The sources of ionising radiation

Previous chapter: 5.2.5 *Interaction of the ionizing radiation with the atomic nuclei*

People are affected by different doses of radiation originating from a various number of different sources. Generally speaking, the human organism can be irradiated from **natural** and **artificial sources**.

Natural exposure describes the human exposure originating from natural radionuclides and cosmic radiation. Natural exposure is not related to work, industrial activity or therapeutic activity. The natural exposure, with the exception of the inhalation of daughter products of radon ^{222}Rn, cannot cause non-stochastic effects (described in the chapter 8.17.2). The inhalation exposure to ^{222}Rn, and its daughter products related to living quarters, plays a major role in the inner irradiation of human tissue caused by natural radionuclides. Possible protection against natural exposure was for a long time seen as being out of reach, even if it was presumed that the natural radiation played a part in stochastic damage observed in population. This assumption assumed a non-threshold relationship between the dose and the effect was assumed. Most of the natural sources of exposure can be influenced to a certain level. The extent of the influence, its financial cost, and difficulties caused by the efforts to lower the exposure vary greatly.

Outside of the natural sources of exposure, the highest population **exposure limits** are represented by the exposure of people examined or treated with the help of ionizing radiation. In some countries, radiation treatment and examinations are practically the only exposure to humans originating from artificial sources. The doses received from therapeutic and medicinal exposure vary greatly among individuals. Exposure reaches values from almost zero to thousand folds higher than the values reached from natural sources.

Populations living in the **vicinity of nuclear reactors** receive higher doses of radiation than the average exposure calculated for people in general. However the sizes of these doses are low, ranging from 0.1 per cent to a couple of per cent of the dose received from the natural sources.

The sources of ionizing radiation are also being used as a part of everyday use objects. For example the data published at the end of the 1980’s showed a relatively high yearly collective committed effective dose coming from a clock painted with radioactive glowing paint. The doses were as high as for air travel, and four times the exposure in sluice gates at nuclear facilities. SE is used to describe the sum of individual dose equivalents received by the individuals in the monitored group. A number of countries have fire detectors with α-radiation emitters, radioactive glowing pain for the exit sings in buildings etc. The use of these sources of radiation does create a low population dose of radioactivity. The radiation is about the same as current televisions, which are able to sufficiently minimize the originating X-radiation.

Sources of positively charged particles

The most important equipment needed in order to obtain **protons** suitable for radiotherapy is a **particle accelerator**, called a **cyclotron** (description of a cyclotron in the chapter 8.20.4). The cyclotron is used to accelerate protons (or ions and α-particles) to a point, where they gain enough energy (exceeding even the values of 250 MeV) to penetrate the skin and reach any part of the human body. The first experimental treatment with high-energy protons was conducted in 1954. The main reason for using protons in radiotherapy is that the dose is spread much more **evenly** than in the case of photons or electrons. Protons have very well defined range in human tissue and almost no side scattering. The range is precisely defined and spatially a defined maximum of the radiation dose is delivered at the end of the track (Bragg peak). After the Bragg peak there is a sharp decrease of the dose, i.e. very small fluctuation in the range. The depth of the Bragg peak’s location depends on the initial energy of protons and on the material they are passing through.

Main indication for the future use of proton therapy will be tumours located in the close proximity or right inside **vitally important organs**. Also tumours with **irregular shapes** can be treated with proton therapy. New techniques and ways of applying proton rays in medical applications allow the doctors to irradiate tumours in any parts of the human body with large doses of radiation. The surrounding healthy tissue remains protected to a certain extent.

So far the finest instrument for external treatment of tumours located deeply within the tissue is a beam of **heavy ions**. Carbon ions are the ideal ions to use. They move along a straight line and stops in a precisely defined depth. More importantly, the delivered energy gradually increases along the track, reaching maximum at the point of Bragg peak. After that, the energy rapidly decreases within over the distance of a couple of millimetres. Today there are several laboratories all over the world that are able to accelerate the ions of all elements, including uranium, until their energy reaches 1 GeV per a unit of mass, which far exceeds the needs of anti-tumour therapy.

Sources of negatively charged particles

The source of high-energy negatively charged particles is the **betatron**, described in 8.20.2. Current betatrons are able to reach energy values of electrons up to about 300 MeV. The mass of accelerated electron at this energy exceeds the electron rest mass about 600 times. Another way to obtain high-energy electrons is also the use of a **linear accelerator**, described in 8.20.3.

Sources of γ-radiation

In order to minimize the strain on humans by the use of radionuclide, there is an intense need for nuclides with short or very short physical half-life. Very promising results in this area of research were obtained following the introduction of **short-term radionuclides generators**. These nuclides are able to emit gamma radiation, and are described in detail in the chapter „Nuclear medicine“.

Sources of neutrons

Clinical trials in the late 1960s indicated that exposure to **fast neutrons** generated by **cyclotrons** was very suitable for the treatment of certain malignant tumours. Most of these devices uses proton beams that leaves the cyclotron with the energy levels of 42 to 66 MeV, and intensities 15 to 60 microamperes. The proton beam is directed to special therapeutic rooms where they produce neutrons, by the irritation of beryllium targets (p, n).

The clinical results of neutron therapy are very encouraging, especially in the case of some tumours placed in specific locations. For example this therapy is considered **the best course of action for the treatment of salivary glands tumors**.

A very promising new direction seems to be the “**boron neutron capture therapy**”. This therapy uses the fact that some tumors, mainly those located within the brain, tend to **accumulate compounds of boron**. When this area is irradiated, a part of the neutrons is captured by the boron nuclei, which produces α particles with high energy. These particles then fully pass on their energy to the surrounding tumor cells and do not reach the healthy tissue. This is a technique that enables us to significantly increase the radiation dose inside the tumor, while the dose inside the healthy tissue remains unchanged.

Links

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