm,
- infrared radiation with l between 800-106 nm,
- microwaves with l between 106-109 nm.

The absorption of electromagnetic radiation by atoms causes transitions of electrons, from basic energy levels to higher levels, thus moving from the ground state to the excited state. If the amount of energy absorbed (the amount carried during an oscillation period) is greater than the binding energy of the electron in the atom, the electron will be ripped off, the atom becoming a positive ion 646e46g. The energy values of UV, visible, IR and microwave radiation are lower than the energy required to atomize the atoms (ionization energy is 13.34 eV for hydrogen, 13.57 eV for oxygen, 11.24 eV for carbon, 14.51 eV for nitrogen, while the energy of UV radiation is between 12.4-3.1 eV, visible radiation between 3.1-1.65 eV, IR radiation between 1.65-1.2 · 10-3eV, and for microwaves between 10-3-10-5eV.

In the case of molecules made up of at least two atoms, we must keep in mind that the energy levels of a molecule are not given (as in the case of atoms) only by the values of the energy of electrons (Eel), but also by the energy of vibration (Evibr) and energy. (Erot) of the atoms in the molecule.

Evibr and Erot values are also quantified, as is Eel, and between these levels much more transitions are possible than in the case of electronic levels. Transitions between electronic levels are made by absorbing or emitting amounts of energy corresponding to UV and visible radiation; vibro-rotational transitions correspond to the IR range and pure rotational transitions correspond to either the remote IR range or microwaves. DEel is of the order of 1eV, DEvibr is of the order of 10-1eV, and DErot is of the order of 10-2eV. Overall, for a molecule like the one described:

$$\Delta E = \Delta E_{el} + \Delta E_{vibr} + \Delta E_{rot}$$

It is known that in an atom (or molecule) there can be two electrons that simultaneously occupy the same energy level (to be in the same orbital), provided that they have the opposite spin (spin means the kinetic moment of the electron due to rotation of its own axis. The electronic spin can have only two equal values in the mode, but opposite as a sign).

When an electron absorbs a certain amount of electromagnetic energy, it goes to a higher energy level (it is excited) and does not normally change its spin state. That excited state is called a **singlet** in this case. Although with a much lower probability, it is still possible that with the excitation, the electron reverses its spin, the condition being called a **triplet**.

The lifetime of excited states is generally very short (10-9 ÷ 10-8s), due to the spontaneous tendency of the electron to return to the ground state. Because the transition from the triplet state to the ground state again means a spin reversal, the lifetime of the triplet state is longer (between 10-5 and a few seconds) than that of the singlet state. During this longer time, the excited molecule may transmit excess energy to another molecule (by collisions) and emit it in the form of electromagnetic radiation.

The excitation of the molecule can therefore be done by non-radiative transitions and, respectively, **radiative transitions** (fluorescence, phosphorescence):

Ultraviolet and visible radiation

Electromagnetic radiation between 150 and 800 nm is radiation that activates molecules. The absorbed radiation has enough energy to determine the transformation of molecules based on photochemical reactions. The main types of photochemical reactions are:

• Excitation of molecules. M ---------------> M *

• Photochemical reactions M * + A ---------> D

• Dimerization reactions M * + M --------> MM

• Photosensitization reactions. M * + N --------> M + N *

The first relationship shows the excitation of the initial molecule, the third and fourth relationship are particular cases of photochemical reactions.

The photochemical efficiency is defined as the ratio between the number of molecules transformed and the number of energy quanta absorbed.

The efficiency is subunit, the absorbed radiation does not necessarily lead to a photochemical reaction (photon absorption is only the primary stage, followed by a succession of other secondary stages, leading to the photochemical transformation itself).

Photo biological processes

Although **the photo biological processes** are very diverse and still incompletely elucidated, for some of them the following stages can be distinguished:

• **photo-allergic effects.**

2.3. Determining the exposure of employees and others to non-ionizing radiation.

• Exposure to non-ionizing radiation is determined by calculating or measuring the modified intensity of an induced electric field in the body of the exposed person, the absorbed output measured in the body of the exposed person, the radiation flux and spectral radiation density, electric field strength, induction magnetic field, radiated flux density or contact current.

• If the reference values are not exceeded, this ensures that the maximum permissible values of non-ionizing radiation have not been exceeded. If the comparison of the calculated or measured values of the relevant quantity indicates that the reference values are exceeded, it must be proved by calculation or measurement that the maximum permissible values will not be exceeded.

• By comparing the exposure of an employee or other person with maximum allowable values or reference values, the uncertainty caused by calculation errors, approximations of the theoretical model, or measurement errors of the instrument used and the measurement conditions are included as follows:

• if the average relative calculation or measurement error of the relevant quantity is less than 1 dB or 12,5 % for field strengths and 25 % for energy quantities, the maximum allowable value or reference value shall be deemed not to have been exceeded if the calculated or measured value is equal to or less than the maximum permitted value or the reference value;

• if the average relative error of the determined quantity is greater than 1 dB, the maximum permissible value or reference value shall be deemed not to have been exceeded if the calculated or measured value of the relevant quantity is less than the maximum permissible value or reduced reference by the sum of the decibels by which the average relative error exceeds 1 dB The maximum allowed values and the reference values are provided in the normative acts in force.

2.4. Determining the exposure of an employee and another person to non-ionizing radiation.

In assessing the exposure of an employee and another person to non-ionizing radiation in the frequency range 0 Hz to $1{,}7\times10^{15}$Hz, in addition to the maximum permissible values of non-ionizing radiation and reference values, the following shall be taken into account:

• direct biophysical effects;

• radiation intensity, frequency spectrum, duration and type of exposure;

• exposure to fields and radiation with different frequencies and exposure to multiple sources of non-ionizing radiation;

• information provided by the manufacturer of non-ionizing radiation equipment, including laser classification;

• indirect biophysical effects such as:

• interference with electronic devices and equipment, pacemakers and other electronic medical instruments;

• risks related to the elimination of ferromagnetic objects by a static magnetic field with magnetic induction greater than 3 mT;

• danger of ignition of electrically controlled detonators;

• fire and explosions caused by ignition of flammable materials by optical equipment, sparks caused by contact currents or overvoltage;

• the risks related to the interactions between the optical equipment and the chemicals with photosensitization effects or the risks related to the temporary blinding caused by the optical equipment;

• all effects on the health and safety of specifically endangered employees, in particular employees with implanted electronic medical devices and pregnant employees;

• information obtained by a healthcare provider during the workplace during regular workplace supervision focusing on the establishment and assessment of risk factors.

2.5. Minimum scope of health protection measures for employees working with non - ionizing radiation.

If the exposure assessment indicates that an employee is or may be exposed to non-ionizing radiation in excess of the maximum permitted values, in particular the following measures must be taken to protect his / her health:

• a working procedure is specified that reduces the risk of exposure to electromagnetic fields;

• ensures that the workplace is organized to limit employees' exposure to the electromagnetic field.

2.6. Minimum scope of information provided to an employee for occupational health protection.

Before commencing exposure to non-ionizing radiation in the 0 Hz to $1{,}7\times10^{15}$ Hz frequency range, the employer must provide the employee with information on:

• the maximum allowed values of non-ionizing radiation, the way in which they can be determined and the possible risks resulting from exceeding them;

• direct and indirect effects on health;

• how to recognize and report harmful effects;

• working procedures adopted;

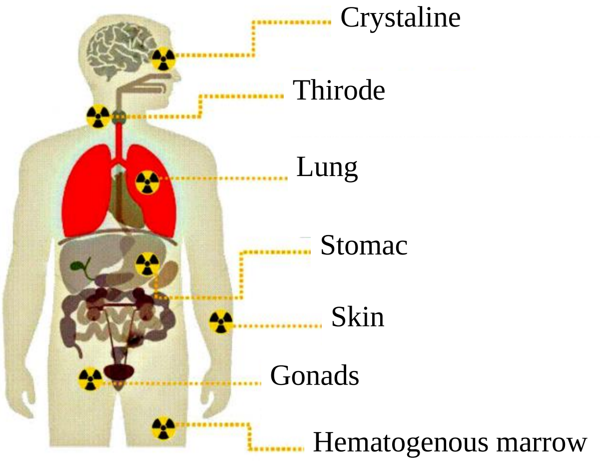
• occupational health protection measures adopted and

• correct use of personal protective equipment at work.

III. IONIZING AND NON-IONIZING RADIATION EFFECTS ON HEALTH.

3.1. Ionizing radiation effects on health.

We are „bombarded” with radiation from the air, earth, water, vegetation, food, but what effects do they have on our body (*Picture 6*).



Picture 6. **Effects of ionizing radiation**

3.2. Mechanisms of production of biological effects.

When directly ionizing radiation is absorbed into a biological material, the effects on the cells can occur through two mechanisms of action:

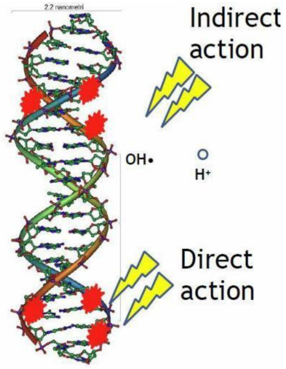
- **direct action** - radiation interacts directly with one of the critical components of the cell leading to direct microlesions of the cell structure;
- **indirect action** - is due to the irradiation of free radicals and

ions with high chemical reactivity occurring in the interaction of radiation with water in the body;

- **remote action** - leads to the appearance of effects on non-irradiated cells.

The main target of ionizing radiation is **DNA**. As a result of **cellular DNA** damage, cell death, mutagenesis, and malignant transformation occur (*Picture 7*).

At low doses of radiation, specific to the natural background of radiation, man reacts within normal physiological limits or sometimes there is even a temporary stimulation of metabolism. High doses over the natural background lead to metabolic disorders followed by cell damage, and eventually the death of the cell, tissues and even the body as a whole. **Ionizing radiation is considered to be a classical genotoxic agent.**



Picture 7. **Mechanisms for inducing biological effects.**

- **Biological effects** (*Figure 8*).

Biological effects are classified as:

1. from a time perspective:

• **immediate (acute) -** appear shortly after exposure;

• **late (chronic) -** occur at intervals of months, years after exposure.

2. depending on the person affected:

• **somatic -** occur in individuals exposed to radiation,

• **genetic** - occur in the offspring of exposed individuals.

3. by degree of damage:

• **lethal** - are irreversible, lead to cell death,

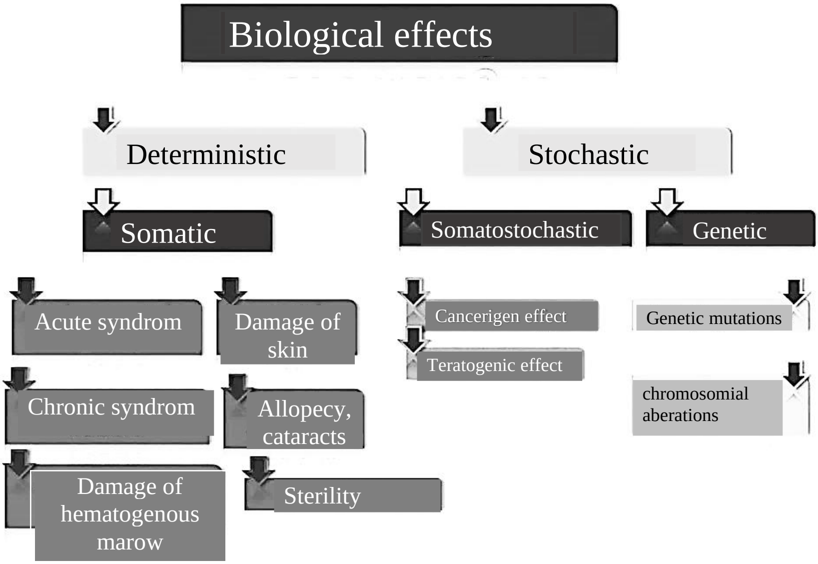
• **sublethal** - can be repaired,

• **life-threatening** - can be repaired if the cell is not in a state of division.

4. from the point of view of radiobiology:

• **stochastic**,

• **deterministic (not stochastic).**



Picture 8. **Classification of biological effects.**

3.3. Deterministic effects

They appear after altering over 99,9 % of the cells that make up the tissues of the human body. Deterministic effects were common especially in the early stages of radiation use, mainly anemia and skin lesions. After the introduction of precautionary measures, they became rarer, appearing today only in accidental cases. They have an appearance threshold (no effects appear below this threshold). The severity of the effects and the frequency increase with the dose received by the population composed of individuals with varying susceptibility, depending on the affected tissue. The most sensitive tissues to the action of nuclear radiation are the ovarian tissue, the testicular tissue, the bone marrow and the eye (*Table 2*).

Table 2.

Radiosensitivity classification

Large	**Medium**	**Small**
Crystalline	Skin, organs with mesoderm ((liver, heart, lung, other parenchymal organs)	Muscles Bones Nervous system
Gonads		
Hematogenous marrow		
Spleen		
Thymus		
Lymph nodes		

These effects are classified into:

- Acute irradiation syndrome, which occurs at intervals of hours to months, with local and general manifestations in the hematopoietic marrow, skin, lens, gastrointestinal system;
- Chronic irradiation syndrome - occurs at intervals of months to years due to damage to blood vessels, permanent cellular alteration and / or development of fibrosis.

Acute irradiation syndrome

Occurs in exposures at single or repeated high doses at short intervals and differs after irradiation of the body segment. Thus, when irradiating the whole body with a dose of 0.25 Gy, reversible hematological changes appear - lesions of the lymphoid and myeloid series (leukopenia). From 1 Gy there are signs of acute irradiation disease, from 2 Gy deaths from irreversible hematological lesions and from over 5 Gy a 100 % probability of death. At over 10 Gy there is nervous breakdown with intense agitation followed by deep coma.

Acute radiation sickness of the whole body occurs exceptionally in cases of accidental exposure. At first there are nervous phenomena - adynamism, loss of appetite, altered condition and then a short period of remission, depending on the dose received, followed by the period of condition characterized ***by the following 3 syndromes:***

- Hematological syndrome 1 Gy> Dose <10 Gy,
- Gastrointestinal Syndrome 10 Gy> Dose <100 Gy,
- Neuro-vascular syndrome Dose> 100 Gy.

1. Hematological syndrome dominated by permanent destruction of the blood system (myeloid, lymphoid). As a result, leukopenia, anemia, thrombocytopenia, and severe bleeding occur frequently. After exposure, the number of **lymphocytes decreases** during **the first hours**, and **platelets and granulocytes decrease** in the **first days or weeks**, while **erythrocytes** begin to decrease slowly only **after a few weeks**. Destruction of other tissues that play a role in the body's immunity, such as the thymus, often leads to bleeding and severe impairment of general immunity.

2. Gastrointestinal syndrome whose manifestations appear a few hours after exposure: nausea, severe vomiting and watery diarrhea with abdominal cramps. The irradiated person does not show symptoms for a few hours or days, then there is a marked asthenia, fatigue, severe dehydration. Later, the period of intense clinical manifestation with vomiting with fever, bloody diarrhea with very marked dehydration with shock and death is installed, if the medical intervention is not very efficient and urgent.

3. **Neuro-vascular syndrome** having the major cause of damage to vascular endothelial cells. At first a few minutes after exposure, there is a burning sensation, nausea, vomiting and confusion, prostration. There is an apparent improvement in the general condition for a few hours, the irradiated person becomes lucid, painless, but is asthenic, and then quickly develops watery diarrhea, respiratory disorders, signs of CNS damage and hypotension with accelerated pulse, shock with total collapse. Death occurs through massive hemorrhages often accompanied by sepsis due to its own intestinal flora.

High-dose irradiation of body segments (much higher doses than in the case of acute radiation of the body as a whole) occurs due to mishandling of radiation sources and skin lesions (acute radiodermatitis), alopecia, eye damage, sterility.

1. The skin is one of the largest organs in our body and is the most important **physical barrier to protection** against environmental risk factors, it controls the loss of lichens and electrolytes and protects against infections.

The cells most sensitive to the action of ionizing radiation are the cells in the basal layer of the epidermis. Skin lesions related to radiation dose in acute radiodermatitis are: erythema and epilation above 3 Gy; desquamation, ulceration and necrosis at doses greater than 15-25 Gy (*Picture 9*).

Picture 9. **Skin lesions related to radiation dose.**

2. Crystalline lens has **increased radiosensitivity**, protein coagulation at this level occurs at doses higher than 0.5 Gy (ICRP 2012). There are no cell recovery mechanisms.

Affected cells migrate to the posterior pole producing in the first stage various opaque bodies that decrease the normal functionality of the eye, and in time cataracts appear (*Picture 10*).

Picture 10. **Normal eye and cataract eye.**

3. The germ cells of the human reproductive system are highly radiosensitive. Temporary sterility lasting several weeks occurs at a threshold dose of 0.15 Gy for men and approximately 5 times higher for women. The recovery period is dose dependent and lasts for several years. Permanent sterility is caused by a minimum dose of 3.5 Gy for men and 2.5 Gy for women, respectively.

3.4. Stochastic effects.

They appear after damage to one or more cells that make up the tissues / organs of the human body. The severity of the effect is dose independent, occurring at very low doses.

The frequency of occurrence of the effect increases with dose, without evidence of a dose threshold. It is due to cellular changes in DNA and malignant cell proliferation. It is classified into:

- **Genetic effects -** genetic mutations, chromosomal aberrations,
- **Somato stochastic effects -** radio induced cancer, teratogenic effects,
- **Teratogenic effects**.

They appear after irradiation in the uterus of the embryo / fetus. The maximum period of vulnerability is between the 8th and 90th day after fertilization. High doses of external irradiation can lead to minor / severe malformations up to embryo death and miscarriage.

After 90 days, the vulnerability decreases, leaving the risk of nerve damage (oligophrenia, poor neuropsychiatric development). The effects on brain development were observed in Hiroshima and Nagasaki children's survivors, with mental retardation, low intelligence, and learning difficulties. Deterministic effects are more severe in children due to increased sensitivity of tissues to ionizing radiation. Thus, their brain suffers a cortical atrophy at a single dose of 10 Gy; at a dose above 1Gy there is a severe mental retardation of 75 %. External or internal irradiation of the uterus can also lead to an increased frequency of childhood leukemias after the age of 7 and other solid tumors.

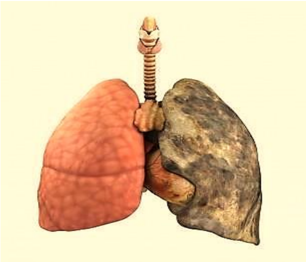
3.4.1. Radio induced cancers

The worst latent effect of irradiation is cancer, especially cancer with fatal consequences. The fundamental processes by which radiation induces cancer are not fully understood, but an increased incidence of various malignancies, in short, cancer, has been observed in groups of people who have been exposed to various strong doses of radiation. Not all people exposed to this type get cancer because cancer has many causes. However, each person exposed has an additional chance of contracting it and this probability depends a lot on the dose received. If the number of people in an irradiated group is known and the doses they have received, and if the number of cancers actually observed in the group is greater than the number expected in similar non-irradiated groups, then the excess number of cancers may be assigned to the radiation and thus the risk of cancer can be calculated per effective dose unit. This is called a risk factor.

Example: Calculation of risk factors. If each of a group of 50,000 people received a dose of 2 Sv for a particular organ and if they had 100 more cancers in that organ than in a similar unexposed group, the risk factor would be 100 / (50000 x 2), which is 1 in 1000 per Sv or 10-3 in Sv at 10-1 in scientific notation.

Cancer of any etiology is defined as a pathological alteration of the systems of control and regulation of cell division, a permanent and anarchic multiplication of cells. Ionizing radiation can be carcinogenic and strongly immunosuppressive, can activate endogenous latent viruses, and even disrupt the endocrine balance. Radiation-induced cancer does not necessarily occur in all people exposed to radiation, and not all of these cancers are fatal, so breast cancer mortality is below 50 %, compared to only 5 % for thyroid cancer. However, it is difficult to estimate the risk of radio induced cancer because the population is exposed for life to ionizing radiation at or near natural background.

Radio induced cancer has been described for the first time in radiologists, namely skin cancer in the hands with a higher frequency than in other doctors; lung cancer in uranium miners; bone cancer in workers working with luminescent dials. The relationship between the increased frequency of leukemias in Hiroshima and Nagasaki atomic bomb survivors was later described; increase in cases of thyroid cancer (epithelioma) in adults irradiated in childhood in the neck region. Studies on the late effects of a nuclear explosion consider cancer to be a major effect that can be detected 2-4 years after the accident, as in the case of leukemias, but also up to 35 years in the case of solid tumors. The term „risk factor" is used to evaluate fatal radio induced cancer, ie the factor of proportionality between the occurrence of malignancies and the absorbed dose. It is estimated that 0.5 Gy irradiation of the body may result in a significant excess of the overall incidence of cancer. Life Span Study shows how many cancers for which a significant excess of risk has been determined are multiple, first leukemia, thyroid cancer, lung cancer, skin cancer, then even breast cancer, bladder cancer, urinary tract, colon, liver, stomach, esophagus, ovary, multiple myeloma. Mainly, thyroid and skin cancer are two locations with a significantly increased incidence among the population exposed to ionizing radiation (*Picture 11*).



***Picture 11*. Lung cancer.**

3.5. Teratogenic effects.

Particular attention should be paid to the risk of irradiation of the baby in the womb. If an embryo is exposed to radiation, growth defects can be induced, such as a reduction in the diameter of the head or mental retardation, if the exposure occurs during the formation of organs.

There will be an increased risk of developing malignancies during childhood: the risk factor is uncertain, but estimated at about 1 in 40 per

Sv, twice the total risk of cancer in the average person. These are the reasons why pregnant women are not allowed to do abdominal x-rays unless there is a clinical motivation to do so, and there are also special restrictions on the doses that fertile or pregnant women can receive when working in the abdomen. radiation medium. These effects occur after irradiation in the uterus of the embryo / fetus. The maximum period of vulnerability is between the 8th and 90th day after fertilization. High doses of external irradiation can lead to minor / severe malformations up to embryo death and miscarriage.

After 90 days, the vulnerability decreases, leaving the risk of nerve damage (oligophrenia, poor neuropsychiatric development). The effects on brain development were observed in Hiroshima and Nagasaki children's survivors, with mental retardation, low intelligence, and learning difficulties. Deterministic effects are more severe in children due to increased sensitivity of tissues to ionizing radiation. Thus, their brain suffers a cortical atrophy at a single dose of 10 Gy; at a dose above 1Gy there is a severe mental retardation of 75 %.

External or internal irradiation of the uterus can also lead to an increased frequency of childhood leukemias after the age of 7 and other solid tumors.

3.6. Genetic effects.

They are random, are the late clinical consequences, manifested in the first and subsequent generations reaching the balance in the 20th generation.

- **Chromosomal aberrations.** They occur by acting on gametes with damage to hereditary material, causing chromosomal alterations that consist of translocation, rupture, loss or addition to the normal chromosomal apparatus on which future cell growth depends. They can be of varying degrees, sometimes so large that it is impossible for the egg to form or the viability of the embryo to form.
- **Mutations**

There are changes in genetic information, which can be lethal, the viability of individuals carrying such genes is low and non-lethal, which produce a large number of genetic abnormalities in future generations. Experimental studies have shown that there is a linear relationship between dose and mutagenic effect, so no repair process is involved. In conclusion, any low dose received by the germ tissue produces mutagenic effects that can be added to previous and subsequent doses. These effects are related to the probability that a germ cell carrying the mutation will actually participate in fertilization.

In the first generation, the genetic effects produced by radiation are: reduced birth rate, congenital and hereditary malformations, and in the next generations the damage to the genetic background of the population, recessive malformations and decreased immunobiological capacity. The individual genetic risk is taken into account in the case of high doses, while at low doses the effect is estimated on the entire population, leading to changes in the genetic structure of the entire affected group.

To avoid the possibility of radiation-induced congenital anomalies, abortion should only be considered if the fetal dose has exceeded 0.1 Gy.

3.7. Immediate injuries.

If the whole body is exposed to a very high dose of radiation, death can occur in a few weeks: *an instantly absorbed dose of 5 Gy or more would probably be fatal*. If only a small part of the body is exposed for a short time to a very high dose, death may not occur, but other immediate effects may occur: *an instantly absorbed dose of 5 Gy, or more, received only by the skin will redden in about a week, and a similar dose received by the testicle or ovaries could cause sterility.* But if the same total dose is received in a much longer time, there may be no immediate signs of harm. However, defects may occur and may occur later in the case of the irradiated person, or perhaps in the case of the person's descendants.

3.8. Hereditary defects.

Another important effect of radiation is hereditary defects, the probability of which, but not the danger, depends on the dose. Defects occur by irradiating the gonads that produce sperm in men and eggs in women. Ionized radiation induces mutations, which are usually malignant, in these cells or in their precursors. The exact processes by which mutations occur are not known, but they involve chemical changes in DNA. The hereditary effects of these mutations range from the most serious, such as severe mental retardation, to trivial ones, such as skin blemishes (*Table 3*).

Table 3.

The main harmful effects of radiation.

Incidence conditions and sources of information			
Effect		***Circumstance***	***Information***
Immediate	Death	Doses and flow rates of very high doses on:	Human data from various sources.
	Erythema		
(Precocious)	Sterility	The largest part of the body	Risk data by limited extrapolation from the area of high doses or high dose rates.
Subsequent	Malignant disease		
		Skin surface	
		Testicles and ovaries	
	Hereditary defects	Any dose or dose flow	Different sensitivities of the organs.
	Non-malignant changes		
	Develop-ment changes	The probability depends on the dose	Human data compared to mouse data.
		It manifests itself over the years.	
		Any dose or dose flow	the case of humans
(Tardive)			Upper limit in body
		The probability depends on the dose	
		Manifested to descendants.	Data on people from different sources
		Very high dose.	
		Different periods of manifestation	Limited data on people
		Embryo irradiation	
		It manifests itself after birth	

Mutations also occur spontaneously in the human population, ie without any apparent cause, but radiation of natural origin can contribute to this. However, no direct evidence of hereditary defects in either natural or artificial radiation was found. Extensive studies of the survivors of the bombings in Hiroshima and Nagasaki, in particular, have failed to show a statistically significant increase in hereditary defects, but have given us a higher estimate of the risk factors for these defects.

Irradiation of the gonads is potentially harmful only if it occurs before or during the reproductive period of life. For those who will not have children, there is, by definition, no hereditary risk. The percentage of people in a group for whom gonadal irradiation is hereditary means depends on the age of the people and thus the number of children they are likely to have, but a value of 0.4 would be appropriate for the general population. Thus, the average risk of serious hereditary defects in the first two generations would be 1 to 250 per Sv.

3.9. Collective risk.

An important consequence of the assumption that we assumed a linear dose-risk relationship, without any threshold, is that the collective dose becomes an indicator of collective risk. In terms of community, it does not matter if in a community of 40,000 people each receives an equivalent effective dose of 2 mSv or if in a community of 20,000 people each receives 4 mSv: the collective dose in each community is 80 Sv-man and the collective price paid by each community can be a cancer death. However, in individual terms, members of the smaller community face a higher risk.

3.10. Records of personnel working with radiation

Due to the way in which they were obtained, the risk factors used in radiological protection can be considered as approximate. Therefore, it is essential that we use any circumstances to test the validity of current estimates. One way to do this is to study the incidence of fatal malignancies among people who, through their profession, are exposed to radiation under controlled conditions.

As it accumulates, this information is analyzed to find out what the differences are between mortality among those working with radiation and that of other groups, as well as between groups of workers with radiation, but with different cumulative doses. In particular, the record of excess cancer cases is kept and the limits within which the risk factors are included are estimated.

IV. RADIATION PROTECTION.

4.1. Providing medical assistance in accidents with radioactive contamination.

External contamination of the skin is assessed with a portable contaminometer / dosimeter or by wiping off the presumed contaminated site with cotton swabs or gauze soaked in medicinal alcohol with which the site is wiped and then measured at a dosimetric facility. If the measured values are well above those of the natural irradiation background, then the measured area is considered to be radioactively contaminated. Decontamination of the skin or minor wounds can be done by washing the area with soap and water, at body temperature, until the dosimetric control shows low values. These washes, but with water or saline, can also be done on the mouth, nose and possibly the eyes. The lower the amount of radionuclide at these inlet gates, the less radionuclide will enter the body. The assessment of internal contamination is done directly by measuring the body's radioactivity (whole body metering method) or excretion products (urine, feces), or indirectly by measuring the radioactivity of air, drinking water or food. The method of indirect assessment of human contamination involves continuous monitoring of environmental factors, water and food, which means the possibility of avoiding the contamination of many people after a nuclear accident. In internal contamination, the first aid consists in the administration of digestive decontaminants, especially when the radionuclides are in the gastrointestinal tract.

The main substances with decontaminating action are: gastric bandages such as aluminum phosphate, magnesium sulfate, aluminum hydroxide (antidotes to strontium, radium, iron, barium, etc.), ferric cyanide, also called Berlin blue (antidote to cesium). The decontaminating substances listed reduce intestinal absorption, fix radionuclides by adsorption, ion exchange or formation of insoluble metal compounds, the elimination of radionuclides is achieved through feces. The deposition of radionuclides in the organs of choice can be reduced by saturating the blood with stable radioactive isotope compounds, such as reducing thyroid fixation of radioactive iodine by administering stable iodine or consuming large amounts of water to reduce hydrogen 3 in the body.

It is recommended that antidotes be given in case of first aid, or in specialized clinics. The administration of these decontaminants (less stable iodine), along with the administration of some decontaminants against plutonium, as well as some drugs, is done only in specialized clinics under medical supervision, which involves the emergency transport of the contaminated person to the nearest specialized medical facility.

Providing first aid in case of radioactive contamination after a nuclear accident or in laboratories working with radioactive solutions requires the presence of medical kits with decontamination instructions, including antidotes of major radionuclides of great radiobiological importance to humans (iodine, cesium, strontium, etc.) see table 4.

Table 4.

Antidotes administered in case of first aid or in specialized clinics.

Radionuclide	**Antidote**	**Administration method**	
		skin	**inhalation, ingestion**
Hydrogen 3 (tritium)	-	consume 3-4 liters of water + furosemide	
Iodine 131	100-300 mg KI	drink one tablet of KI with water	
Strontium 90, 89	aluminum phosphate or hydroxide	-	about 10 g a day, three times with a mild laxative
	cationic decontaminant	wash contaminated skin or sores	-
Cesium 137, 134	ferric ferrocyanide, tablets of 1 g each	-	administered three times a day
	cationic decontaminant	wash contaminated skin or sores	-

Rare earths, plutonium, transplutonium	DTPA-Zn1) spray or solution	wash contaminated skin or sores	- DTPA-Zn is inhaled - slow intravenous perfusion 1 / day, several days
Uranium	Na bicarbonate solution 8.4 %	wash contaminated skin or sores	intravenous perfusion

4.2. Basic principles of the radiological protection system.

The approach to radiation protection is remarkably the same all over the world. This is largely due to the International Commission on Radiological Protection, an autonomous scientific organization that has been publishing, for over half a century, recommendations on protection against ionizing radiation.

We reproduce the central principles of radiological protection, as expressed by the International Commission on Radiological Protection:

• No procedure will be adopted if its introduction does not bring a net positive benefit.

• All exposures will be kept to a level that is as reasonable as possible, taking into account economic and social factors.

• The individual dose equivalent should not exceed the limits recommended by the Commission for those circumstances.

This radiation protection system is based on three main requirements. In each of these requirements there are social considerations, in the first two explicitly, in the last implicit; thus, there is considerable room for decision makers.

Other practical measures.

People can protect themselves from radiation by keeping their distance from the source, combined or not, with shielding from it so that the radiation level decreases as we move away from the source. We can protect ourselves by limiting the time spent near a source to the maximum. If radionuclides get into the body - for example by breathing contaminated air, or by consuming water and foods containing radionuclides - the dose cannot be reduced by any of these measures. Consequently, the main way to control this type of radiation exposure is to prevent ingestion or inhalation of radionuclides. Preventing the release of radionuclides into the air, water and food (these are the routes of penetration into the body, covers a wide range of measures, starting with the control and monitoring of „routine” emissions of radionuclides into the environment and of course to prevent accidents in the nuclear industry).

If radionuclides or the radiation source are in a well-defined place - for example in the ground or in a container - people can protect themselves by blocking radiation. This form of protection is called shielding, and the type and thickness of the shielding material depends on the type and intensity of the radiation. For very intense radiation, coming from a nuclear station, or from a container carrying spent nuclear fuel, the shielding may consist of a few meters of cement or tens of centimeters of steel or a few centimeters of lead.

4.3. International principles.

Due to the assumption that any dose of radiation generates certain risks and because there is always a certain level of background radiation in nature, it is not possible to eliminate all the risks associated with this radiation. In order to keep this risk as low as possible, while allowing the beneficial use of radiation and radioactive materials, a number of protection principles have been developed for those activities that lead to increased doses received by humans:

These activities should only be carried out if the positive effects outweigh the negative ones, ie if the benefits of these practices outweigh the risks.

The risks of radiation - from a certain activity - must not exceed the specified limits.

Even below these limits, radiation risks should be kept to the lowest possible level - ALARA (As Low As Reasonably Achievable), ie measures should be taken to minimize the risks, unless they are too expensive or difficult compared to the possible dose reduction.

4.4. Limit.

For those sources of radiation that can be controlled, there are limits to the doses that the population can receive. An individual must not receive more than 1 millisievert per year from all nuclear units and other radiation-generating activities. This does not include doses received by a person from natural sources of radiation or for medical purposes. A worker working with radiation must not receive more than 20 mSv per year from that activity. There are special restrictions on pregnant women who work with radiation to ensure the protection of the fetus.

It should be noted that these are upper limits, but it is not enough to limit ourselves to complying with these limits. Doses should be kept as low as possible within reasonable limits, which usually means that they are well below these limits. In fact, only a limited number of people living near the facility can receive doses close to the population limits, but for most people the doses at those facilities will be much lower. Most workers in the nuclear industry do not receive more than a few mSvs a year, and workers in other fields - such as airline personnel or medical personnel - receive similar doses in their work.

V. BASIC PRINCIPLES AND RADIOLOGICAL PROTECTION MEASURES.

Radiological protection is the totality of methods to reduce the harmful effects of ionizing radiation. Based on the effects of this radiation on human health, we can say that in the case of:

- ***deterministic effects*** **-** their production must always be avoided, as far as possible;
- ***Stochastic effects*** **-** their incidence should be reduced to an acceptable level.

Acceptability must be defined by the risk-benefit balance regarding radiation both in the case of potential exposure and in its use for medical and industrial purposes.

5.1. The basic principles of radiological protection are:

- **Justification -** the introduction of an activity that uses ionizing radiation is justified if the benefits resulting from the practice for people and society in general are greater than the negative effects on health that it can have. Decisions to introduce or change a route of exposure for existing and emergency exposure situations are justified, in the sense that they should be more beneficial than harmful.
- **Optimization -** radiological protection of individuals or the population is optimized in order to keep the size of individual doses, the probability of exposure and the number of exposed persons as low as possible taking into account the current state of technical knowledge and economic and social factors (ALARA principle).
- **Dose limitation -** in planned exposure situations, the number of doses to which a person is exposed does not exceed the dose limits provided for occupational or public exposure. Dose limits do not apply to exposures for medical purposes.
- **Intervention -** actions taken to mitigate serious negative consequences for human health and safety, quality of life,

property or the environment, or a risk that could lead to such serious negative consequences.

Exposure categories

Exposure to ionizing radiation of the entire population is classified into:

1. professional, medical and public exhibitions;
2. normal and potential exposures;
3. emergency exposures (emergency and accidental occupational exposure).

The first category of human exposure includes:

- **Medical exposure** is the exposure of patients or asymptomatic persons as part of diagnosis or medical or dental treatment performed to improve health, as well as the exposure of persons involved in the care and support of patients or volunteers in medical or biomedical research;

- occupational exposure which means the exposure of workers, apprentices and students during their activities;

- **public exposure** refers to the exposure of persons, except for occupational exposure or medical exposure. It is due to natural and artificial sources, as well as the exacerbation of natural radioactivity due to human activity.

The professional exposure includes:

- **Normal exposure** means exposure that is likely to occur under normal conditions of operation of an installation or the carrying out of an authorized activity (including maintenance, inspection, decommissioning), including minor incidents that can be kept under control, such as normal operation and anticipated operational incidents;
- **Potential exposure** is that exposure that does not occur with certainty, but which may result from a probable event or series of events, including due to equipment deficiencies or operating errors.

Exposure refers to an emergency exposure situation, defined as an exceptional situation or event, involving a radiation source, which requires rapid intervention, to mitigate the serious negative consequences for the health and safety of human beings, for the quality of life, for property or the environment, or a risk that could have such serious adverse consequences. The two components would be:

- **emergency occupational exposure** means the exposure to which a worker is exposed in a situation of emergency exposure;
- **accidental exposure** means the exposure of persons other than workers in emergency situations as a result of an accident.

Table 5.

Annual dose limits by categories of exposed persons.

	Professionally exposed people	**Apprentices, students (16-18 years old)**	**Occupational exposure population / pregnant women**
Total effective dose	20 mSv	6 mSv	1 mSv(1)
Cristalin equivalent dose	20 mSv	15 mSv	15 mSv
Equivalent dose Skin (2), extremities	500 mSv	150 mSv	50 mSv

(1) Under special conditions, a dose of up to 5 mSv is accepted in a single year, provided that the average dose in 5 consecutive years does not exceed 1 mSv / year.

(2) This limit applies to the average dose for any skin area of 1 cm^2, regardless of the exposed area.

5.2. Protective measures against ionizing radiation differ depending on the nature of the radiation sources:

Protection against **external sources** of radiation includes:

- **Physical protection -** achieved by means of reducing the exposure dose such as **exposure time, distance from the source, shielding**, as well as **measures to organize** work with sources in nuclear units;

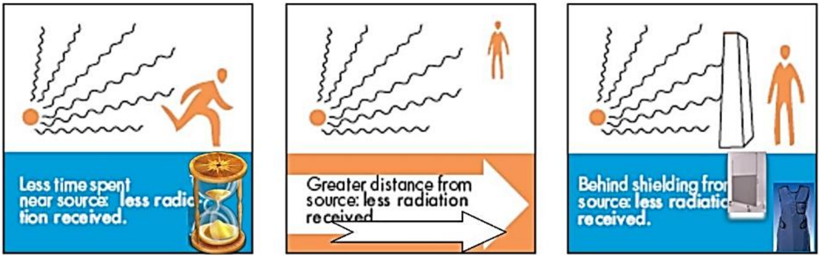


Figure 12. **Means of physical protection against ionizing radiation.**

- **Chemical protection -** administration of chemicals (eg cystamine, gamafos) before or after irradiation that reduce the harmful effect;
- **Biochemical protection -** administration immediately after irradiation of biological preparations and macromolecules (e.g., blood, plasma, homogenates of organs), which have the effect of cell recovery;
- **Biological protection -** performing immediately after irradiation a transplant of viable hematoforming red marrow cells to restore hematopoietic function.

In the case of the risk of internal contamination of the body with various radionuclides, it is more effective to act by rigorously controlling the contamination of environmental factors with which humans come into contact or the food they consume. In the case of the risk of direct human contamination, then the radionuclides are acted upon directly at the entrance gate or at the level of the internal liquids before they are fixed in various critical organs, where it is possible to act only with minimal effect.

The reduction of the degree of **internal contamination** is obtained by various measures:

- **Decontamination methods -** removal of radioactive isotopes from the digestive tract with certain substances (sodium alginate, aluminum phosphate) or from the respiratory tract by washing with plenty of saline;
- **Decomposition methods -** elimination of isotopes fixed in various critical organs with zinc or calcium salt of diethylenetriaminepentaacetic acid;
- **Isotopic dilution -** for example the administration of potassium iodide against radioactive iodine (Chernobyl accident 1986), so that thyroid cancer can be prevented. The explanation lies in the fact that iodine has the peculiarity of saturating the thyroid, the radioactive iodine being then unable to attach to the gland. For optimal results, it should be administered within the first half hour after exposure to radiation. Another example is high water consumption which can reduce the attachment of tritium to the human body.

5.3. International and national bodies with a role in radiological protection.

- United Nations Scientific Committee on the Effects of Atomic Radiation (**UNSCEAR**)
- International Commission on Radiological Protection (**ICRP**)
- European Commission through the European Atomic Energy Community **(EURATOM**)
- International Atomic Energy Agency (**IAEA**)
- World Health Organization (**WHO**)
- National Agency for Radiological and Nuclear Activities (**ANARN**)
- Ministry of Health, Labor and Social Protection (**MSMPS**) through the National Agency for Public Health).
- other ministries such as: Ministry of Internal Affairs, Ministry of Agriculture and Environment, etc.

VI. BENEFITS AND APPLICATIONS OF IONIZING RADIATION

Despite its many negative effects, the use of ionizing radiation has been an innovation, especially in medicine and industry.

Ionizing radiation has wide applications in medicine - in diagnostic radiology, interventional procedures and in radiotherapy - the major benefit being the increase of the quality of the medical act. It should be noted that the oncological treatment of malignant tumors uses the effects of ionizing radiation in order to destroy malignant tissues.

In the industry, the use of ionizing radiation is also beneficial, an example being the widespread use of the genetic mutation method by irradiation to increase the efficiency of penicillin and streptomycin production by penicillin and streptomyces. The method consists in irradiating the spores of these fungi with gamma radiation until their almost total destruction. Another use of gamma radiation is as a sterilizing agent for the destruction of harmful microorganisms in food and other products used in everyday life.

Other applications of ionizing radiation include:

- irradiation with gamma radiation of works of art in order to restore and protect them;

- radioactivity allows the dating of bones and paintings in caves;
- the radioactivity of the rocks allows to determine their age;
- very sensitive detectors used as an alarm for fire prevention.

The presence of ionizing radiation in our lives must be reduced to an acceptable level. Acceptability is defined by the risk-benefit balance of this radiation.

VII. RADIATION PROTECTION IN THE DENTAL OFFICE

Patient radiation protection includes:

1. Patient consent.
2. Useful irradiation of the patient and decrease of unnecessary irradiation.
3. Necessary equipment.
4. Adequate image receivers.
5. Lead apron.

7.1. Patient consent

- ***The informed consent*** of the patient is mandatory.
- ***The written consent*** of the patient is mandatory:
  - In the case of patients recruited in research projects, who must receive the approval of the Ethics Committees;
  - In the case of patients undergoing forensic exposures who do not have a direct health benefit.
- **Explaining the risks of dental radiography** should highlight the potential benefit in patient and prognosis management, compared to the very low risk of adverse consequences.

Two ideas should be highlighted:

- Dental radiography is a very low risk procedure.
- Without x-rays, the patient's treatment will be compromised.

In addition, dentists can inform the patient that they are using risk reduction techniques and that they have established quality assurance programs to optimize image quality.

Regarding the radiography of patients who are or could be pregnant, the same ideas can be emphasized, explaining that the risks of dental radiography are not different when the patient is pregnant.

Because the dose and therefore the risk of developing the fetus are very low, **there is no contraindication for x-rays in women who are or may be pregnant**, provided that the x-ray is clinically justified.

7.2. Useful irradiation of the patient and decrease of unnecessary irradiation.

Useful irradiation of the patient and a decrease in unnecessary irradiation include:

<u>a) Decrease in the number of radiographs:</u>

- The practitioner should obtain x-rays and / or reports to avoid unnecessary repeated examinations.

- There should be no barriers to borrowing x-rays and / or reports from a previous dentist.

- Clinical evaluation of the result of each radiograph is mandatory. e.g., if the patient has had an X-ray a week ago, it will not be sent to another.

Previous x-rays may:

- Eliminate the need for a new x-ray if they meet current clinical needs;

- Ease of monitoring a disease process (e.g., progression and regression of caries);

- Allow healing evaluation (e.g., healing of a periapical lesion).

<u>b) The decision to do a dental x-ray</u> is made only if the x-ray brings a benefit for diagnosis or treatment.

Depending on the patient we choose:

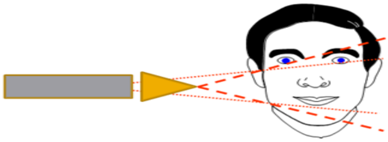
- Type of radiography;
- Frequency;
- Extension of the radiological examination.

7.3. X-ray selection criteria:

The reference criteria are the clinical or anamnestic signs that identify those cases in which the radiological examination will influence the treatment or prognosis of these patients.

- **The equipment includes:**

1. Focus-film distance.
2. Source-movie distance.
3. Filtering.
4. Collimation, field size adjustment.
5. Equipment factors in dose reduction.
6. Technical verification of equipment.



1. Focus-film distance

Short point devices (conical):

- They were long ago favorites;

- The conical shape allowed a visualization of the film-tooth relationship and provided a visual indication of the central axis of the beam.

2. Source-movie distance

The distance between the source and the movie **must be:**

- ***at least 20 cm*** for equipment using more than 60kV;
- ***at least 10 cm*** for equipment using less than 60kV.

3. Filtering

X-ray beam filtering:

- It preferentially absorbs photons with lower energy from the radiation beam;
- Reduces the patient's skin dose;
- Aluminum filtration is fixed during the manufacture of the equipment and consequently the filtration cannot be easily checked by a dentist.

Filtration reduces low-energy radiation that only increases skin irradiation.

4. Collimation, field size adjustment

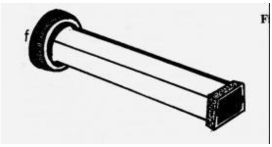
Reducing the size of the Rx beam to the minimum size required to form the image of the object of interest leads to:

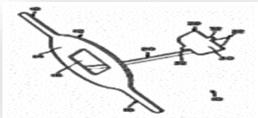
- Limiting the radiation field to the surface of the patient's skin;
- Limiting the irradiated volume of the patient;
- The distance from the Rx source to the skin plays a role in limiting the dose. Due to the divergence of the Rx beam, the increase in the source-skin distance reduces the divergence of the beam in the patient and therefore the irradiated volume.

For the last 20 years, cylindrical collimation with an open end with a diameter of 60 mm has been used. A circular beam with this size is 135 % larger in surface area than a conventional dental film (30x40 mm).

Rectangular collimation helps to reduce the dose by more than 60 % in dental radiography.

It has been reported that both long and short rectangular collimation result in the lowest doses, with values of 3.5-5 times lower than in the case of circular collimation.





Disadvantage:

- requires a very good technique;
- requires the use of a film fixing device to prevent the radiation cone from being cut.

In the UK and the US, it has been recommended to adopt rectangular collimation (30×40 mm beams, ie beams equal in size to conventional radiological film).

Collimation in panoramic radiography

The new panoramic equipment is equipped with „child imaging mode" which reduces the exposed area by 27-45 %.

5. Equipment factors in dose reduction

They include:

- kV
- mA
- X-ray repetition rate
- interpreting images

➢ **kV (kilovolts)**

kV influences the quality of X-rays.

If we have low kV, we have low energy so high absorption at the surface of the skin and low penetrability (radiation does not penetrate the tissues, so they cannot reach the radiological film).

Low kV values:

- lead to higher doses, patients, skin,
- requires longer exposure time than would require higher kilovolts (at the same mA).

The lower limit for kV is 50 kV.

If we have high kV, we have high energy and therefore high penetrability which:

- decreases the dose to the surface (skin),
- increase the dose in depth,
- we have more scattered X-rays.

There is no agreement on the optimal kilovoltage in dental radiology, in some countries the authorities recommend higher values, especially in the USA.

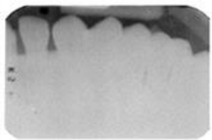
A kilovoltage around 60-70 kV for intraoral radiography is considered a reasonable compromise choice, between limiting the patient's dose and the effectiveness of the diagnosis.

➢ **mA (milliamperes)**

Influences the number of X-rays produced (image density).

Patient exposure is directly proportional to mA.

Errors:



- underexposed;
- Overexposed.

In order not to repeat the X-ray, overexposure can be offset by underdevelopment.

The rate of X-ray repetition depends on:

- movie processing errors,
- technical errors.

Interpretation of images can be done with:

- the negatoscope. The adjustable light intensity of the negatoscope compensates for overexposure;
- semi-dark room with light that is directed only on film;
- magnifying glass.

6. Technical verification of equipment

Verification bulletins are required, by an accredited expert, annually.

7.4. Image receivers

Choosing the picture receiver

In intraoral radiography:

- the **fastest films** should be used, which should produce satisfactory diagnostic results;

- Intraoral films from ISO speed groups E or F are recommended. They reduce the radiation dose by more than 50 % compared to movies in speed group D.

For **panoramic, cephalometric and other extraoral radiographs**:

- the **fastest available film-foil intensifier combinations** must be used, which give satisfactory diagnostic results;

- the light sensitivity of the film must match the intensifying foils correctly (green-green or blue-blue);

- The introduction of rare earth film-enhancing film combinations has shown a dose reduction of around 50 % for panoramic and cephalometric radiography.

Intensification foils can be:

- Blue: with calcium tungstate.

- Green: with rare earths (gadolinium, lanthanum). They are more sensitive.

Digital imaging produces very good quality diagnostic images, at least the same as conventional radiographic films.

Images are immediately displayed on a computer monitor, and no camera, chemicals, or developer machines are needed for semi-automatic or automatic movie processing.

The optimal exposure time for all digital systems was about half that required for conventional film (even up to 5 times shorter).

The advantage of digital radiography: it offers a significant dose reduction.

Disadvantages of digital radiography:

- the number of recurrences may result in an increase in the patient's dose. The number of replays is mainly due to incorrect positioning of the CCD sensor with cable which makes positioning difficult;

- Due to the smaller size of the sensor, more than one exposure may be required to cover the anatomical surface, which can only be viewed with a single radiological film.

7.5. Lead apron and thyroid collar

- Lead aprons do not protect against scattered radiation inside the body.

In the case of panoramic radiographs, it may physically interfere with the procedure and degrade the final image.

Despite the dose of extremely low gonads associated with dental radiography, the use of a lead apron has been recommended in the past in order to reassure the patient. However, it has been shown that the doses to the gonads are not significantly different in dental radiography with or without the lead apron.

An official report from the American Academy of Oral and Maxillofacial Radiology points out that the value of the lead apron is minimal compared to the benefits of using speed E films and rectangular collimation. It was concluded that their use could be considered optional, except when required by law.

- **Collar for thyroid protection**

The thyroid gland is one of the most radiosensitive organs in the head and neck region. It is frequently exposed to scattered radiation and occasionally to the primary beam of radiation during dental radiography.

The lead collar for thyroid protection should be used in intraoral radiography, especially in people under the age of 30, as they are more prone to the risk of cancer due to radiation. However, for intraoral radiography, rectangular collimation is likely to provide the same level of thyroid protection as the lead collar for the thyroid.

Thyroid shielding in panoramic radiography is inappropriate because the protective collar is located in the primary radiation beam.

Lead cephalometric radiography is required to protect the thyroid with lead if the beam collimation does not exclude the thyroid gland.

It has been found that the lead collar for the thyroid reduces the radiation dose by 45 % during the CT scan of the head and is therefore highly recommended especially for younger people.

Effect of equipment changes on dose compared to 70kV AC reference equipment with a 60 mm cylindrical beam used with E-speed films (see *Table 6*).

Table 6.

Effect of equipment changes on dose.

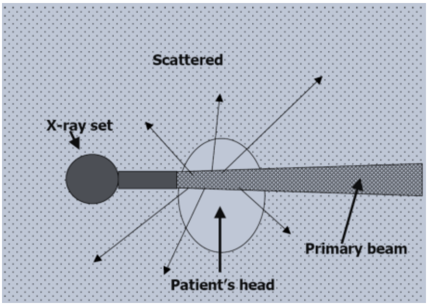
Equipment factors	Dose multiplication factor
Digital systems (phosphor plates or CCD)	0.5 – 0.75
Rectangular collimation (30x40 mm)	0.5
Film with speed F	0.8
Film with speed D	2
Constant potential DC	0.8
Short cone (skin source distance 10 cm)	1.5
50kV	2

7.6. Radiation protection of personnel.

➢ ***<u>Primary beam and scattered radiation</u>***

The radiation emitted by the X-ray is **primary radiation**.

X-rays have a rectilinear direction but the interaction with matter can change their direction, they are deflected, scattered, ie they are **scattered radiation.**



➢ ***X-ray intensity.***

The intensity of the radiation (dose) decreases with the square of the distance.

For scattered radiation this principle is sufficient for radiation protection.

For intraoral radiographs, panoramic radiographs and skull (cephalometric) radiographs, observance of a distance of more than 1.5 m from the X-ray is sufficient to maintain an annual dose of 1 mSv / year.

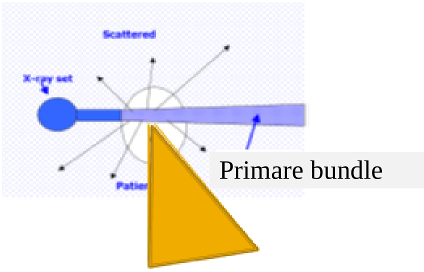
A distance of 2-3 m from the patient is recommended in dental radiology.

➢ ***Operator position***

- 2 m from the tube;
- at an angle of 90-135 degrees to the primary beam.

For intraoral film radiography, the radiation dose in the primary bundle is:

- at the end of the cone: a few mGy;
- at 1 m: at least 1000 times smaller than at the end of the cone (due to scattered radiation).



➢ ***Using distance***

Care should be taken during intraoral radiography not to direct the primary bundle towards doors or any other unprotected area.

It is generally considered good practice if staff are outside the showroom during the exposure.

The device operator must position himself in such a way as to have a clear view of the patient, of another person in the room, and of the Rx warning light. This is necessary to ensure that the operator is all positioned correctly at the start of the exposure and that the exposure ends correctly.

➢ ***Use of protective screens***

If many x-rays are not taken (workload is low) no additional protection is required for staff provided that the room is large enough to allow staff to stand more than 2 m away from the patient.

However, if many x-rays are taken, or the space is crowded, additional protection will be required:

- through protective screens behind which the staff will stand, or
- by wearing aprons by staff.

If such protection is required, it is recommended that a qualified expert be consulted for the opinion.

➢ ***Factors that contribute to the calculation of radiation protection screens:***

- the amount of radiation emitted per kV and mA / week;
- the fraction of time for which the X-ray beam is directed at the radiation shield (wall);
- working time in the radiology laboratory.

7.7. Classification of radiological safety zones

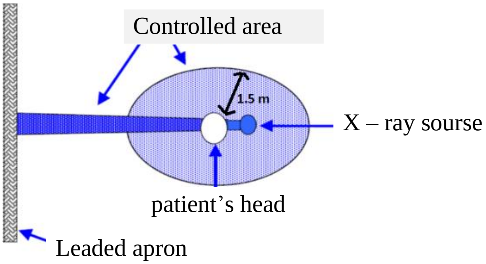
Controlled areas are defined as areas subject to special rules to ensure the safety of personnel.

For dental radiography laboratories in hospitals, it is normal for the entire exposure chamber to be designated as a controlled area.

However, for situations where not many x-rays are taken, the area around the X-ray equipment that the staff should release during exposure is specified as a controlled area.

It is therefore recommended that for panoramic equipment *(not more than 50 exposures per week)* and for intraoral equipment *(not more than 100 exposures per week)* the controlled area be within the area 1.5 m from the Rx tube, of the patient and the primary beam of radiation.

Diagram of a marked controlled area around an intra-oral radiological installation



Personnel should ensure that they are outside this area, 2-3 m away or outside the room, during exposure.

However, the opinion of a qualified expert is required to define the controlled area. This opinion is essential for situations with a higher workload and for cephalometric equipment.

- **In the radiology laboratory the walls** must be of sufficient thickness and density so that the irradiation in the vicinity does not exceed the natural background.
- **Operational procedures**

The operator is not allowed to hold the instruments or the film during the exposure. Used:

- film holding instrument

- in special cases: parents or relatives (with radiation protection apron)

- the X-ray tube must not be held or suspended by the operator.

- **Patient support**

Exceptionally, it may be necessary to provide assistance by supporting a disabled patient or a child.

If patient care is required, the adult caregiver should wear a leaded apron and position it so that its body is outside the primary beam of radiation. If this is a permanent requirement in practice, then the advice of a qualified expert should be sought to determine the most appropriate protection and the need for personal monitoring.

The film or sensor should be held by the patient when there is no other way to keep it in the correct position. It should never be touched by medical personnel. If it is necessary for someone other than the patient to hold the film, this should be done with long tweezers so that the finger is not in the primary beam of radiation.

The anesthetized patient has a particular situation, but it is usually possible to ensure that the film remains in the correct position by immobilization methods.

- **<u>Written procedures and supervision</u>**

To ensure that staff are aware of the precautions to be taken, it is desirable that written interactions be developed and displayed in the dental X-ray laboratory.

These instructions must detail the responsibility for exposure, the positioning of personnel, the use of protective equipment, any restrictions on the direction of the primary beam and the arrangements for personal monitoring.

In addition, a staff monitoring system should be set up to ensure that radiological safety operating instructions are followed and reviewed as necessary.

Conclusions:

- working regulations: written and displayed;

- monitoring of the dose received by the operator is done with individual dosimeters.

➢ **The need for personal monitoring**

Given the relatively low doses received personally, the provision of personal monitoring is generally considered desirable but not universally necessary. It is recommended that monitoring not be required normally, but only if the risk assessment indicates that the individual dose is likely to exceed 1 mSv per year (eg if more than 100 intraoral radiographs are performed or 50 of panoramic movies per week).

However, in other countries, personal monitoring is recommended for all practitioners using dental X-ray equipment.

➢ **Pregnant employees**

Dose limit for the fetus: 1 mSv.

Pregnant women working in the radiation environment must notify the employer and their dose will be carefully monitored not to exceed 1 mSv.

➢ **Working regulations**

Written instructions and displays in the Oral Radiology Office:

- responsibility for exposure;
- patient positioning;
- radiation protection means;
- restriction of the direction of the primary beam, collimation, diaphragm;
- staff monitoring.

Video tracking systems to monitor compliance with working regulations.

➢ **Continuing medical education**

The Radiological Safety Officer must present:

- new techniques, equipment;
- improving the practice and technique of radiography;
- increased exposure, doses;
- radiobiology - possible risks.

➢ **Staff training**

All staff (not just the equipment operator) should be aware of:

- the risks associated with the use of radiological equipment;

- the provisions required to keep the dose as low as possible (ALARA);

- the importance of compliance with these provisions.

Most dental employees will receive radiation protection training as part of their professional training. However, it is very important that local arrangements be explained to all staff.

For staff members who have not received any training in radiation protection (eg some nurses), it is important to take steps (following appropriate training courses, providing appropriate on-the-job training) to ensure that staff are adequately trained.

- **Application of the ALARA principle**

The most important principle for the radiation protection of personnel is to ensure that the dose is kept as low as possible, without affecting the quality of the radiological investigation. This principle is known as the ALARA principle and is the backbone of all radiation protection practices.

Mainly, ALARA requires that any measures that can reasonably be implemented ensure the optimization of radiation protection. Economic and social factors must be taken into account when making a reasonable decision. In the practice of dental radiology, the principles of ALARA must be ensured by taking relatively direct measures.

- **Responsibility of the authorization holder**

Holder of authorization or certificate of registration:

- must issue level 1 **driving licenses to all persons in the unit**, professionally exposed to ionizing radiation, who do not hold a level 2 or 3 driving license issued by CNCAN;

- must ***develop, implement and document a radiation protection program*** commensurate with the nature and extent of the risks associated with the practice of radiology, a program under the responsibility of the holder and which ensures compliance with the requirements of the rules. This program must cover all phases of the practice, from location, construction, use, to decommissioning;

- must **provide the necessary resources** to effectively implement this program;

- must **appoint a radiological safety officer** for each controlled area. He must have sufficient managerial authority with regard to radiation protection regulations and the provisions of the authorization. The person in charge of radiological safety must have a level 2 exercise permit, issued by ANARN, for the field of Radio diagnostics (RDG), Roentgen diagnostics (RTG), Phthisiology (RTGF), Dental X-ray (RTGD) or Interventional Radiology (RI) as the case may be. Radiation Generators (GR), specializing in Installation, Repair, Maintenance, Verification (MRIVX) or Other Applications (AAX), as appropriate. The Level 2 Operating Permit is required and issued in accordance with the Rules on the Issuance of Nuclear Operating Permits and the Designation of Accredited Experts in Radiological Protection.

➢ **Attitude towards incidents**

Incidents, which lead to significant staffing levels, are very rare in dental practice. Exposure to the primary beam of radiation, especially if the equipment fails to stop properly, can be a cause and requires investigation.

It is important that the investigation be carried out immediately, as long as the details of the incident are fresh in the memory of those involved. A qualified expert should be consulted to estimate the dose levels received.

Any incident must be reported to the competent authorities in compliance with local requirements.

7.8. Infection control in the dental radiology office

All patients should be treated as potentially infectious.

➢ <u>**Risk of infection**</u>

- Tuberculosis
- Herpes viruses
- Hepatitis A, B, C, D, E
- Respiratory infections

- AIDS

Infections can be transmitted through blood or saliva.

There is an increased risk of cross-contamination in the laboratory.

- **<u>Prevention of cross-contamination is achieved by:</u>**

1. Surface disinfection;
2. Protective equipment;
3. Storage and transport of materials.

- **<u>Infection control sequence</u>**

1. Film packaging;
2. Sterilization of film holding;
3. Disinfection and coating of radiological equipment and work surfaces.

Areas contaminated with panoramic radiography:

- Bite block,
- Chin support,
- Control panel,
- Exposure button,
- The tape is not contaminated (it is extraoral).

4. X-ray exposure:

- Patient positioning,
- Take gloves,
- Expose the patient.

5. Development of contaminated films:

- Replacement of the contaminated package,
- Placing the film on a transport stand,
- Glove removal,
- Film processing in the darkroom.

6. Disinfection of surfaces, aprons and replacement of protective materials.

7. Staff gloves.

8. Sterilization of the equipment (autoclave or dry heat).

<u>Possible topics:</u>

-3 dose reduction measures in patients,

-3 radiation protection measures for the operator,
- staff dose / year limit,
-dose limit for dental staff / year,
-dose limit for patients / year,
-3 causes of unnecessary irradiation.

Tests - Radiation Hygiene

1. Indicate the types of radiological sections

a) rontghenodiagnostic sections;

b) radiodiagnostic sections with „closed” sources;

c) radiotherapy units with „closed” sources;

d) radiodiagnostic sections with „open” sources;

e) radiotherapy departments with „open” sources.

2. Select what ionizing radiation forms in the air

a) ozone (O3);

b) oxygen (O2);

c) nitrogen oxides;

d) metal oxides;

e) nitrogen.

3. What is used to make the screens and personal protective equipment as the main component

a) heavy metals;

b) light metals;

c) organic glass;

d) plastics;

e) ordinary fabric.

2. Name, which are non-stochastic somatic biological effects of ionizing radiation

a) leukopenia;

b) osteosarcoma;

c) skin cancer;

d) thyroid cancer;

e) aplastic anemia.

7. Select which of the following radiations is most dangerous to the body's internal irradiation

a) alpha;

b) proton flux;

c) beta;
d) x;
e) range.

8. Indicate the methods of radiation protection that do not apply to work with closed sources of ionizing radiation

a) protection with quantity;
b) protection over time;
c) remote protection;
d) protection with screens;
e) the use of personal protective equipment for ultraviolet radiation.

9. For which groups of persons are the maximum allowed irradiation doses of 1 mSv / year

a) persons professionally exposed in the industry;
b) persons professionally exposed in the field of medicine;
c) persons living near nuclear power plants;
d) the population as a whole;
e) patients.

10. Indicate the stochastic biological effects of ionizing radiation

a) thyroid cancer;
b) aplastic anemia;
c) cataracts;
d) pulmonary fibrosis;
e) affecting the genetic background of the population.

9. Name the types of radiation that occur in the process of radioactive decay of elements

a) α - radiation;
b) β - radiation;
c) γ - radiation;
d) neutron radiation;
e) ultraviolet radiation.

10. Name the types of radiation that give the minimum ionization density in the substance

a) α - radiation;
b) β - radiation;
c) j - radiation;
d) neutron radiation;
e) X-rays

11. Name the type of radiation that gives the maximum ionization density in the substance

a) α - radiation;
b) β - radiation;
c) γ - radiation;
d) neutron radiation;
e) X-rays.

12. Name the physical nature of X-rays

a) electron flux;
b) flow of helium nuclei;
c) electromagnetic waves (energy photons);
d) positron flux;
e) neutron flux.

13. Name, the physical character of the α radiation

a) electron flux;
b) flow of helium nuclei;
c) electromagnetic waves (energy photons);
d) positron flux;
e) neutron flux.

14. Name the distance traveled by the rays - γ in the air

a) micrometers;
b) millimeters;
c) centimeters;
d) meters;

e) hundreds of meters.

15. Select the units for expressing the activity of radioactive substances

a) roenten;
b) sieves;
c) disintegrations / sec;
d) mg-equivalent Ra;
e) beqhereli.

16. Name the main characteristics of ionizing radiation

a) energy;
b) penetration property;
c) ionization property;
d) the property of destruction of materials;
e) thermal effect.

17. Name, the consequences of the action of ionizing irradiation on the human body

a) direct somatic effect;
b) indirect somatic effect;
c) teratogen;
d) genetic effects;
e) there are no effects

18. Name the components of the natural radioactive background

a) cosmic radiation;
b) gamma-telluric radiation;
c) ingestion radiation;
d) radiation from the testing of nuclear weapons;
e) radiation with radioactive isotopes.

19. Name the materials used to make the shields against ionizing radiation

a) heavy metals;
b) light metals;

c) plastics;
d) concrete;
e) glass.

20. Permitted dose of irradiation of medical personnel according to NFRP

a) 20 mSv / year;
b) 30 mSv / quarter;
c) 5 mSv / year;
d) 0.5 mSv / year;
e) 0.1 mSv / year.

TEST ANSWERS

1.ACDE	2.E	7. A	12. ABC
2.AC	3.D	8. C	13. ABCD
3.A	4.ABE	9. B	14. ABC
4.ABCD	5.ABCD	10. E	15. AD
5.A	6. C	11. BCDE	16. A

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