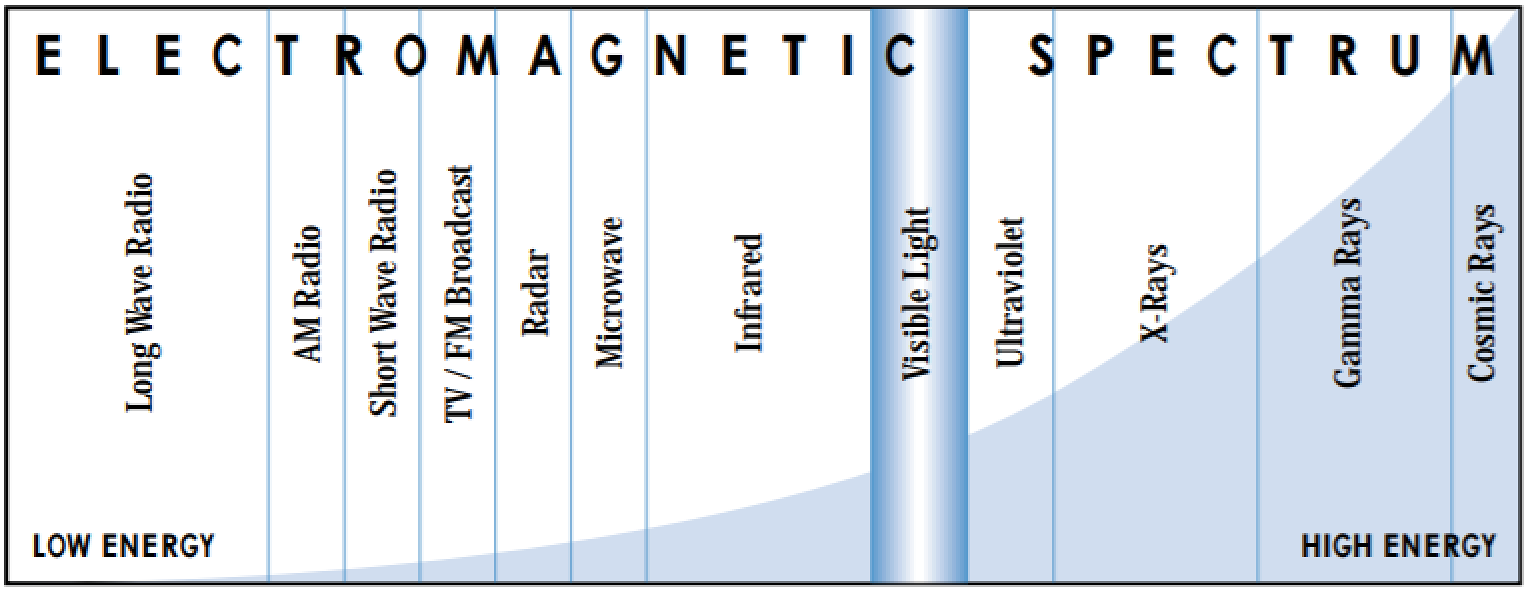
Topic 5 «IONIZING RADIATION»

What is ionizing radiation?



1. TYPES OF IONIZING RADIATION

Ionizing radiation -is any type of particle or electromagnetic wave that carries enough energy to ionize or remove electrons from an atom

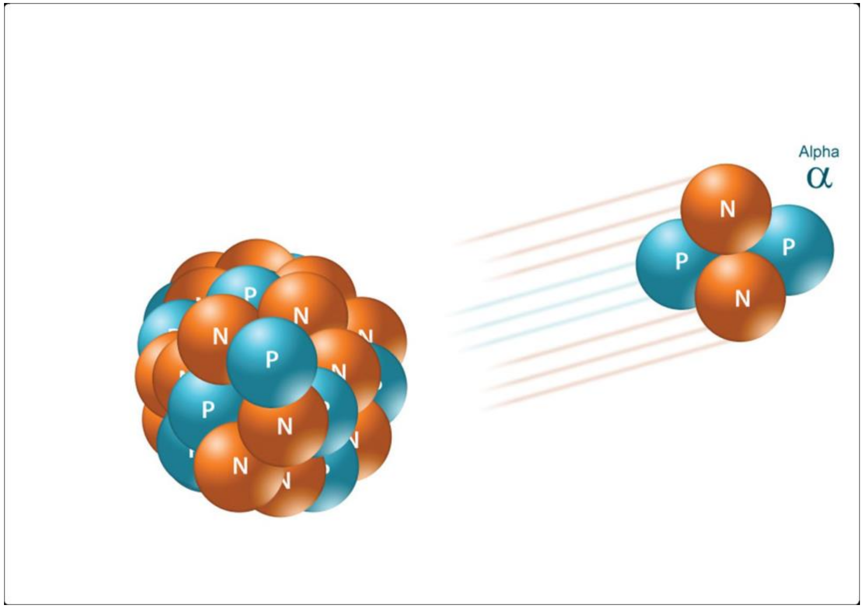
There are officially two types of ionizing radiation:

- **Corpuscular (Alpha, beta, and neutronparticles)**
- **Electromagnetic. (X-rays and gamma-rays, and sometimes they have the same energy.) Gamma radiation is produced by interactions within the nucleus, while X-rays are produced outside of the nucleus by electrons.**

Corpuscular ionizing radiation. Alpha particle radiation (alpha radiation)

1. The alpha particle is composed of two protons and two neutrons, or a helium nucleus

Alpha particles are composed of two neutrons with no charge and two positively charged protons, traveling at very high speed. When alpha particles penetrate solid material, they interact with many atoms within a very short distance. They create ions and use up all their energy in that short distance. Most alpha particles will use up their energy while traveling through a single sheet of ordinary notebook paper. The primary health concern associated with alpha particles is that when alpha-emitting materials are ingested or inhaled, energy from the alpha particles is deposited in internal tissues such as the lungs.



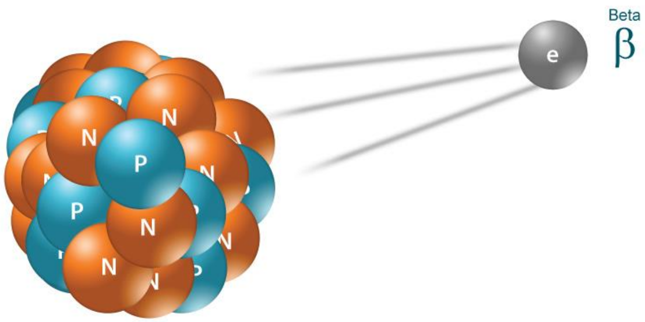
Alpha decay

Alpha decay: a nucleus ejects an alpha particle which is identical to an ionized helium nucleus

Alpha radiation: The emission of an alpha particle from the nucleus of an atom

Beta Radiation

Beta particles are high-speed electrons that are not attached to atoms. They are small - over 7,000 times lighter than alpha particles. The beta particles travel farther through solid material than alpha particles. For example, a very high-energy beta particle will travel about half an inch through plastic before it uses up all its energy. Like alpha particles, beta particles lose energy with every interaction and no longer produce ions once all their energy is spent. Health concerns associated with beta particles arise primarily when beta -emitting materials are ingested or inhaled.



Beta decay

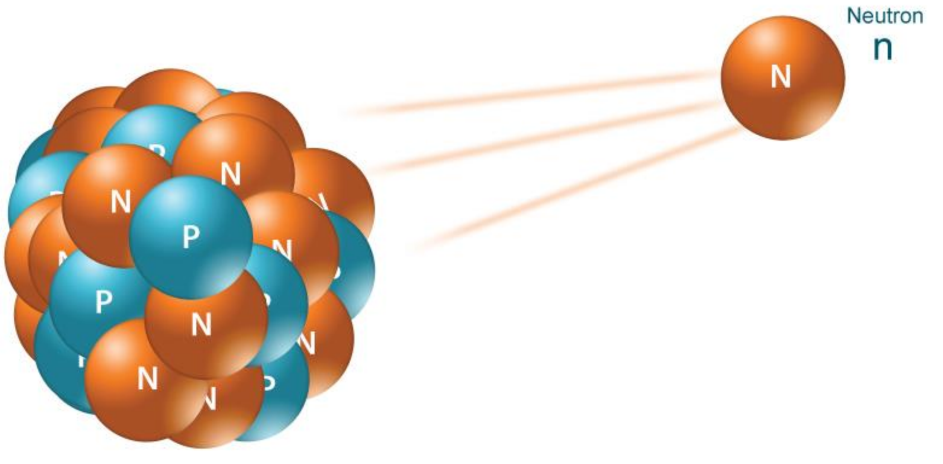
Beta radiation: The emission of a beta particle from the nucleus of an atom

Beta radiation takes the form of either an electron or a positron (a particle with the size and mass of an electron, but with a positive charge) being emitted from an atom.

Neutron ionizing radiation

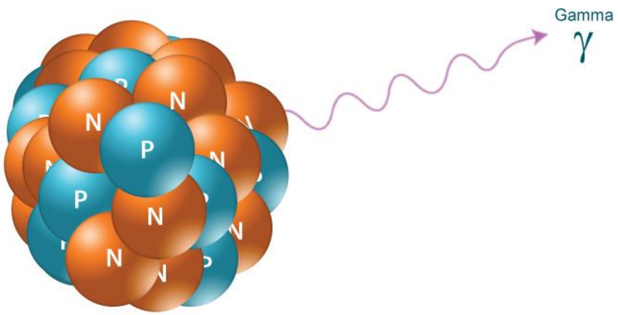
Neutron radiation: The emission of a neutron from the nucleus of an atom

Neutron radiation consists of a free neutron, usually emitted as a result of spontaneous or induced nuclear fission. Able to travel hundreds or even thousands of meters in air, they are however able to be effectively stopped if blocked by a hydrogen-rich material, such as concrete or water. Neutrons are, in fact, the only type of radiation that is able to turn other materials radioactive.



Electromagnetic ionizing radiation

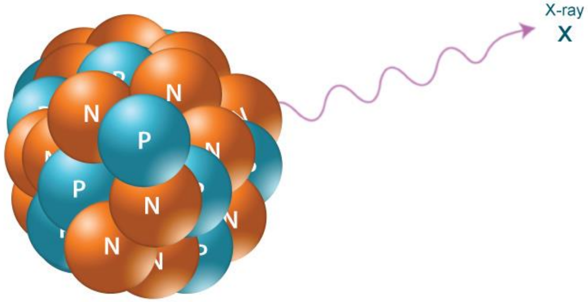
- **Gamma radiation**
- **X-rays**



Gamma radiation

The emission of an high-energy wave from the nucleus of an atom

Gamma radiation, unlike alpha or beta, does not consist of any particles, instead consisting of a photon of energy being emitted from an unstable nucleus. Having no mass or charge, gamma radiation can travel much farther through air than alpha or beta, losing (on average) half its energy for every 500 feet. Gamma waves can be stopped by a thick or dense enough layer material, with high atomic number materials such as lead or depleted uranium being the most effective form of shielding.



X-Rays

The emission of a high energy wave from the electron cloud of an atom

◦X-rays are similar to gamma radiation, with the primary difference being that they originate from the electron cloud. This is generally caused by energy changes in an electron, such as moving from a higher energy level to a lower one, causing the excess energy to be released.

X-Rays are longer-wavelength and (usually) lower energy than gamma radiation, as well.

2. Doses

The system of dosimetricquantities:

1)Physical quantities (the impact of ionizing radiation on the material)

2)Normalized quantities (the hazard of ionizing radiation)

Physical quantities

1) **Exposure ionizing radiation dose (radiation exposure)**

2) **Absorbed dose**

Physical quantities. Radiation exposure

Exposure ionizing radiation dose (radiation exposure) -is a measure of the ionization of the airdue to ionizing radiationfromphotons; that is,gamma rays and X-rays.

TheSIunit of exposure is thecoulomb per kilogram (C/kg),which has largely replaced the roentgen(R). One roentgen equals0.000258C/kg; an exposure of one coulomb per kilogram is equivalent to 3876 roentgens.

As a measure of radiation damage exposurehas been superseded by the concept ofabsorbed dose which takes into account the absorption characteristic of the target material.

Physical quantities. Absorbed dose

Absorbed doseis a dose quantity which is the measure of the energy deposited inmatter byionizing radiationper unit mass. Absorbed dose is used in the calculation of dose uptake in living tissue in bothradiation protection (reduction of harmful effects), and radiology (potential beneficial effects for example in cancer treatment).

TheSIunit of measure is gray (Gy), which is defined as one Joule of energy absorbed per kilogram of matter.The older, non-SIunitis rad (sometimes also used)

Normalized quantities

For biological effects assessment of ionizing radiation
Specifically for radiological protection purposes

1) Equivalent Dose
2) Effective Dose

Equivalent dose **is calculated for individual organs.**

It is based on the absorbed dose to an organ, adjusted to account for the effectiveness of the type of radiation.

Equivalent dose is expressed in millisieverts (mSv) to an organ.

Effective dose **is calculated for the whole body. It is sometimes called whole-body dose.**

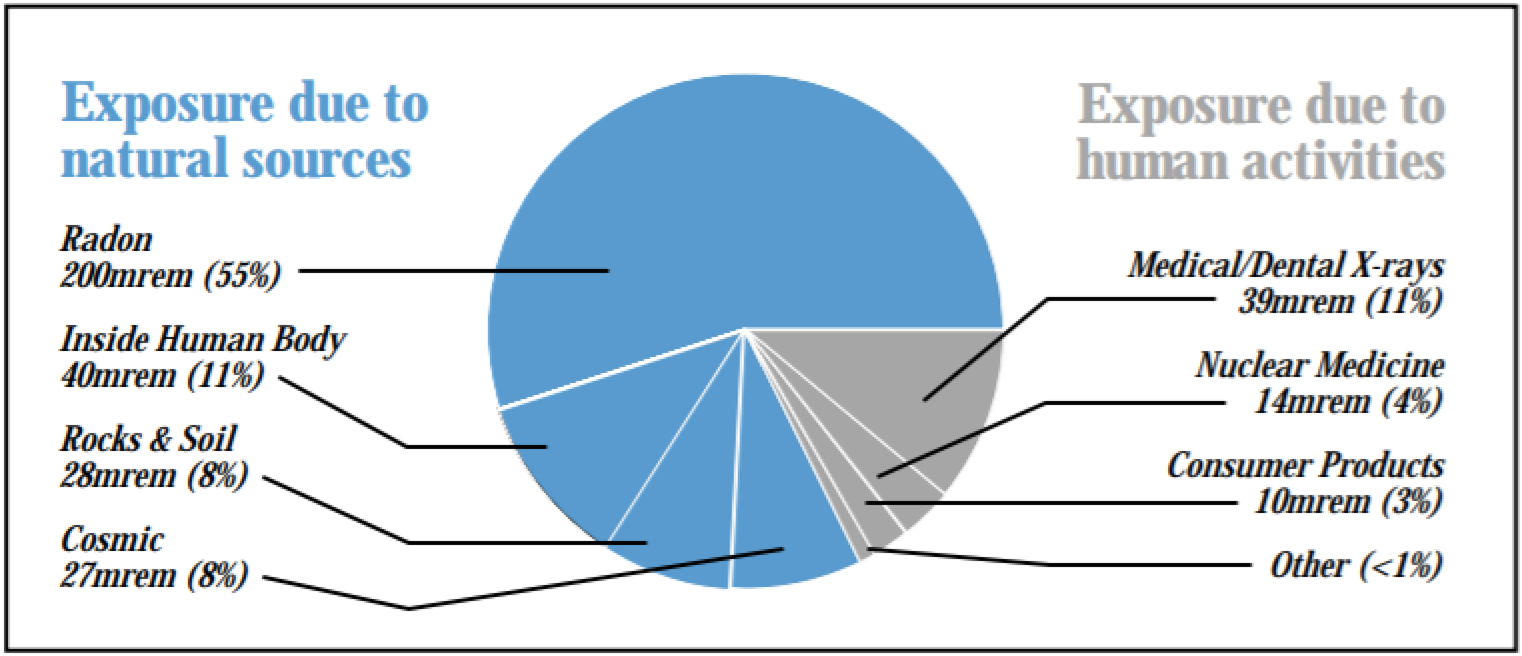
It is the addition of equivalent doses to all organs, each adjusted to account for the sensitivity of the organ to radiation.

Effective dose is expressed in millisieverts (mSv).

3. The main sources of ionizing radiation

1) Natural sources of radiation (background radiation, cosmic radiation, radon gas)

2) Artificial sources of radiation (medical x-rays, generating electricity from nuclear power, testing nuclear weapons, and producing a variety of common products such as smoke detectors which contain radioactive materials, can cause additional exposure to ionizing radiation)



Maximum permissible radiation doses

According to the radiation safety standards:

For the staff (for professional employees, who have permanent contact with the sources of ionizing radiation) –20 mSv, but not more than 50 mSv per year

For other people –1 mSv, but not more than 5 mSv

Average annual doses from different sources (natural and artificial) of ionizing radiation

The source of ionizing radiation	The dose, mSv (per year)
Background radiation	2
Builder's supplies	1,4
Nuclear-power engineering	0,002
Medical examinations	1,4
Nuclear tests	0,025
Plain flight	0,005
Utility (household) devices	0,04
TV-set and PC	0,001
Altogether (common dose)	5

4. Dosimetricand radiometric control

Dosimetriccontrol –the system of arrangements with the purpose of radiation control for people who were in contact with the sources of ionizing radiation (or near them)

Dosimetriccontrol is carrying out in the high-radiation areas or in the case of emergency

Dosimetriccontrol is perfomedwith special device –DOSIMETER

There are two forms of dosimetriccontrol: individual and group forms

Group control –for receiving data about average doses of ionizing radiation of some group of people (in the same conditions of radiation hazard)

Individual control is carrying out for receiving data about personal radiation doses (for each human in the area of radiation hazard)

For individual control there are individual dosimeters (ID -1, ID –11) ИД -1, ИД-11, ДКП-50

INDIVIDUAL DOSIMETER (ИД-1)

Personal dosimetriccontrol device

The purpose -to measure absorbed dose of gamma and neutron radiation (in the range from 0 to 500 rads)

The unit of measure –is rad.

Individual dosimeter (ДКП –50)

To measure personal exposition dose of gamma radiation (in the range from 0 till 50 roentgens)

The unit of measure is a roentgen

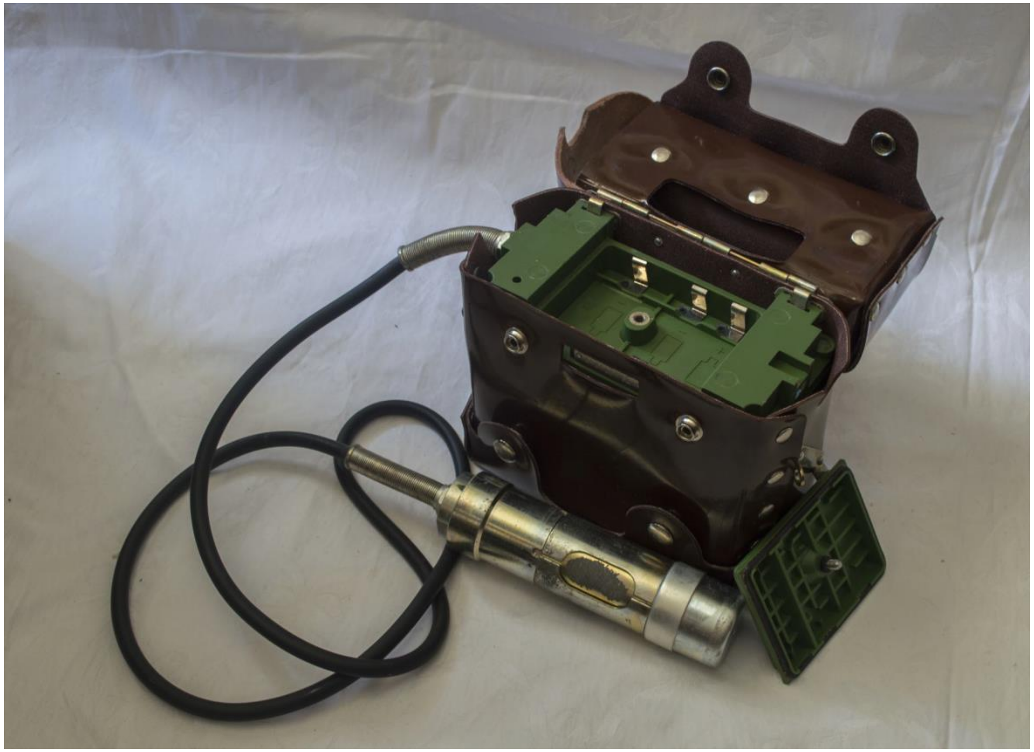
Radiometric control

The system of arrangements with the aim of radioactive contamination control of some area (surfaces of objects, clothes, technics, transport vehicles, equipment and etc.)

The intensity of ionizing radiation characterized by the quantity “the level of radiation”. This is the energy of radiation in the ratio of time (Rad/hour)

The main device is roentgen radiometer (ДП –5А,Б,В)

Allows to measure the level of radioactive contamination of some area (e.g. the surface of clothes, skin, water, food and etc.) in the range from 0,05 rad/h till 200 rad/h



Radiometric control (ДП-5в)

Allows to measure the level of radioactive contamination of any surface

5. Biological action of radiation

The main features of biological effects of radiation:

The absence of subjective feelings at the first moment

The presence of hidden period

Discrepancy between acute radiation syndrome severity and low quantity of damaged cells at first

The summing of small doses

Genetic effects

Different radiation perceptibility of different organs

The speed of onset of symptoms is related to radiation exposure

Thecells that are most affected are generally those that are rapidly dividing

The dose that doesn’t cause acute radiation injury: single dose -50 rad, multiple dose – monthly --100 rad, annual 300 rad

Acute radiation syndrome

Acute radiation syndrome(ARS), also known asradiation sicknessorradiation poisoning, is a collection of health effects due to exposure to highamounts (usually over 1 Gy) ofionizing radiation(gamma-rays, neutrons, X-rays) over a short period of time.

◦**Severity of ARS depends on the dose of radiation**

Dose (Gy):	**The level of severity:**
1-2	Mild
2-4	Moderate
4-6	Severe
Over 6	Extremely severe

There is a strict dependency between absorbed dose and clinical manifestation of ARS

Acute radiation syndrome

The first description of acute radiation syndrome was made after atomic bomb explosions in Japan during World War II in 1945.Other sources of human data came from radiation accident at Chernobyl nuclear power plant.

High-risk situations include:

- **nuclear power plant accidents**
- **nuclear or radiological weapons use**
- **radiation therapy**

Acute radiation syndrome

Clinical presentation

Within the first days symptoms may include nausea, vomiting, and loss of appetite.

Classically, acute radiation syndrome is subdivided into three subsyndromes: the hematopoietic syndrome, the gastrointestinalsyndrome and the neurovascular syndrome. Classical radiobiology explain the failure of each of these organs by radiation-induced death (cytocidal effects) of a great number of parenchymal cells (target cell theory) but today we know that radiation not only cause lethal effects but also functional and indirect effects in many cells (multi-cellular target theory)

The syndrome has a number of phases:

- **prodromal phase: symptoms are non-specific but can include: anorexia, diarrhea, fever, erythema of the skin, nausea, vomiting and headache. This usually appears 1-3 days after exposure.**
- **latent phase: with an apparent improvement in symptoms and may last hours or weeks.**
- **symptomatic phase:with a number of possible sub-syndromes occurring such as:hematopoietic symptoms (1-8 Gy): infection, hemorrhage**
- **gastrointestinal symptoms (5-20 Gy): diarrhea, electrolyte and fluid disturbances, gastrointestinal bleeding and perforation**
- **neurovascular symptoms (>20 Gy): headache, focal neurological deficits, altered level of consciousness**
- **final phase:either recovery or death depending on the total dose and dose rate received**

Acute radiation syndrome

There are four clinical phases in the development of radiation sickness:

Prodromal phase: is the initial phase of acute illness. Signs and symptoms appear within 1–3 days after the exposure, characterized by nausea, vomiting, anorexia, fever, headache and early skin erythema. Depending on the dose received these symptoms can be mild viral like or severe. The onset of vomiting is also related with absorbed dose and can be seen within few minutes after a high dose exposure.

Latent phase: is a delusive phase characterized by improvement of symptoms and an apparent cure. Individuals look and fill good but laboratory tests become abnormal with lymphopenia and granulocytopenia. This phase is also dose dependent and may last hours to weeks.

Manifest illness phase: in this phase specific signs and symptoms of each syndrome appear depending on the dose. The hematopoietic syndrome develops at doses of between 1 and 8Gyalthough slight decrease in blood cell counts can be seen with doses below 1Gy. The gastrointestinal syndrome occurs at doses of between 5 and 20Gyand the cerebrovascular syndrome at doses higher than 20Gy.

Final phase: recovery or death depending on the absorbed dose, dose rate and the heterogeneity of exposure.

6. Medical protection means

Preventive medical protection means -to prevent cellular damage due to ionizing radiation.

1. Radioprotective substances (agents) can decrease radiation-related deleterious effects on cells, they decrease sensitivity of the organism to ionizing radiation

Indralin, cystamine

Cystamineis a part of individual medical kit (radioprotective remedy). Dose -6 pills (1,2 g). Radioprotective action continues about 4-5 hours.

Indralinis the emergency radioprotective remedy, is destined for emergency prophylaxis

Single dose –3 pills (0,45 g)

Medical protection means

2. Prophylaxis means of first day symptoms. The main purpose is to prevent vomit.

Aethaperazinumis a part of individual medical kit

Single dose –1-2 pills a day, but not more than 6 pills

3. Medical protection means in the case of internal radiation exposure hazard

1) means (agents) that decrease absorption of radioactive materials (e.g. sorbent agents –they can tie RS and form new non-absorbable compounds)

2) means (agents) that increase elimination of radioactive materials from the body (e.g. complex formers–Pentacinumand Unithiol)

Iodine prophylaxis

Iodine-131: with a halflifeof 8 days, known to lead to thyroid problems was one of the main radioactive elements released from the Chernobyl disaster.

Radioactive iodine (I-131) is a by-product of energy production in a nuclear reactor.

As radioactive iodine decays, it emits radiation and affects the thyroid and the nearby tissue.

Administration of stable iodide in the form potassium iodine (KI) is considered the most effective preventive radiation management when exposed to high doses of iodine-131 radiation

A single dose of potassium iodine is 1 pill a day for adults