



Strahlenschutzkommission

Geschäftsstelle der
Strahlenschutzkommission
Postfach 12 06 29
D-53048 Bonn

<http://www.ssk.de>

**Perspectives for the 6th Framework Programme
in the Fields of Radiation Protection and Health**

Statement of the German Commission on Radiological Protection

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The objectives of the 5th framework programme of the European Commission are sufficiently realistic and, at the same time, ambitious that they will doubtlessly carry over into the subsequent framework programme. Nevertheless there will be certain shifts and changes in emphasis that should be identified early, although they will take definitive shape only during the forthcoming years. A general remark ought to precede the subsequent detailed commentary: The current concepts of radiation protection need to be further developed and improved. Certain deficiencies have been indicated by Clarke in his proposals on "Controllable Dose". Apart from these matters, current and future studies on individual radiosensitivity and potential specific molecular signatures may raise problems – or may open possibilities – that will necessitate new or changed concepts and strategies in radiation protection. In line with these considerations it is proposed that the future framework programme should include efforts to explore and develop conceptual issues in radiation protection.

The subsequent commentary indicates some of the current and emerging topics of special importance:

Molecular radiation biology

There is little doubt that the critical attention to radiation risks will prevail in the near future, and that efforts towards a balanced perception of different risk factors will need to be increased. This will necessitate a clarification of the question, whether and to what extent *radiation specific lesions in DNA* – such as spatially clustered double strand breaks or other bulky DNA lesions – are induced that occur neither spontaneously nor due to chemical mutagens. Further studies on the *relative effectiveness of sparsely and densely ionizing radiations* will be a key element in these investigations; they will have to make increasing quantitative use of *microdosimetric theory*.

The search for radiation *specific molecular signatures* in tumors or in hereditary changes is a closely related issue. There are at present no indications of a break-through in this regard. But even limited findings – such as the preponderance of large DNA deletions in the action of ionizing radiations – will be of great importance as steps towards a molecular radiation epidemiology. This synthesis will be required to overcome the impossibility inherent to conventional epidemiology to recognize low-dose effects in terms of conventional radiation epidemiology.

The exploration of the multitude of *DNA-repair path ways* will retain priority. But there needs to be increased attention towards the elucidation of the influence of *non-repair-related effects* of radiation on cells (e.g. *signal transduction pathways; genetic instability; bystander effects*).

The association between repair and chromosomal aberrations, mutations, radiation sensitivity, and cancer proneness is a focus of current attention. Molecular and epidemiological investigations of this topic need to be accompanied by strategies to account for these complexities in the practice of radiation protection. In this context it will be highly desirable to develop *inexpensive and rapid screening methods* that allow to recognize and quantify *individual radiosensitivity*.

Radiation Physics and Dosimetry

Work on *densely ionizing radiations* will increasingly be a challenge to radiation physics and to dosimetry. This is true with regard to the study of the primary molecular mechanisms of radiation action where molecular biology is beginning to be sufficiently quantitative that *microdosimetric data* are required as a quantitative tool. Densely ionizing radiation will also remain a central topic, because their specific action is the challenge in *domestic exposure to radon*, as well as in the *exposure of air crews* and the radiation risks in *space missions*. In this regard there will be a specific need to combine European research expertise and resources. It will also be necessary to interlink the efforts related to these problems of radiation protection with those required in the development of *heavy ion tumor therapy*. This needs to cover the entire range from the improvement of high energy *nuclear cross sections* to *macroscopic dosimetry*.

There is currently insufficient *dosimetric instrumentation* for use in high energy radiation fields of unspecified composition, and specifically for measurements in *complex neutron fields*. While promising developments – especially in terms of tissue equivalent proportional counters – may be implemented in the current framework programme, there will be a need to continue and expand the efforts. Otherwise politically sensitive issues – such as the transport of spent or reprocessed reactor fuel – will be aggravated by the impossibility of reliable real time dose determinations. There is also currently – and this applies even to the planning of NASA for the International Space Station or to the envisaged Mars mission – no provision for adequate neutron dosimetry, although this will be a highly critical factor.

In the face of a dual and partly inconsistent system of *concepts for the quantification of radiation quality in radiation protection* (quality factor, Q , versus the radiation weighting factors, w_R). The efforts to resolve – in cooperation with ICRP – these issues will need to include a joint effort of specialists in the European partner states.

Individual monitoring may also change its major goal from passive monitoring which only registers exposures to an active monitoring and warning system in order to avoid or reduce exposures e.g. in accidental situations. The *development of new electronic dosimeters* able to fulfill these tasks needs to be supported.

Radiation Epidemiology and Risk Modelling

The *quantification of low dose and low dose rate risks* will remain the central objective of radioepidemiological investigations and risk modelling efforts.

The work on the analysis of the *atomic bomb survivors' data* will need to be continued. This will require continued efforts to link the work of RERF, Hiroshima, and European institutions in terms of exchange of data and the joint use and development of *common statistical techniques as well as software*. Important efforts are currently underway towards the resolution of the "Hiroshima neutron dose discrepancy". This is a highly complex issue that may partly be clarified by atomic mass spectrometry of ^{63}Ni in copper and of other neutron activation products in samples from Hiroshima. But there is now an urgent lack of further samples from Hiroshima and Nagasaki, and also a need for *added methods of retrospective dose reconstruction* to resolve this highly complex issue. These tasks will – due to their complexity – need to be carried over into the next framework programme.

Additionally, *studies on continuous low dose radiation exposure* should be continued in order to compare results from the risk modelling with direct observed risk estimates. Most prominent examples are studies among radiation workers in different countries and studies of persons exposed to cosmic radiation. Moreover, new epidemiological studies in populations exposed to radiation for therapeutic or diagnostic reasons can complete the epidemiological research. Exposures in from diagnostic radiology are at an intermediate level between occupational and therapeutic exposure and should be used for further dose response analysis.

The investigations on the *continuously exposed populations* in the former Soviet Union will need to be extended beyond the results that should be achievable in the 5th framework programme. This will require even closer ways of cooperation and more flexible funding of the Russian partner teams.

Participation in the establishment of *blood, tissue, and tumor banks* – as they are presently being planned in Russian-American agreements – will be an important need to secure a singular source of information on radiation dosimetry, radiation induced health effects, and molecular mechanisms of radiation action.

Data banks

The *European Radiobiological Archives (ERA)* have laid the ground work for preserving and making generally available radiobiological data from the large animal studies that have been conducted in the past. Continued support of this effort will be essential, because similar experiments have, for a variety of reasons, become impracticable, and part of the information has not yet been fully exploited. Reevaluations of the *RBE of different types of photon radiations and of neutrons* are of particular interest. These need to be complemented by molecular studies with newly emerging techniques, and it is, therefore, desirable to *include in the ERA studies with genetically modified animal strains*.

The successful implementation of the ERA suggests the desirability of adding to the European Radiobiological Archives a *bank for human epidemiological data on late stochastic radiation effects*. This data bank will greatly facilitate the intercomparison of the major epidemiological studies on radiation risk, and it will help to generate the openness and transparency which is, in the US, already mandated by the Federal Freedom of Information Act.

Radiation Protection in Medicine

The application of ionizing radiation in medicine contributes considerably to the radiation exposure of man. Therefore *innovative concepts for medical diagnoses* without application of ionising radiation should be developed further (i.e. ultrasonography, nuclear magnetic resonance tomography etc.). In addition, the *diagnostic efficacy of imaging procedures* in medicine should be improved by fusion of functional and morphological images (i.e. scintigraphy with ultrasonography, nuclear magnetic resonance tomography or computed tomography).

In the near future, *reference values* will be implemented *for optimization of radiation protection* in medicine. Up to now, no procedures have been developed to control the effectivity of reference values. This issue should be followed with high priority. With respect to nuclear

medicine therapy, the dosimetric approaches should be optimised (i.e. by precise determination of target volumes with 3D-imaging procedures and/or accurate determination of activity distribution after therapy with adequate measuring devices). In addition, ***biodosimetric procedures*** capable to follow the radiation effects after therapeutic application of radiopharmaceuticals at the level of "critical" organs such as the bone marrow should be improved (i.e. GPA-test, HPRT-test etc.).

Protection against and treatment of medical consequences of ***emergency radiation exposures*** should retain high priority. Here improvements are still possible (i.e. by detailed studies of the prophylactic effects of iodine blockade of the thyroid and of therapeutic measures for decorporation of radioiodine). In the framework of radiation emergency preparedness the experiences gained by the medical treatment of radiation casualties should be collected and evaluated continuously (i.e. by computer based search and retrieval systems).

In the context of risk epidemiology and risk modelling, ***individuals exposed medically by high doses should be followed consequently*** (i.e. children, who have been treated by high-dose radioiodine therapy because of thyroid cancer developing after Chernobyl).

Radioecology and Exposure Modelling

Radioecological aspects should be considered in the 6th Framework Programme. They are of importance to gain a deeper insight into the transport processes of radionuclides in soils and in soil-plant systems and to evaluate the influences of speciation of radioactive materials in the environment onto mobility and bio-availability in marine, aquatic and terrestrial ecosystems. Taking into account the importance of increased human radiation exposure due to natural sources and due to elevated radioactivity in non-nuclear wastes, respective investigations should not only cover relevant radionuclides from the nuclear fuel cycle, but also naturally occurring radionuclides. To be specific, the following topics should be covered:

Given new scientific results available in plant physiology, in soil physics and chemistry and in hydrology, it is timely to develop ***mechanistic models of the transport of radionuclides in soils and in soil-plant systems***. The main emphasis should be put on the dynamics of long-lived radionuclides in soil-plant systems relevant after nuclear routine and accidental releases as well as in remediation of areas affected by uranium mining and milling and in radioactive waste disposal.

The speciation of radioactive materials in the atmosphere and in marine, aquatic and terrestrial ecosystems and the influences of speciation and concurring chemical reactions onto mobility and bio-availability should be investigated both experimentally and by simulations. Emphasis should be given to natural and artificial long-lived radionuclides which are released from installations of the nuclear fuel cycle as well as from other technological sources into the environment and which are transported into the biosphere.

The new demand for the ***surveillance of human radiation exposures resulting from naturally occurring radionuclides*** requires the extension of experimental investigations and the improvement of models describing the transfer of the respective radionuclides from their sources through the environment to man. Here, not only the remainders of uranium mining and milling and related remediation situations should be covered but also the consequences of releases originating from non-nuclear technologies producing waste materials with elevated radioactivity.

Follow-up studies of the radioecological and radiological situations in areas of increased environmental radioactivity after nuclear accidental or routine releases including remainders of uranium mining and milling are important for validating and improving models currently in use for prediction of medium to long-term radiation doses. Therefore those studies should be continued in the 6th framework programme. This has to include the classical medium-lived radionuclides of the nuclear fuel cycle in order to provide a radioecological assessment of present exposures as well as long-lived actinides, fission products and nuclides of the natural decay series to allow for improved predictions of the development of the exposure in the future. In addition, the possibility of retrospective dosimetry provided by long-lived radionuclides such as iodine-129 should be systematically exploited.