RADIATION PROTECTION

TRAINING MATERIALS FOR INITIAL AND PERIODIC TRAINING

CYCLOTRON OPERATORS AND INTERNAL EMERGENCY TEAM

LEGAL REGULATIONS ESTABLISHING PROTECTION AGAINST IONIZING RADIATION

The Atomic Law and its implementing provisions.

In view of the above of hazards, employees and the population are subject to special legal protection due to the effects of ionizing radiation. The basic legal act in this regard is the Atomic Law and its implementing regulations.

The President of the National Atomic Energy Agency is the authority responsible for compliance with the radiation protection regulations.

Labor Code

The Labor Code also imposes obligations on employers related to the protection of employees.

"Art. 223. § 1. The employer is obliged to protect employees against ionizing radiation from artificial and natural sources present in the work environment.”

BASIC TERMS AND THE ALARA PRINCIPLE

Exposure - the process by which the human body is exposed to ionizing radiation;

Threat (potential exposure) – exposure that may occur, but the probability of its occurrence can be estimated in advance;

Radiation protection - preventing human exposure and environmental contamination and if such situations cannot be prevented - limiting their effects to a level as low as reasonably achievable, taking into account economic, social and health factors;

The basic principle of radiation protection - the ALARA principle (As Low As Reasonably Achievable), which means that all activities carried out with ionizing radiation sources should be organized in such a way that human exposure is as low as reasonably achievable.

CONDITIONS OF ADMISSION TO WORK EXPOSED TO IONIZING RADIATION

Responsibility. The head of the organizational unit is responsible for compliance with the requirements of nuclear safety and radiological protection. Some of his duties in this respect are entrusted to an employee with the qualifications of a radiological protection inspector.

Initial and periodic training. The Atomic Law Act requires the employer to ensure that the employees he employs in work involving exposure to ionizing radiation have the necessary knowledge obtained as a result of initial and periodic training.

This training, in addition to providing knowledge about threats, also includes on-the-job training.

The head of the organizational entity is obliged to ensure that initial and periodic training of employees in the field of nuclear safety and radiological protection is conducted - at least every 5 years - in accordance with the program developed by him/her.

Training of members of the internal emergency team should take place at least once every 2 years.

Medical report. The Act also stipulates that an employee may be employed in exposure conditions after a certificate of no contraindications to such employment issued by a doctor with appropriate qualifications.

IONIZING RADIATION - TYPES OF IONIZING RADIATION

Radiation symbol and name	Radiation description
α, alpha	The nuclei of helium atoms emitted by some radioactive elements
β, beta	Negatively or positively (positrons) charged electrons emitted by some radioactive elements or produced in X-ray machines or accelerators
γ, gamma	Electromagnetic waves emitted by radioactive elements
X, X-rays	Electromagnetic waves generated in X-ray machines or accelerators as a result of braking accelerated electrons
n, neutron radiation	Elementary particles that are electrically neutral, produced in nuclear reactions, e.g. fission of the uranium nucleus

ATTENUATION OF DIFFERENT KINDS OF RADIATION

Type of radiation	Properties and methods of attenuation
α	- Poorly penetrating, strongly absorbed by matter, a sheet of paper will absorb them - maximum range in the air up to 10 cm; - Very strongly ionizes directly, so it is dangerous when alpha radionuclides are absorbed into the body.
β	- Effectively absorbed by light materials, e.g. plastics, aluminum; - Directly ionizing; - Relatively penetrating - the maximum range in the air is several meters.
γ and X	- Effectively absorbed by heavy materials, e.g. lead, concrete; - Indirectly ionizing; - Very penetrating.
n	- Absorbed by slowing down in a moderating material containing hydrogen atoms, e.g.: water, paraffin, polyethylene; - Indirectly ionizing; - Very penetrating.

PRACTICAL PRINCIPLES OF RADIATION PROTECTION

When carrying out and planning work involving exposure to ionizing radiation, the following measures should be taken in particular:

- **Minimizing exposure time;**
- **Increasing the distance from the source of ionizing radiation or using radiation-reducing shields;**
- **Avoiding radioactive contamination and absorption into the body by complying with the rules of hygiene, including the use of personal protective equipment: work clothes, disposable gloves, protective glasses, evacuation masks;**
- **Systematic measurement of dose rates, doses and radioactive contamination, if necessary and possible.**

Ionizing radiation is an energy carrier.

Radiation passing through a medium (e.g. body cells) leaves its energy in it, which results in changes in the cellular structure of tissues or heating of the medium.

The unit of energy is 1 J (Joule). 1 J corresponds approximately to the energy of a 0.1 kg mass lifted 1 m above the ground. A weight dropped from this height, hitting, for example, a glass vessel can give it its energy in a spectacular way, breaking it into pieces.

Ionizing radiation dose

The dose is a measure of the effects of ionizing radiation on the tissues of the body.

The effects of the impact are cumulative during irradiation, although they can be weakened by the body's self-healing actions.

The dose unit is 1 Sv (Sievert). The dose of 1 Sv is very large, so in the practice of radiological protection it is easier to use fractions of Sv:

1 mSv = 0,001 Sv (milli Sievert), 1 µSv = 0,000001 Sv (micro Sievert).

Milli and micro Sievert conversions as follows:

1mSv =1000 µSv, 1 µSv = 0,001 mSv, 1 Sv = 1000000 µSv.

Radiation dose rate

The dose rate of ionizing radiation is a parameter giving the "strength" of ionizing radiation in a given place.

The dose rate can be used to calculate the dose that a tissue or organism can receive at a given location at a certain time. The unit of dose rate is Sv/h.

In the practice of dosimetric measurements, smaller units are used, adapted to real situations:

1mSv/h= 0,001 Sv/h, 1 Sv/h = 1000 mSv/h,

1 µSv/h = 0,000001 Sv/h, 1mSv/h=1000 µSv/h.

The dose rate can be measured using a dosimetric device and then the dose is calculated using a simple formula:

"dose" = "dose rate" x "exposure time"

Example 1. Measured dose rate: 40 μSv/h, exposure time 3.5 h. The dose is:

"dose" = "dose rate" x "exposure time"=40 μSv/h x 3,5 h = 140 μSv = 0,14 mSv;

Example 2. At a certain point the dose rate is 80 μSv/h. How long would it take a worker to receive a dose of 1.25 mSv at this location:

***"exposure time" = "dose" : "dose rate"*= 1250 μSv : 80 μSv/h ≈ 16 h**.

We use dosimetric devices to measure the dose rate, ionizing radiation dose and radioactive contamination.

Dosimetric devices are divided according to the measured quantities and intended use:

- Radiometers - measurement of radiation dose rate,
- Dosimeters - measuring the dose of radiation,
- Contamination monitors - detection of radioactive contamination.

The dosimetric device must have a detector in which the effect of ionizing radiation passing through it is converted into an electrical signal. This signal, after "processing" by the electronics of the device, is displayed on the indicator of the device.

Calibration certificate. Dosimetric devices used to control and assess exposure should have a calibration certificate.

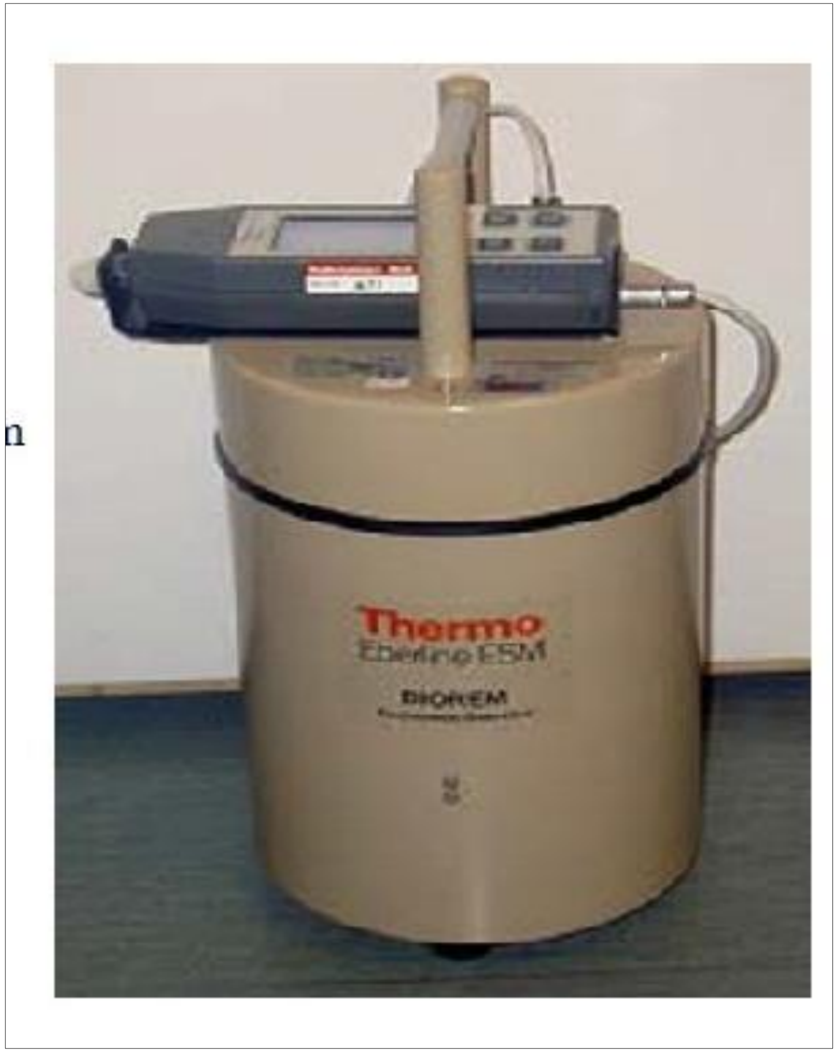
Accredited laboratory. Instrument calibration is performed by measurement laboratories accredited by the Polish Center for Accreditation. The confirmation of calibration of the device is a calibration certificate issued by such a laboratory.

According to radiation protection regulations, instruments should be calibrated once every 12 months or once every 24 months if the instrument is equipped with an internal calibration source.

RK-100 dose rate meter with an external probe for measuring radioactive contamination


FH 40G-L10 gamma dose rate meter

FH 40G-L10 dose rate meter set with a probe for measuring the dose rate from neutrons



TYPES OF SOURCES OF IONIZING RADIATION

Source of ionizing radiation. This is the name of all isotopic and non-isotopic radiation emitters, e.g.:

- substances containing radioactive isotopes (e.g. Co-60, Am-241),
- a device containing such a source (defectoscope, sterilizer of medical dressings, smoke detector),
- a device generating ionizing radiation (X-ray machine, accelerator),
- radioisotope generators (Mo-Tc generator).

Radioactive source. In the nomenclature of radiation protection, isotope sources of ionizing radiation are called radioactive sources.

Radioactive sources are divided into:

- **sealed sources** - when the radioactive substance is enclosed in a sealed enclosure that prevents the radioactive substance from entering the environment.
- **open sources** - when a radioactive substance can be broken down (dispensed) for medical, research or other purposes.

EXAMPLE OF A SEALED RADIOACTIVE SOURCE Eu-152

EXTERNAL AND INTERNAL EXPOSURE

External exposure occurs when the radiation source is in the vicinity of the exposed person.

The source of external exposure are emitters of highly penetrating radiation (X, γ and neutron). This type of exposure concerns both occupationally exposed persons and the general population.

Internal exposure occurs when there is a risk of a radioactive substance entering the human body. This type of exposure concerns people working with open sources of radiation. The exposure of the general population may only occur in the event of a radiation emergency resulting in the release of radioactive substances in the gaseous or liquid state into the environment.

WAYS OF INTERNAL EXPOSURE

Ways of entry into the body. Radioactive substances can enter the human body: by inhalation, food or directly into the blood through skin wounds.

Metabolism of radioactive substances. After the radioactive substance enters the body, it is subjected to metabolic processes. The human body treats all isotopes of the same element, stable and radioactive, equally.

The type and speed of metabolic processes depend on: the element, the route of entry, the properties of the element whose isotope was found in the body.

From the point of view of internal exposure, the most dangerous isotopes emitting α radiation, due to their strong ability to ionize in the cells of the body.

INFORMATION ABOUT THE BIOLOGICAL EFFECTS OF IONIZING RADIATION

Ionizing radiation can affect living organisms directly by damaging cells or indirectly through free radicals, which damage cells.

A cell may lose its ability to reproduce and die, but it may well reproduce with the resulting defect, which may lead to cancer or hereditary characteristics.

The smallest dose at which the health effects of irradiation become noticeable is 200 mSv. Radiation sickness begins at doses of 1000 mSv (1Sv), while the lethal dose is 5 Sv (if it is accepted in a short time - up to an hour).

A large dose of radiation absorbed by the body over a long period of time, eg a month, will cause less health effects than the same dose taken over a short period of time, eg a day.

Somatic effects arise as a result of damage to the cells that sustain life processes. The time after which they may appear after irradiation depends on the extent of cell damage caused by radiation. They can manifest themselves after a few minutes or weeks, and even later - after years.

Somatic effects are divided into: **stochastic** (random, accidental effects with a certain probability of occurrence in the population) and **deterministic** (e.g. radiation sickness, cataracts, erythema or hair loss).

Genetic effects are caused by damage by ionizing radiation to cell elements responsible for the transmission of hereditary characteristics. As a result of the negative genetic effects of ionizing radiation, the following may occur:

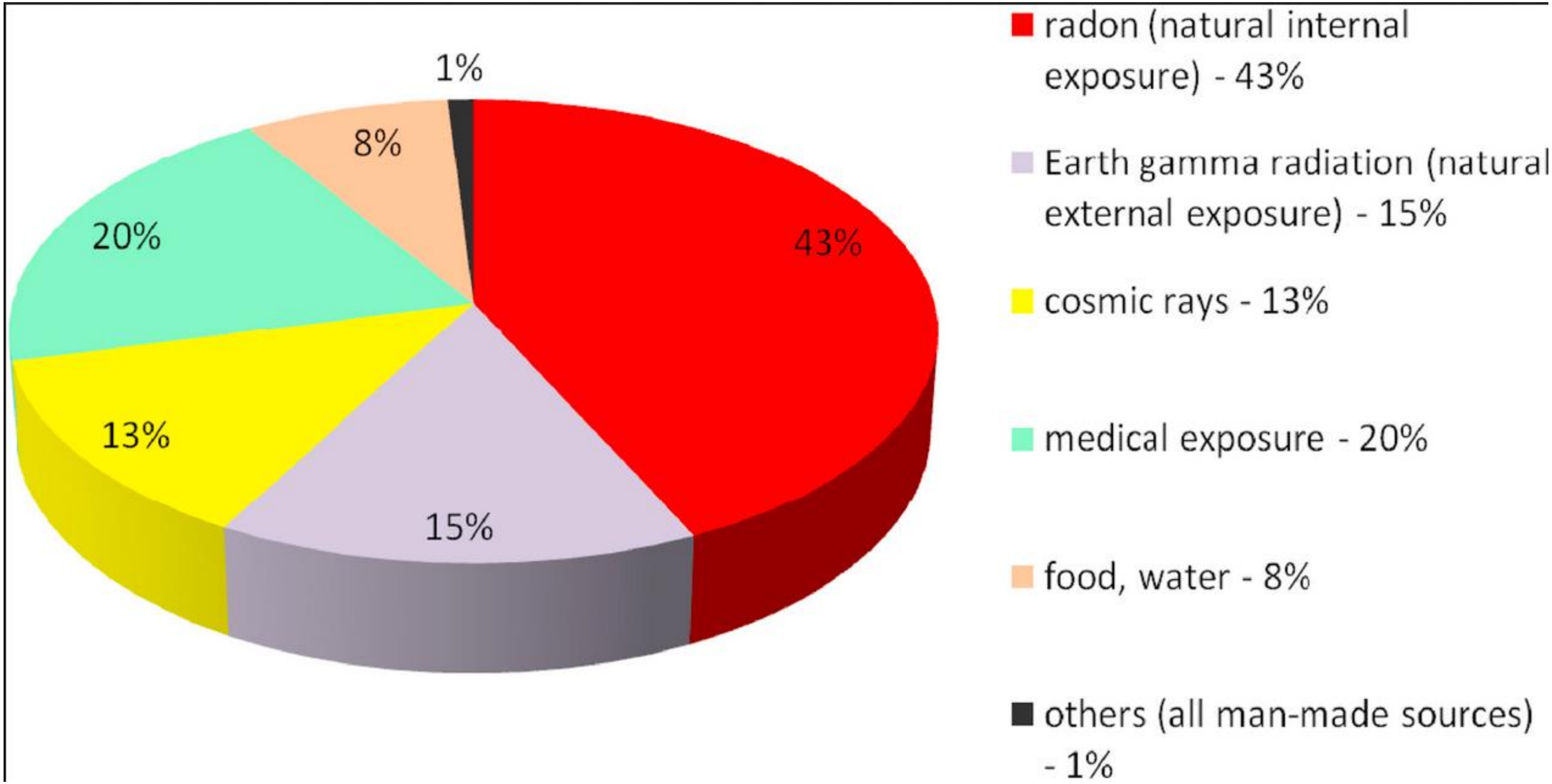
- having more than normal symptoms of inherited diseases such as Down syndrome

- birth anomalies such as miscarriage or fetal mortality.

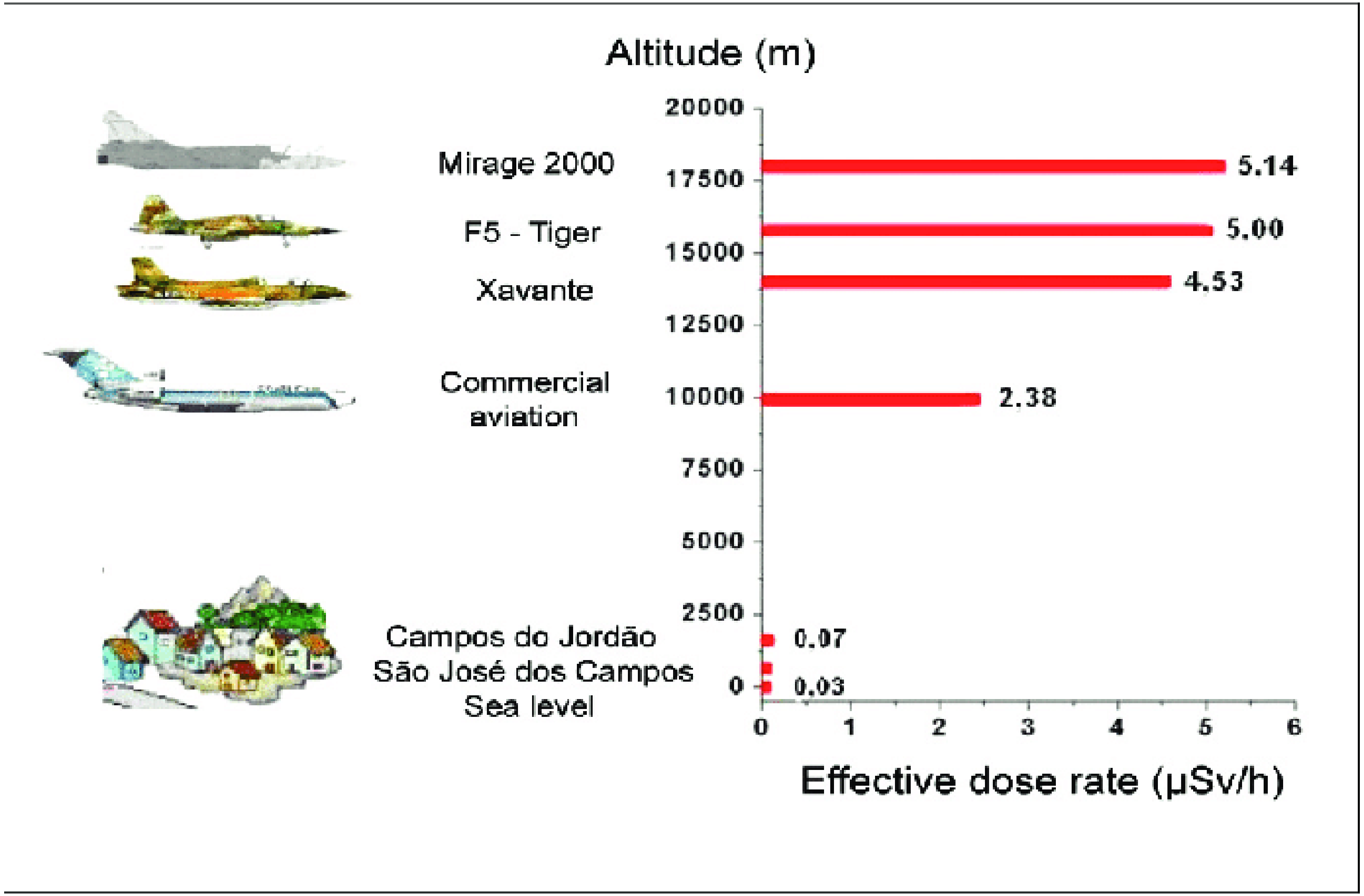
DOSE LIMITS FOR EMPLOYEES AND THE GENERAL POPULATION

To whom it applies	Effective dose D_s (mSv)	Equivalent dose D_r (mSv)		
		Eye lenses	**Skin**	**Hands, forearms, lower legs and feet**
Employees	20	20	500	500
Employees category A	$6 < D_s \leq 20$	20	500	500
Employees category B	$1 < D_s \leq 6$	20	500	500
A person removing the effects of a radiation emergency	100	-	-	-
A person saving human life	500	-	-	-
Students and apprentices over 18 years	20	20	500	500
Students and apprentices from 16 years to 18 years	6	15	150	150
Students and apprentices under 16 years	1	15	50	-
People from the general population	1	15	50	-
Woman from notification of pregnancy (baby dose)	**1**	-	-	-

THE MAIN SOURCES OF RADIATION AND THEIR CONTRIBUTION TO HUMANS AS WORLDWIDE AVERAGE



RATES OF EFFECTIVE DOSE DUE TO COSMIC RADIATION AS A FUNCTION OF ALTITUDE



CONTROL OF EXPOSURE OF EMPLOYEES AND THE GENERAL POPULATION

- **Employee** - a person employed in a unit who, due to the work performed, must stay near sources of ionizing radiation. This person is usually equipped with an individual dosimeter.

- **A person from the general population** - other employees of the unit and persons not working in the unit, but staying in the vicinity of places where ionizing radiation sources are located.

- **The limit doses** are 20 mSv/year for workers and 1 mSv/year for people from the general population.

- Measurement of individual (employees) and environmental (general population) doses using dosimeters delivered and read by a laboratory accredited by the Polish Center for Accreditation.

- A breastfeeding woman cannot work exposed to external and internal contamination.

EXPOSURE CATEGORIES AND WORKPLACES - EXPOSURE CATEGORY CRITERIA

The Atomic Law introduces two categories of employees depending on the expected level of risk and adjusts the risk assessment methods accordingly:

1) **category A** covering workers who may be exposed to an effective dose exceeding 6 mSv per year,

2) **category B** covering workers who may be exposed to an effective dose of more than 1 mSv per year, but not more than 6 mSv per year.

<u>Workers employed in exposure conditions are assigned to category A or B by the head of the organizational unit, depending on the expected level of exposure of these workers.</u>

Employees exposure control is carried out on the basis of individual dose measurements or dosimetric measurements in the work environment:

- **Category A employees** are subject to exposure assessment based on systematic individual dose measurements, and if they may be exposed to internal contamination affecting the effective dose level for this category of workers, they are also subject to internal contamination measurements.
- **Category B employees** are subject to exposure assessment conducted on the basis of dosimetric measurements in the work environment in a way that allows to determine the correctness of assigning workers to this category, unless the head of the organizational unit decides to include them in systematic measurements of individual doses.

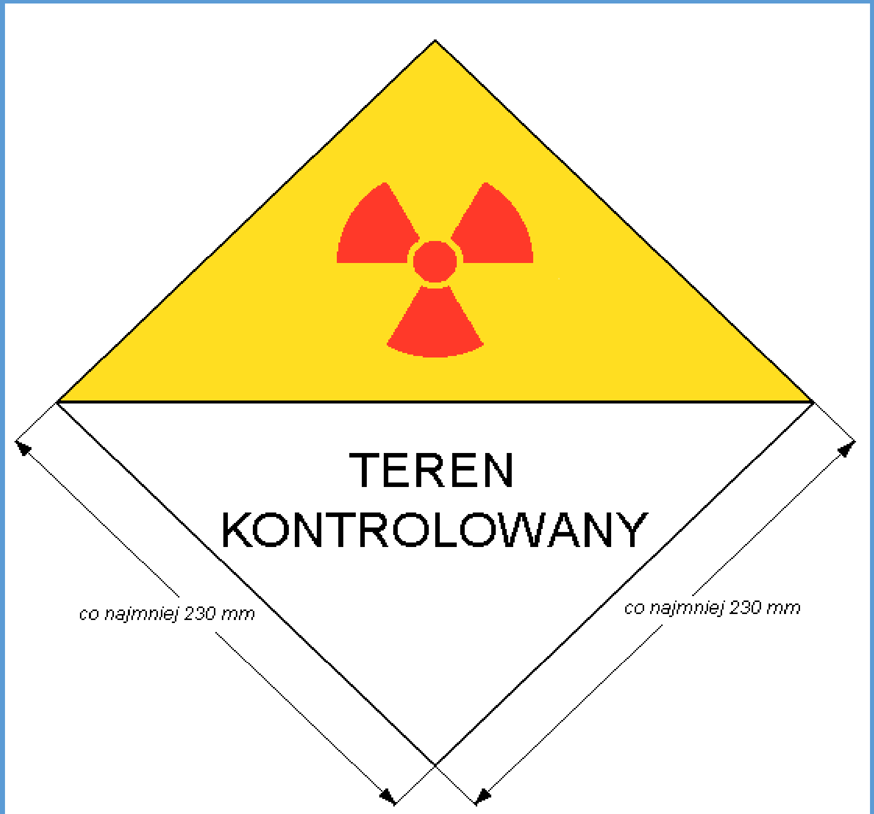
DIVISION OF WORKPLACES ACCORDING TO THE VOLUME OF EXPOSURE

In order to adapt the activities and means of radiological protection of employees to the size and types of threats, the head of the organizational unit divides the location of workplaces into:

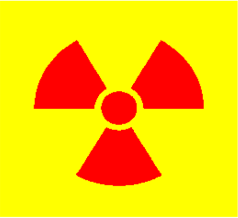
Controlled areas (teren kontrolowany) where there is a possibility of receiving doses specified for category A employees, there is a possibility of dissemination of radioactive contamination or large variations in the dose rate of ionizing radiation;

Supervised areas (teren nadzorowany) where it is possible to receive doses specified for category B employees and which have not been classified as controlled areas.

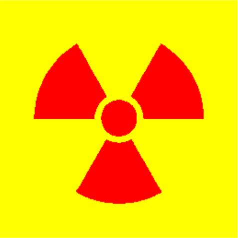
LABELING BY EXPOSURE LEVEL



MARKING BY TYPE OF WORK



PRACOWNIA
KLASY III



PRACOWNIA
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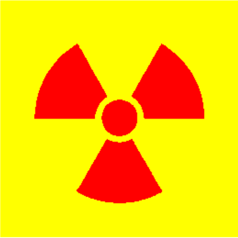

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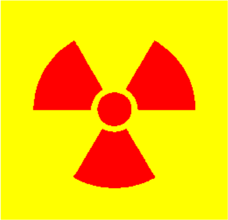
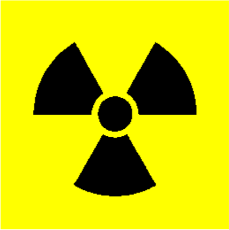
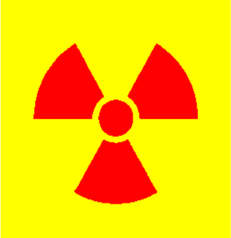


PRACOWNIA
KLASY II



PRACOWNIA
AKCELERATOROWA



MAGAZYN
ODPADÓW
PROMIENIOTWÓRCZYCH

Radiation emergency – a situation related to the risk of ionizing radiation, requiring urgent action to protect employees or the public.

Company Emergency Procedure Plan - a basic document describing potential emergency situations in the organizational unit and the rules of conduct.

Exercise to check the operation of emergency procedures - the regulations on radiation protection impose an obligation on the employer to conduct such exercises at least once every two years. All employees affected by the exercise should be familiarized with the conclusions of the exercise, regardless of whether they participated in the exercise.

DESCRIPTION OF KNOWN OR HYPOTHETIC RADIATION EVENTS OF SIGNIFICANCE

Fire in the supervised area*
Loss of source or radioactive waste used or stored in the supervised area
Leaks of the radioactive source used in the supervised area
A person in the box or bunker of the cyclotron will remain without the consent of the radiological protection inspector after introducing the ion beam into them
Exceeding the individual or environmental dose limit*
***Supervised area: Cyclotron Bunker, Boxes in the Experiment Hall, Storage of Radioactive Sources and Waste in the Experiment Hall**

If you detect or suspect that any of the following events have occurred, you should:

- Secure the event area against access by people.
- Immediately notify: A tutor of a group of students or a cyclotron operator, Radiation protection inspector.

The notification should include:

- name, surname and position or function of the person stating the radiation emergency,
- contact details of the notifying person,
- the exact location of the event site,
- brief description of the event.

RADIATION EMERGENCIES - PROCEEDINGS OF THE HEAD OF THE ORGANIZATIONAL ENTITY

The head of the organizational unit or a person representing him should:

1) organize the security of the event site in order to:

- prevent third parties from staying at the scene of the event,

- prevent the spread of radioactive contamination.

2) organize first aid for the injured;

3) if necessary, immediately notify:

- fire brigade,

- Emergency medical Services,

- police,

- Crisis Management Department at the Voivodship Office,

- Voivodship Inspector for Environmental Protection,

- President of the National Atomic Energy Agency.

REMOVING THE CONSEQUENCES OF RADIATION EMERGENCIES - AUTHORIZATION AND PREPARATION FOR REMOVAL

Persons authorized to remove the effects of radiation emergencies

The following persons are entitled to remove the effects of a radiation emergency:

- Radiological Protection Inspector;
- A member of the internal emergency team trained in emergency operations.

Preparation for removal.

- Do not start the action to remove the effects of the emergency situation before the Radiation Protection Inspector estimates the maximum duration of the action;
- Determine whether, together with the radioactive materials, there were no materials or devices at the site of the emergency that could pose a threat during the removal operation. On this basis, agree on the security conditions;

- Prepare appropriate protections for the participants of the action as indicated by the Radiological Protection Inspector;
- Prepare plastic bags to protect radioactive contamination and damaged sources as well as used personal protective equipment;
- Prepare a place for temporary storage of collected radioactive contamination, damaged sources and contaminated personal protective equipment;
- Contact the Radioactive Waste Management Plant regarding the transfer of the above-mentioned items to be liquidated.

NOTE: Only volunteers who have given written consent to take such actions may be delegated to remove the effects of an emergency situation. Refusal to participate may not result in professional consequences.

SPECIAL THREATS FROM IONIZING RADIATION

Radioactive activation - the elements of the cyclotron can become radioactive as a result of nuclear reactions taking place in them, caused by e.g. neutrons generated as a result of conducting beams of light ions. Any work on an open cyclotron must be preceded by dosimetric measurements and estimation of exposure to ionizing radiation.

ECR source control – when some ions are produced in the source, quite “strong” X-rays are generated at the source outlet. Avoid staying in this place when the ion beam is being emitted from the source. Photo of the critical spot on the next slide.

Boxes and Mezzanine in the Experimental Hall - some elements of ion optics or shield materials can excite neutron radiation, which, due to reflections from the walls and ceiling, can reach places outside the walls. An example of such threats is the Ion Separator. During its operation, the level of neutron radiation reached 5 µSv/h in the corridor of the Hall and up to 150 µSv/h in the Mezzanine.

MIEJSCE PODWYŻSZONYCH POZIOMÓW PROMIENIOWANIA W ECR