

Chapter 6 System of radiological protection

Approaches to protection against ionizing radiation are remarkably consistent throughout the world. This is due largely to the existence of a well established and internationally recognized framework.

The United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) regularly reviews the natural and artificial sources of radiation in the environment to which people are exposed, the radiation exposure due to those sources, and the risks associated with that exposure. It reports its findings to the UN General Assembly on an ongoing basis.

The International Commission on Radiological Protection (ICRP) is a non-governmental scientific organization founded in 1928, which has regularly published recommendations for protection against ionizing radiation. Its authority derives from the scientific standing of its members and the merit of its recommendations. It bases its estimates of the probability of fatal cancer mainly on studies of the Japanese survivors of the atomic bombs and their assessment by bodies such as UNSCEAR.

The International Atomic Energy Agency (IAEA) has a statutory function to establish safety standards, where appropriate in collaboration with other relevant international organizations. In doing this, it relies heavily on the work of UNSCEAR and ICRP. It also has a responsibility for providing for the application of those standards at the request of a State and it does this through various mechanisms, including the provision of services and training.

General principles

For all human actions that add to radiation exposure, or practices, ICRP recommends a system of radiological protection based on three central requirements. Each of these involves social considerations — explicitly in the first two and implicitly in the third — so there is considerable need for the use of judgement.

ICRP system of radiological protection for practices

Justification of a practice

No practice involving exposure to radiation should be adopted unless it produces at least sufficient benefit to the exposed individuals or to society to offset the radiation detriment it causes.

and all reasonable steps should be taken to adjust the protection so that exposures are “as low as reasonably achievable”, economic and social factors being taken into account.

Application of individual dose limits

Optimization of protection

In relation to any particular source of radiation within a practice, the dose to any individual from that source should be below an appropriate dose constraint,

A limit should be applied to the dose received by any individual as the result of all the practices (other than medical diagnosis or treatment) to which he or she is exposed.

In some cases, as for example after an accident that releases radioactive material to the environment or when high indoor levels of radon occur, it may be necessary to intervene to reduce the exposure of people. Under such circumstances, ICRP recommends a system of radiological protection for intervention based on two further principles that mainly differ from the first set in that they omit dose limits for individuals. Specifying limits, however, might require measures out of all proportion to the likely benefit and would, therefore, be in conflict with the first principle. The application of this system again requires the exercise of judgement.

Both systems of radiological protection are endorsed in the International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources or BSS, which are sponsored by the IAEA and five other international organizations.

ICRP system of radiological protection for intervention

Justification of intervention

The proposed intervention should do more good than harm, that is, the benefits resulting from the reduction in dose should be sufficient to justify the harm and the costs, including social costs, of the intervention.

Optimization of intervention

The form, scale, and duration of the intervention should be chosen so that the net benefit of the reduction of dose, that is, the benefit of the reduction in dose less the costs of the intervention, should be as large as reasonably achievable.

The ICRP system is widely incorporated into national legislation throughout the world. In this chapter, we shall concentrate mainly on the system of protection for practices: in later chapters, we shall discuss circumstances in which intervention may be necessary.

Scope of application

Practices are activities involving the deliberate use of radiation. Such uses are clearly defined and can be regulated. On the other hand we can generally do nothing practical to reduce the normal levels of dose from natural radiation, although it is appropriate to intervene when people are exposed to high levels of radon in their homes or at work. For workers, some control also needs to be exercised over exposures to radiation from ores and other materials, such as scales in oil and gas rigs, with elevated levels of naturally occurring radionuclides.

The use of radiation in medicine is mainly a matter of clinical judgement since medical exposures are intended to benefit patients. Setting limits on doses to patients would not be sensible: it might also limit the benefits. However, the principles of justification and optimization, discussed next, should apply in full, particularly as there is scope for reducing individual doses, and the collective dose from medical procedures is high.

Justification of practices

The first requirement in the system of radiological protection for practices emphasizes the obvious need to consider harmful costs in the light of the benefits. In most cases, radiation effects are just some of a number of possible harmful outcomes that make up part of the overall social and economic costs. If there are other ways to achieve the same end, with or without radiation, it is important to analyse the costs and benefits of the alternatives before making a final decision in favour of one or the other.

The issues that arise in the process of justification extend far beyond radiological protection and may be illustrated by the arguments about the *nuclear power* programme. The radiological consequences of the programme include the discharge of radioactive substances to the environment and the doses received by workers in the *nuclear power industry*. In addition, a full analysis would deal with the potential for nuclear reactor accidents, as well as the creation of *radioactive wastes*. Account should also be taken of doses and accidents to uranium miners (who are often in countries other than those using the uranium).

An assessment should then be made of the consequences of doing without the energy provided by nuclear power or of using alternative methods to produce it — with coal for instance. Generating electric power from coal creates large volumes of waste and releases gases that worsen the greenhouse effect. Coal-fired power stations also discharge toxic substances and natural radioactive materials, coal miners suffer

Aerial photo of uranium tailings retention structure, showing the central decant structure and evaporation ponds for removal of excess water Western Mining Corporation/ Australia



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A nuclear power plant

occupational diseases, and there is the potential for mining accidents. A complete analysis would also need to consider several strategic and economic factors: the diversity, security, availability, and reserves of various fuels; the construction and operating costs of various types of power station; the expected demand for electricity; and the willingness of people to work in a particular industry.

Proper justification is also required for the use of radiation in diagnostic medicine. Few of us would question the practice: the benefits are undoubted even though individual doses for some examinations, and collective doses generally, are high. Nevertheless each procedure needs to be judged on its own merits. A mass X ray screening programme for cancer that might cause more cancers than it was likely to reveal would clearly be unacceptable. For this reason, there is unlikely to be clinical justification for the routine screening of employees except in special circumstances, such as the prevention of tuberculosis. Medical irradiation during pregnancy in particular requires clear justification and careful techniques. Radiological examinations for legal or insurance purposes are usually unwarranted since they do not benefit the health of the exposed person.

Practices are proposed from time to time that fail to satisfy the test of justification: these include the production of toys and jewellery containing radioactive material and other devices such as security tags for which there are perfectly adequate non-radioactive alternatives.

Optimization of protection

Since we assume that no radiation dose is entirely free from risk, it is important to pay attention to all doses and to reduce them whenever it is reasonably achievable. Eventually the point must come when further reductions in dose become unreasonable, because social and economic costs would outweigh the value of the reductions. On the other hand, the benefits and risks associated with a particular practice are often not distributed evenly in society, and so this second requirement — the optimization of protection recommended by ICRP — also includes a constraint on the procedure, in the form of restrictions on doses or risks to people so as to prevent inequitable exposures from radiation.

Constraints are imposed on a practice involving exposure to radiation at the planning stage. For workers, the value of the dose constraint should be chosen so as to reflect the annual value of dose that can reasonably be reached in a particular industry or procedure; it may well be a small fraction of the dose limit. For members of the public, a typical constraint, 0.3 mSv in a year, can be used as a planning value for a new source of radiation exposure, such as a factory that intends to discharge radioactive material to the environment.

Optimization of protection has been increasingly influential during the past two decades throughout the world and, in most countries, the average annual dose to

radiation workers is well below (i.e. by a factor of ten or more) the 20 mSv per year that ICRP has recommended. Some groups of workers receive doses a few times the average, and some workers receive more than 20 mSv/a, but the number doing so is a very small percentage of the total. Analysis by UNSCEAR shows that the average annual dose to workers from man-made sources is 0.6 mSv, whereas the average annual dose to workers from enhanced natural sources (e.g. in mining) is higher at 1.8 mSv.

In most countries the annual doses to individual members of the public from practices that cause exposure have been brought below 0.3 mSv in a year — the primary dose constraint recommended by ICRP for the public. Even the groups of people who are most exposed to radioactive discharges from nuclear facilities, because they live nearby or have particular eating habits, typically receive annual doses that are a fraction of this constraint.

Dose constraints or guidance levels are also appropriate for medical exposures of patients, the objective being to minimize doses in a sensible way. Some routine medical procedures can give significant doses (i.e. several mSv) and, importantly, can vary greatly from hospital to hospital. The use of guidance levels can provide a practical means of reducing doses to patients without a reduction in the diagnostic information available to physicians.

International dose limits and constraints (mSv/a)

Limitation of doses

The third requirement for practices is an obligation not to expose individuals and their descendants to an unacceptable degree of risk. This is fulfilled by imposing strict dose limits and applying the principle of optimization of protection. The BSS specify dose limits for workers of 20 mSv per year (averaged over a five-year period, with no more than 50 mSv in any year) and for members of the public of 1 mSv in a year.

Parameters	Workers	Public
<i>Effective dose</i>		
<i>Prime limit</i>	20 ^a	1
<i>Constraints</i>	— ^b	0.3 ^c
<i>Equivalent dose</i>		
<i>Lens of eye</i>	150 ^a	15
<i>Area of skin^d</i>	500 ^a	50
<i>Extremities^e</i>	500 ^a	50

Notes

- ^a For students and apprentices, three-tenths of these values.
- ^b There are no agreed international values; constraints should be set according to the particular circumstance (e.g. type of industry or operation).
- ^c Prospective value for a single new source of exposure.
- ^d Averaged over any 1 cm² of skin regardless of area exposed.
- ^e Forearms and ankles as well as hands and feet.

**Organizations
sponsoring the
International
Basic Safety
Standards**

Food and
Agriculture
Organization*

International Atomic
Energy Agency*

International Labour
Organization*

Nuclear Energy
Agency of the
OECD

Pan American
Health
Organization*

World Health
Organization*

* denotes
United Nations
Agency

These prime limits, expressed in terms of effective dose, are intended to control the incidence of serious effects such as cancer and hereditary harm that involve an element of probability. Another set of limits, expressed in terms of equivalent dose, is to protect the eyes, skin and extremities against other forms of damage.

There are two common misconceptions about dose limits. The first is that they mark an abrupt change in biological risk, a line of demarcation between safe and unsafe. It should be clear from the discussion on dose and risk that this is not so. It should also be apparent from the fact that there are different dose limits for workers and members of the public. These limits differ because higher risks are deemed more acceptable for workers, who receive a benefit from their employment, than for members of the public, whose risk is involuntary. The second misconception is that keeping doses below the limits is the only important requirement in radiological protection. On the contrary, the overriding requirement is to keep doses as low as reasonably achievable. This is reflected in the increasing emphasis on investigation levels, which are, of course, set below dose limits.

The International Basic Safety Standards

The BSS, published in 1996, are based primarily on the ICRP system of radiological protection described above. These standards lay down detailed requirements for occupational, medical and public exposures, and specify dose limits and exemptions. They also specify requirements for ensuring the safety of radioactive sources and for dealing with nuclear emergencies. IAEA Safety Guides give more detailed guidance on how the requirements should be met in particular situations. Most countries apply these standards in their own legislation and regulatory requirements.

Regulatory infrastructure

The BSS specify technical, scientific and administrative requirements for the safe use of radiation. However, these requirements presuppose that certain basic arrangements are in place to control uses of radiation. These basic arrangements are sometimes referred to as 'infrastructure for safety', and include such things as laws and regulations on the use of radiation and radioactive materials, and a regulatory body responsible for making sure these are followed. In countries with nuclear power programmes, this infrastructure has normally been developed. But this infrastructure is necessary (albeit on a smaller scale) for any uses of radiation, not just nuclear power. Almost all countries make some use of radiation in medicine or industry. Around the time the BSS were published, the IAEA realized that many countries without nuclear power programmes did not have a proper safety infrastructure, and so a major project was initiated to assist them in improving their capabilities to manage these uses of radiation safely.

