Lecture.

# Sanitary protection of the environment from radioactive contamination as a hygienic problem. Hygienic aspects of the Chernobyl accident.

Radiation as unfavorable physical production factor.

Naturally occurring ionizing radiation originates both from outside the body, in the form of:

- cosmic radiation;
- radiation from natural radio-isotopes in the environment,

and from inside the body from natural radio-isotopes deposited from food, water and air.

During the present century, mankind has been subjected to increasing levels of ionizing radiation from man-made sources, such as X-ray equipment, nuclear weapons, the nuclear fuel cycle, and artificial radioisotopes used for medical and other purposes.

Feature action of this factor on organism is pathological changes even at small levels of influence that demands especially strict observance hygienic requirements, norms of radiating safety (NRS) and careful survey of working.

Concept "Radio-activity".

Radio-activity is ability of substances to spontaneous disintegration (transformation nucleus of atoms of one element into others) with allocation of energy as particles or radiation.

Ionizing radiations may be divided into two main groups: (1) electrmagnetic radiations (X-ray, and gamma rays), which belong to the same family of electromagnetic radiations as visible light and radio waves; and (2) corpuscular radiations, some of which — alpha particles, beta particles (electrons), and protons — are electrically charged, whereas others (neutrons) have no electric charge.

The characteristic kinds of ionization radiation:

1. Corpuscular radiation:

- Alpha radiation is a stream of alpha-particles (nucleus of helium). This is basically from natural isotopes. Ionization ability is forming 6000 pairs ions in 1 $mm^3$, penetrating ability is run in air 11 mm, in fabrics 1/6 mm running. they penetrate only into a superficial layer of skin. Protection is by clothes, by aluminum foil. The basic danger is at internal hit in an organism with water, food;
- Beta radiation - a stream of beta-particles (electrons or positrons). Ionization forms 6 pairs ions in 1 ml, penetrating ability is up to 1m in air, in tissues it makes up to 1 cm. Protection can used any materials, except lead (formation braking X-ray radiation).
- Neutron radiation is a stream of neutrons. Ionization is 400 pairs ions in 1 ml, run in air is hundreds m, in tissues it makes up to 10m. Protection against fast neutrons is substances with a small serial number (hydrogen) - water, paraffin, polymer materials. Slow neutrons are absorbed by borum, cadmium.

2. Electromagnetic radiation:

X-ray and gamma - radiation. Ionization forms 0,1 pairs ions in 1 ml, running in air makes up hundred m, in tissues it makes up some m (depends on rigidity of radiation - from length of a wave). Gamma - radiation is more rigid.
Protection is materials with high density - lead, concrete.

Natural radiating background (NRB)

Natural radiating background - a natural level of radio-activity in the given district, basically dependent on natural factors. On the average it makes about 100 miliBER / year, but can test significant fluctuations in view of the natural and anthropogenic reasons.

Structure NRB:

It has three components:

1) cosmic (space) radiation originating in outer space and reaching the earth's surface after reacting with, and being partially absorbed by, the earth's atmosphere;

2) terrestrial radiation coming from natural radioisotopes present in the earth's crust; and

3) radiation from natural radioisotopes that have been accumulated in the body as a result of the consumption of food and water and the inhalation of air containing such radioisotopes.

The average values of the dose rates of these three components of environmental radiation lead to a total of about 90 mrad per year to gonodal tissue and bone marrow.

- Space radiation (25-40 %) - (2 filters protection from it - EMF of the Earth and ozone cloud) it varies in connection with fluctuations of solar activity and interplanetary EMF, on the average the person on the Earth by it receives 28 mBER/year;
- Natural radio-activity of ground (granite), air, water;
- Food stuffs - about 25 % NRB.

Thus, in NRB the external irradiation makes 75 %, internal 25 %.

Additional anthropogenic sources of increase NRB for the population:

The contributions to the total dose from man-made radiation will be considered under the following headings:

(1) radiation to patients from the medical uses of radiation;
(2) radiation to occupationally exposed persons;
(3) radiation from "fallout" from nuclear tests;
(4) radiation from other forms of radioactive contamination; and
(5) radiation from radioactive consumer goods and from electronic devices.

Dynamics of changes NRB.

It is investigated since 50th years. Rise of it was in 50th years (reason -mass tests of the nuclear weapon), than - decrease to 70th years (convention about interdiction nuclear tests in 3 environments - now permissible only underground explosions), growth since 70th years (development atomic power stations).

## ACTION of RADIATION ON the ORGANISM

The basic stages of development of radiation injuries:

1. Formation of ionized and excited atoms and molecules which cooperate among themselves and various molecular systems, forming biologically active substances; also they are possible breaks of intermolecular connections (initial or starting processes).
2. Action of biologically active formed substances (free radicals, ions etc.) on biological structures of cells in organism. It is destruction of biosubstances and formation new substances unusual for an organism.
3. Violation of metabolism of biological systems with changes appropriate functions.

The major biological reactions organism at action of radiation.

Information concerning these effects has been obtained from studies of:

a) patients who have undergone diagnostic or therapeutic procedures with X-rays and radioisotopes;

b) occupationally-exposed persons (for example, pioneer medical radiologists, early workers with radioactive luminous paints, workers, engaged in mining radioactive ores, persons who have been involved in accidents in or around nuclear reactors, and persons who have been exposed continuously to low radiation doses for long periods); and

c) members of general populations who have been affected by atomic bomb explosions or tests of nuclear weapons. This information has been supplemented by evidence from extensive animal experimentation. Despite these studies, there are still many gaps in our knowledge and further investigations are needed. The effects can be regarded as falling into two main groups, namely, somatic effects and genetic effects.

All consequences of radiation action on organism can be conditionally divided on SOMATIC effects and REMOVAL effects. Somatic effects are ones at the irradiated organism, removal effects are ones appeared after long time or at future generations.

### Somatic effects

These effects are relatively soon after individuals have been irradiated ("early" or "short-term" effects), or after periods of a few months to several years ("late" or "long-term" effects). A dose of 1000 rad and above of total body irradiation, delivered over a short period of time, results in death within about a week. Doses of 100-1000 rad of total body irradiation delivered over a short period of time can result in damage and death in a proportion of the individuals exposed.

Acute radiation effects can be observed after irradiation of the greater part of the body. A latent period supervenes after initial symptoms of malaise, loss of appetite and fatigue. The length of this period is inversely proportional to the radiation dose received. The end of the latent period is followed by the onset of the illness: early lethality, destruction of bone marrow, damage to the gastrointestinal tract associated with diarrhea and hemorrhage, central nervous system symptoms, epilating, dermatitis, sterility. Pathological acute effects arise after exposure to doses hundreds of times greater than those likely to be received from environmental contamination, except in major accidents.

Much less is known as to the effects of small doses (up to 100 rad), received over long periods of time, yet it is these effects that are particularly important for the population at large. There are many uncertainties here — the variation of sensitivity to radiation with age and the possible reduction in effect per unit of radiation dose as compared with single large doses (over 100 rad).

It is not known whether the linear relationships between radiation dosage and the incidence of harmful effects that are sometimes observed at high dose levels also apply at low dose levels; present estimates of risk from low dose levels are based on the assumption that a linear relationship docs apply and that there is no "threshold" of radiation exposure below which no effect is produced.

At low dosage levels, leukaemogenesis and carcinogenesis are accepted as the most serious long-term risks for the individual. There is also evidence, however, of other late effects following high doses, e.g., cataract formation, and possibly neurological damage and a general shortening of the life span. These are all examples are called <u>somatic effects</u>.

The frequency of different types of tumor has been found to be increased in irradiated populations. This is true of thyroid carcinomas in patients given X-ray therapy to the neck in childhood, carcinomas of the lung in workers engaged in mining uranium ores, haematite and fluorspar, haemangioendotheliomas of the liver in patients injected intravenously with

Thorotrast,' and miscellaneous types of neoplasms in atomic bomb survivors and in patients subjected to radiotherapy.

An increased incidence of cancers occurred in workers engaged in painting watch and clock dials with luminous paints containing radium. They ingested large quantities of radium and radium daughter elements. These radionuclides, which are preferentially deposited in bone, lead in time to skeletal injury and to osteosarcoma in some victims.

It has only recently been possible to attempt quantitative estimates of the incidence of harmful effects (leukaemia and other forms of cancer and certain genetic effects) per unit dose of radiation, and even now the margins of uncertainty are very wide. In general, most knowledge has been gained of the effects of relatively large doses received at high intensity, notably from epidemiological studies of the survivors of Hiroshima and Nagasaki and of patients treated with radiation for ankylosing spondylitis and other disorders. Although these estimates are still imprecise, they are adequate to give a rough indication of dose-effect relationship.

Leukaemia is the malignancy whose rate of induction per rad is best known, and risk estimates are available over a fairly broad range of doses. For lung cancer and all solid cancers — the incidence of which is also clearly increased by radiation — estimates are much more uncertain, particularly as none of the surveys of irradiated people carried out so far has been pursued for a time sufficiently long to exclude the possibility that further cases of malignancies, besides those already recorded, will be observed after longer periods of observation, and because it is not known whether, some twenty years after exposure, peak incidence has yet been reached.

Despite the lack of direct, quantitative information on the sensitivity of the human embryo to irradiation, it is generally assumed that small amounts of radiation may carry some risk of teratogenic effects in man, as in other species. Thus, to minimize the risk of accidentally irradiating an embryo in a particularly sensitive stage of development, the International Commission on Radiological Protection has recommended that radiological examinations of the lower abdomen and pelvis in a woman of reproductive age should be limited, as far as possible, to the ten days following the onset of menstruation; an undetected pregnancy in such a woman is most improbable at this time.

Because of the paucity of human data on the teratogenic effects of graded doses of radiation and the marked variation in susceptibility of animals to malformation with stage in development at the time of irradiation and with known- species differences, it is not possible to estimate precisely the risks of radiation injury to the human embryo and fetus.

Likewise, studies aimed: at detecting teratogenic effects associated with increased levels of environmental background radiation have -given inconclusive.

Data on human populations on ageing and longevity are incomplete. One of the first indications of life-shortening effects of radiation in man' was the observation that radiologists in the USA have a higher age-specific death rate than medical specialists in other fields. This difference implies that occupational irradiation causes a non-specific impairment of health that manifests itself in accelerated ageing. If this interpretation is correct, the lessening of the effect in recent years, during which time there has been increasing attention to radiation safety standards, suggests that the hazard may not be detectable under present working conditions. This is also suggested by the absence of increased mortality in British radiologists.

## Genetic effects

Genetic effects are the results of gene mutations or chromosome anomalies that, arising in the germ cells of the irradiated individuals. Genetic effects are generally detrimental but may have various degrees of severity, from prenatal death to major malformations or mental dysfunctions, to mild impairments of an individual's reproductive performance or of his viability. Because they occur among the descendants of irradiated persons, they are of greater concern to the population than to the individuals actually exposed to radiation. Clear evidence of genetic damage in the offspring of irradiated human subjects is so meager that the genetic harm cannot be quantitatively expressed in terms of the social burden to which a given dose of radiation will eventually give rise. However, the possibility that genetic damage, once induced, may persist for generations must be constantly borne in mind when exposing individuals or populations to new sources of radiation.

There are two types of biological effects of radiation. One is acute, where the amount of damage is proportional to the value of the dose equivalent received by the person. These effects typically relate to high dose levels. This type of biological damage is called a non-stochastic effect of radiation. Sometimes, when controlled, this type of effect may be beneficial to our health. For instance, some forms of cancer therapy utilise high doses of radiation to kill cancerous cells. In our university, large doses causing acute effects are not commonly encountered.

The second types of effects are delayed and statistical (or stochastic) effects. These effects are related to intermediate and low-level doses received by a person. There is no dose-response relationship. The dose relates to a statistical probability of developing a certain effect. The best example is cancer. Exposure to a certain dose can increase the risk of developing cancer. With respect to the foetus, if the dose was received in the first two months of gestation, mental retardation may occur in the offspring.

Radiation is one of the best known carcinogens. Since the last half of the 20th century, our knowledge of this type of cancer has increased dramatically. A statistical proportionality between the level of dose received by a large number of people and the expected effects was proven at a high-to-intermediate level of dose equivalent. Only at much higher doses than those encountered at the University is there a statistical proportionality between cause and effect. A linear extrapolation of this data has been made to low and very low levels of dose equivalent. However, this linear extrapolation method has not been proven scientifically.

Conversely, some studies show that low levels of irradiation are in fact beneficial to our health. However, in the absence of scientific evidence, the regulators adopted a conservative approach and consider all levels of radiation as being damaging to the human body. Because of this, any procedure that involves radioactive materials must abide by a principle called ALARA, keeping all doses 'As Low As Reasonably Achievable'.

<u>All radiating effects divide on:</u>

STOCHASTIC - it is no threshold of harmful action, have probable character - estimated on possible risk - the cancerogenic, mutagen action, hereditary effects, it is difficult investigate in experimental research, it is impossible to establish threshold of harmful action precisely. These effects are basically shown at action of small dozes (when the professional and natural irradiation for life does not exceed 100 BER)

NOT STOCHASTIC (threshold) effects. Weight of defeat depends on doze and it is possible to establish threshold of harmful action and to determine safe levels influence of radiation. All norms of radiation are based on the prevention of these effects. Not stochastic effects are concerned:

1 Sharp radiation sickness is possible at dozes of irradiation at once more than 100 BER (100-200 - easy degree; 200-300 - average; 300-500 -heavy and from above 500 BER - the heaviest).

Dozes 500-600 BER at a unitary irradiation are absolutely fatal.
2. Chronic radiation sickness is possible at long irradiation in a doze less than 100 BER.
3. Beam burns on the skin are possible reaction of 1 degree - at doze up to 500 BER; 2 degrees - up to 800; 3 - up to 1200; 4 - from above 1200 BER.
4. Beam cataract makes up at doze of radiation more than 30 BER per one year.

It is showed, that somatic effects do not arise at observance established hygienic specifications. However if there are not threshold of stochastic and hereditary effects, hygienic specifications can not guarantee their absence.

## GROUPS CRITICAL BODIES. LAW of BERGANIE.

For the development of radiation protection guides, the identification of the particular organs or tissues that are critical because of the damage they may suffer is the essential simplifying step. For example, in the case of radioisotopes of iodine, the critical organ is the thyroid, since the concentration of such isotopes in it, and therefore the dose received, is far greater than for any other organ. Since radioiodine is widely used in medicine and may also be of importance in nuclear energy, the thyroid may often be the critical organ, especially among children.

In general, for irradiation from internally deposited sources, whether alone or combined with external irradiation, the critical organ is determined more by the metabolic pathways of nuclides, their concentration in organs, and their effective residence times, than by inherent sensitivity factors. Depending on the individual radionuclide under consideration, the critical organ may be the gastrointestinal tract, lung, bone, thyroid, kidney, spleen, pancreas, muscle or fatty tissue.

For general irradiation of the whole body, the critical organs and tissues are the gonads (fertility, hereditary effects), the haematopoietic organs, or more specifically the bone marrow (leukaemia), and the eye (cataracts).

The relation between choice of a critical organ and the development of radiation protection guides is not always evident. The position has been summarized as follows: "The dose to the critical organ from any particular mode of radiation exposure does not define the overall risk which will always be greater than this to the extent to which other organs are irradiated. The concept of critical organ is administratively convenient and in some circumstances logically justifiable, but it does not allow summation of risks according to the relative radiosensitivities of the irradiated tissues" (International Commission on Radiological Protection, 1969b).

Law of French scientist Berganie is: radio sensitivity of tissues is directly proportional to its ability to division and inversely proportional to degree of its differentiation. Thus, than more intensively in a fabric or body there are processes of duplication of cells and the less a fabric is differential, the more sensitively it is to radiation. According to this law ail bodies share on 3 groups of critical bodies:

1 - all body, gonads, bodies of blood formation (red bone brain);
2 - all internal organs,
3 - skin, bones.

Based on possible consequences of irradiation the following categories of irradiated people are determined:

**Category A.** It includes medical staff (professionals) and people, who work with sources of ionizing radiation directly regularly or temporarily.

**Category B.** It includes people, who do not work directly with sources of ionizing radiation, but their working places are located so, that they can be exposed to the influence of radionuclides and other sources of radiation, used in the establishments.

**Category C** is population in the whole that is the population of a district, a region or a country**.**

## HYGIENIC NORMATIVES of RADIATION

### Radiation Safety

During the process of obtaining the permit, the radionuclide work procedures will be examined together with other aspects such as the applicant's training, previous work experience with radioactive materials, adequacy of workplace facilities and preparation, dosimeters used, protective equipment, etc.

As explained earlier, it is better to order radioactive materials only when they are needed or as close as possible to the date of the experiment from both an economic and ALARA perspective. This will also reduce the risks associated with long-term storage, source leakage, external irradiation, etc.

There are three essential methods used to minimize external exposure to radiation in radiation safety: time, distance, and shielding

### Time

Reduce the time spend working with radioactive materials as much as possible. A good work practice is to perform the experiment without radioactive material first, to get used to the procedures, and perform the first experiment (if possible) with the smallest amount of radioactive material that will give a readable result. After becoming familiar with the procedures and safe handling of these materials, the quantities used can be increased.

### Distance

The second method involves increasing the distance between the body and radioactive materials. Always store radioactive materials and radioactive waste far from other working areas and/or offices. What if the procedure requires working with radioactive materials close to the body? Whenever possible, especially for strong beta and gamma emitters, use tools. Don't touch the materials with hands unless strictly necessary. However, if hand contact cannot be avoided, manipulation of the materials with gloved hands is required.

### Shielding

Most work with radioactive materials at the University will require that the user be quite close to the material. Therefore, working behind shielding is recommended. As explained earlier, different kinds of shielding must be used for different radionuclides. No shielding is required for pure alpha or pure low energy beta emitters. Plexiglass shielding is required for beta emitters, metal for gamma or X-rays, water, and wax or concrete for neutrons. Large enough layers of air, water, or concrete can protect the human body from all types of radiation.

Always check the effectiveness of the shielding before starting an experiment.

For protection working and the population from radiation there are established the following norms. On influence on critical bodies maximum permissible doses (MPD) radiation are established at external irradiation:

Category A - the persons professionally contacting to radiation -
MPD 2 BER / year (0,2 Zivert / year) or 40 miliBER in week.
Category B - people which are taking place near with sources of
radiation - MPD - 0,2 BER (0,02 Zv / year).
Category C - other population - MPD - 0,1 BER (0,01 Zv / year).

In hygiene all sources of radiation share on CLOSED and OPEN:

- CLOSED source is as radiation acts only in environment (example - X-ray tube);
- OPEN source is in environment can act both radiation, and particles (example - radioactive isotopes).

Principles of radiation safety at work with the closed sources of radiation.

CLOSED SOURCE allocates in environment only electromagnetic radiation such as X-ray or gamma - radiation. Basis protective measures are rules of transmission of radiation:

a) The doze of external irradiation is proportional to intensity and time of action;
b) Intensity of radiation is inversely proportional to a distance;
c) Intensity of radiation decreases depending on thickness of screens.

4 principles of protection from radiation are: 1) protection by amount of doze, 2) by distance, 3) by time, 4) by screens.

There are 5 kinds of screens for protection from radiation:

- Protective containers for storage radioisotopes;
- Screens for the equipment;
- Mobile screens;
- Screens in building designs (walls, ceilings, doors, floors);
- Screens individual means of protection - lead gloves, aprons, etc.

Principles of radiating safety at work with open sources of radiation.

OPEN SOURCE allocates in environment not only x-ray and gamma - radiation, but also streams of radioactive particles (alpha, beta-particles and neutrons). Main principles of protection are:

- Use principles of protection at work with the closed sources;
- Hermetic sealing, automation of the equipment, isolating suits, special boxes and exhaust devices for work with isotopes;
- Special not adsorbing coverings of surfaces, often cleaning surfaces of radioactive pollution;
- The special equipment of ventilation (exhaust ventilation is equipped with filters), water drains (in special sediment bowls), sufficient water supply;
- Special lay-out of premises with the built protective designs; a lay-out of a site - distance radiological laboratories from residential buildings, branches etc. depending on their class (4 classes by annual amount used radioactive substances);
- Careful radiating and medical control personnel;
- Observance personal hygiene and requirements to overalls.