Radiation Protection of Humans and Biota in the Environment

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Keynote Speaker Address

The evergrowing releases of radioactive substances to the environment in the second half of the XXth century have resulted in a global extra (above background) irradiation of all living organisms in the environment and exposure from ionining radiations has been recognised one of the key radioecological factors on our planet. In addition to a general growth of natural radiation background, in the last decades many territories appeared on the Earth with increased content of technogenous radionuclides having resulted from the discharge of radioactive wastes to the environment due to disposal to the atmosphere and aquatic environment of radionuclides from nuclear industry and nuclear power engineering enterprises. Of special concern in the last decade of the outcoming century became accidental situations in the nuclear power engineering which have led to radioactive contamination of rather extensive areas, with some of them being unsuitable for farming and human residence. The accident at the Chernobyl Nuclear Power Plant in 1986 has been recognised one of the greatest technogenous catastrophes of the XXth century.

The growth of the natural radiation background on a global scale, involvement into the orbit of radiation exposure of ever-growing quotas of people, exposure to doses above the natural background of all the biota on the Earth, all this made the problem of radiation safety extremely topical. While at the beginning of the century problems of radiation safety only referred to relatively small number of people connected with sources of ionising radiation by their occupation (primarily physicians – radiologists and scientific workers), in the middle of the century, after testing of nuclear weapons (especially in the atmosphere) these problems concerned virtually all the population on the globe. In the last two decades, in the period of keen perception by the public of technogenous changes in the biosphere, the question is about the radiation safety of the environment. Therefore, the termination of the XXth and entry into the XXIst century place the task of harmonious exposure from ionising radiations of humans and other living organising (biota) in the environment. This is consonant with the motto of the 10th International Congress of the International Radiation Protection Association – “Harmonization of Radiation, Human Life and the Ecosystem”.

The basic principles of the radiation protection of man are a result from almost century-old theoretical investigations as well as a result of a practical use of sources of ionising radiations. These are best formulated in publications of the International Commission on Radiological Protection established in 1928. The ICRP publications outline problems such as effects of ionising radiations on humans, dosimetry, models of radionuclides transport in the body of humans and present dose limits. The ICRP practical recommendations cover all aspects of radiation safety of man when using radionuclides and sources of ionising radiation. In fact the ICRP recommendations form the basis of laws in many countries on the protection of human health against ionising radiations. Problems of the environmental protection against ionising radiation have become subject of activity of a number of authoritative international organizations (IAEA, WHO, UNSCEAR, etc.).

The need for the analysis of likely impacts of ionising radiations on living organisms in the environment, and not only the consequences of irradiation of man, has prompted a logic way to solve these questions: is it possible to transfer the methodological approaches and principles of the protection of human health to that of nature? The ICRP, as one of international organisations, made the first step in this direction and in 1977 formulated in Publication 26 a thesis which rings aphoristically like this: if radiation standards limiting exposure from ionising radiations protect man, then biota are also protected in the same radiological situations. This thesis in Publication 26 reads:

“Although the principal objective of radiation protection is the achievement and maintenance of appropriately safe conditions for activities involving human exposure, the level of safety required for the protection of all human individuals is thought likely to be adequate to protect other species, not necessarily individual members of those species. The Commission therefore believes that if man is adequately protected then other living things are also likely to be sufficiently protected”.

In the last ICRP Publication which contains the Commission’s recommendations (Publication 60) this thesis has not practically been altered and reads as follows:

“The Commission believes that the standard of environmental control needed to protect man to the degree currently thought desirable will ensure that other species are not put at risk. Occasionally, individual members of non-human species might be harmed, but not to the extent of endangering whole species or creating imbalance between species”.

The basis for the ICRP concept “protected is man, protected are biota” is primarily a high radiosensitivity of man (mammals in general) – it is maximum for living organism representatives on the whole. It is therefore natural that if the most radiosensitive components (mammals) are protected against ionising radiations, then more radioresistant components are also protected. At the same time, the difference in radiosensitivity between man (and mammals), on the one hand, and other relatively radiosensitive biota representatives, on the other hand,

is not large. Thus, one of the discoveries in radiobiology and radioecology in the 50s of the current century was a detection of low radioresistance in woody species (mainly coniferous): radiosensitivity of coniferous species such as pine and spruce – widespread cenosis forming woody species for forests in different zones of the world – is quite close to that of mammals.

Another argument in favor of anthropocentric ICRP conception in the protection of man from ionising radiations is a high priority of the problem of human health protection. In recent years, however, the anthropocentric centre such as the principle of radiation protection came to be considered as debating. As an alternative a thesis is considered that primary is the protection of the environment and if biota in the environment are not subjected to negative effects of ionising radiations, then no harm from irradiation is traced in this environment.

It should be stressed when critically analyzing the ICRP concept "protected is man, protected are biota" that the concept assumes (though not emphasizes de facto) exposure of man and biota representatives to the same doses. This dosimetric pattern of man and biota exposure under real conditions of radioactive contamination of the environment (eg. during radiation accidents with the release of radionuclides into the environment) is, however, incorrect. In most radiological situations exposure doses to biota (living organisms) are higher than to man, with the difference being sometimes significant (a factor of 50 and more) (Table 1).

Table 1

Biota/man ratio of absorbed doses of irradiation for the South Urals and Chernobyl NPP accidents (first years after the accident)

Ecosystem type	South Urals	Chernobyl NPP
Coniferous forests	7–27	47–116
Deciduous forests	14–57	40–100
Meadows	17–77	45–95
Rodents	1,4–28	30
Hydrobionts	0,02–2,6	–

The above difference in doses of biota versus man exposures is mainly connected with different role of β-radiation in the overall dose burdens to these objects. The importance of β-radiation and its contribution to the overall dose burden in plants and animals is higher because energy of β-radiation in them is absorbed in the "sensitive" volume of biological tissues (in humans β-radiation is absorbed by clothes, upper low-sensitive skin layers, etc.). Man, as opposed to plants and animals, has greater possibilities, such as active decontamination (removal of radionuclides from outer covers), application of active forms of radiation protection (eg, can use protective properties of dwellings, etc.). Consequently, typical for living organisms (biota) and man is a non-equidosal irradiation.

A need should be emphasized in solving a range of dosimetric problems when biota are irradiated. For humans a concept has been developed of effective equivalent dose which considers the non-uniform irradiation of different organs and tissues (say, when radionuclides are taken in with food or accumulated in the body). Unfortunately no analogues dosimetric position exists in the dosimetry of ionising radiations in biota.

In recent years marked tendencies are evident towards the need for an isolation of the problem of radiation safety of the environment from that of radiation protection of man. The arguments in favour of an independent analysis of radiation protection of the environment are as follows:

- occurrence of real situations when man is not a component of the environment, so there is no problem of human protection while a similar task in relation to biota persists;
- criteria for radiation protection of biota and man may differ significantly and in this case difficulties are inevitable when comparing potentialities of radiation safety of man and biota simultaneously;
- there are large difficulties in comparing risk from the effects of different components on human health

and living organisms (relative to ionising radiations effects). It should, however, be taken into account that in real situations in most cases we deal with a combined effect of ionising radiations and factors of non-radiation nature.

An independent problem in radiation protection of the environment is criteria for assessing radiation consequences. As far as radiation safety is concerned, the ICRP has developed a harmonious system of definitions of irradiation impacts (non-threshold linear concept of biological effects of ionising radiations, despite a constant criticism of the concept, isolation of deterministic and stochastic irradiation effects, system for determination of collective and individual exposure doses, risk – benefit theory when ionising radiations are used). A characteristic feature in the ICRP activity in assessing consequences of ionising radiations effects on man is in recent years orientation towards protection at an individual level.

If we analyze the system of criteria for radiation protection of components of the environment, the attention is focused on the population and ecosystem levels. In accordance with the recommendations of the Rio Conference (Rio Declaration), much attention is paid to the preservation of biodiversity in living nature as one of the most representative indicators in the assessment of technogenous changes in the environment.

Extensive experimental information is now available in modern radioecology on the effects of ionising radiations on various natural and agricultural ecosystems. These data cover the results of observation within a wide dose range – from relatively little above the natural radiation background to absolutely lethal for living nature. Unfortuantely in serious radiation accidents, among which are the South Urals accident at one of nuclear industry enterprises (1957) and the accident at the Chernobyl NPP in 1986, factors of severe radiation damage to nature have been reported (death of individual ecosystems and entire populations of plants and animals) at very high dose rates and cumulative doses. The results from these observations significantly stimulated interest in radiation alterations in the environment and emphasized once again importance of biota exposure to ionising radiations.

Apart from the situations connected with accidental radionuclides releases to the environment as a result of nuclear enterprises activity, an independent problem in the radiation protection of man and biota is management of radioactive wastes and their storage. Of great concern in this case is the uncertainty of consequences of a long-time storage of radioactive wastes, particularly long-lived and containing α-emitting nuclides, taking into account the probability that these radionuclides can be transferred to the environment and involved in the biological migration chains. And it is precisely influence on biota that is of special importance, since it is possible to achieve situations in waste storage when radioactivity-man contacts are excluded. This enhances the arguments in favour of an independent analysis of radiation protection of the environment when dealing with radioactive wastes. Of course, quite understandable is the public's concern regarding a sound assessment of waste management damage.

If the problem of harmonization of relations between man and sources of ionising radiations is to be solved in the aspect of radiation safety of the populations of living organisms, then only an integrated approach to the system "sources of ionising radiations – man – biota (the environment)" can yield satisfactory results.

An independent consideration of the problem of radiation safety of biota in the environment has generated a need for establishing exposure dose limits for some representatives of plants and animals.

Some quantitative criteria have been currently suggested by a number of international and national organizations for the permissible irradiation of biota in its environment. According to IAEA, the permissible dose rates under chronic irradiation of any biota representatives amount to 10 mGy/d (4 Gy/year). According to UNSCEAR these dose rates for plants are 10 mGy/d (4 Gy/year), animals 10 mGy/d (4 Gy/year) for mortality in the population and 1 – 2,5 mGy/d (0,4 – 1 Gy/year) – for disturbances in the reproductive cycle. In the USA the following permissible dose rates were suggested and discussed: hydrobionts – 10 mGy/d (4 Gy/year), terrestrial plants – 10 mGy/d (4 Gy/year), terrestrial animals – 1 mGy/d (0,4 Gy/year).

Natural is to compare these permissible according to the present radioecological views exposure doses to biota with the similar standarts adopted by the ICRP. It seems reasonable to think that during chronic exposure in the environment at a dose rate below 1 mGy/day no significant deviations in plant and animal populations (even most radiosensitive) are to be expected. According to the recent ICRP views, the minimum permissible exposure dose for man is 1 mSv/year for critical groups of the population. It may be said with a high degree of probability that in the environment with all conditions suitable for human life at a dose of 1 mSv/year, similar doses to biota in the same area will hardly exceed 1 mGy/day (even with the account of nonequidosal irradiation of biota and man, i.e. markedly higher irradiation of plants and animals, as mentioned above). In this respect, in the context of modern quantitative assessments of biota radioecology, on the one hand, and humans radiobiology, on the other hand, the ICRP thesis "protected is man, protected are biota" remains valid.

Returning to realities, the critical groups of the population considering the recent ICRP recommendations will receive exposure doses noticeably below the permissible 1 mSv/year. So, allowance for real conservatism in dose limits to biota increases by a factor of 10-100. Nevertheless, even in these optimistic calculations, we must be very careful in our predictions – we need to take into account ecological processes of radionuclides concentration, possible creating of combine effects of some damaging factors (in addition to ionising radiations),

possible existance of synergetic and additive mechanisms of ecological agents.

If the question was raised of a harmonious radiation protection of man and biota within the framework of unified conceptual views, it appears reasonable to solve the following tasks:

- which way the unified permissible dose limits for man and biota should be related;
- what principles must form the basis of endpoint effects of man and biota exposure (individual or collective conceptual indicators);
- how to achieve optimum in ensuring radiologically and socially acceptable risks for man and biota on exposure to ionising radiation;
- which way to estimate a combined effect on man and biota of a number of ecological factors (including ionising radiations).

The present day situation in the biosphere of our planet at the beginning of a new century and millenium in a radioecological aspect taking into account potential development of nuclear power engineering as one of the main sources to meet growing energy needs of the public allows a solution of the problem of radiation protection of man and the environment (biota) as an integral whole. It is most likely reasonable to proceed from the provision of unified criteria and principles of radiation safety of man and biota. This enables rational realisation of the ICRP ideas in radiation safety of man, on the one hand, and biota, on the other hand. Just in this will be harmonization in the variety of uses by the mankind of nuclear energy while keeping the environment safe and clean and humans healthy.