Safety standards for high-level waste disposal

Internationally agreed safety principles and technical criteria are being issued

by Gordon Linsley and Ivan Vovk

The intensity and longevity of the high-level radioactive wastes (HLW) generated from the operation of nuclear reactors are such that the wastes must be isolated from the biosphere for very long time periods. This is irrespective of whether they are left with the irradiated fuel or removed from it by physical and chemical processing. Deep geological disposal is currently being adopted in all countries with the need to dispose of HLW as the means for permanently isolating them from man's environment. (See related article in this edition, "State-of-the-art report on radioactive waste disposal.")

In common with the planning of other industrial facilities having the potential to pose hazards to man, it has been necessary to develop safety criteria or safety goals for the design of underground repositories for the final disposal of HLW. It must be demonstrated that these can be satisfied before any proposed design is accepted.

The criteria for protecting man against the hazards of ionizing radiations are well established. However, the disposal of HLW presents certain problems which are not addressed in normal radiation protection standards such as the Agency's *Basic Safety Standards for Radiation Protection.** These problems relate to two special characteristics of HLW repositories. These are the long time spans for which protection has to be provided; and the uncertain characteristics of the radiation exposure to members of the public.

Existing radiation protection principles have been established in order to protect radiation workers and exposed members of the public from sources of radiation which are assumed to remain under control for the time periods of interest. In the case of radioactive waste repositories, it is necessary to consider the protection of members of the public at times far into the future, when it can no longer be assumed that the repository will be under any form of control by man. Radiation exposure from HLW repositories is by no means certain to occur, since it is planned that the wastes will be isolated from the biosphere by a series of engineered and natural barriers (the multiple barrier system). At very long timescales, perhaps tens or hundreds of thousands of years after the repository is closed, some radionuclides may reach the biosphere as a result of slow migration following the natural degradation of the waste form and its barrier system. It is also conceivable that radionuclides could be released as a result of some abnormal event, such as an accidental intrusion into the waste vault by drilling or due to an earthquake which disturbs the repository. Although events of this type are considered to be very unlikely, since the repository site will be located to ensure that the chance of their occurrence is very small, it is clear that criteria are needed against which to judge their significance.

Safety principles and technical criteria

These problems have been discussed and debated in recent years by radiation protection and waste management experts. Gradually, a safety philosophy has emerged within which designs of HLW repositories may be considered. In 1984 an Experts Report of the Nuclear Energy Agency of the Organisation for Economic Co-operation and Development (NEA/OECD) set out proposals for extending radiation protection principles to deal with the special issues involved in radioactive waste disposal. It was closely followed in 1985 by a publication of the International Commission on Radiological Protection (ICRP) which endorsed and expanded upon the proposals of the NEA expert group.* The subject has also been considered by expert groups of the IAEA. Their proposals were reviewed by two Advisory Groups and by the Technical Review Committee on Underground Disposal (TRCUD). Finally, a draft report was sent to all IAEA Member States for comment. At the September 1989 IAEA Board of Governors meeting, the report was formally approved for publication as an

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* *Basic Safety Standards for Radiation Protection, Safety Series No. 9, 1982 Edition*, jointly sponsored by the IAEA, ILO, NEA (OECD), WHO, IAEA, Vienna (1982).

* "Long-Term Radiation Protection Objectives for Radioactive Waste Disposal", NEA Experts Report, NEA/OECD, Paris (1984), and "Radiation Protection Principles for the Disposal of Solid Radioactive Waste", ICRP publication 46, *Annals of the ICRP*, Vol. 15, No. 4, Pergamon Press, Oxford (1985).

Agency Safety Standard entitled *"Safety Principles and Technical Criteria for the Underground Disposal of High-Level Radioactive Wastes".**

The Agency's document is generally consistent with the NEA and ICRP documents in the area of radiation protection but it contains additional guidance on the technical implementation of the safety principles. Perhaps the most significant feature of the new Safety Standard is that by virtue of the extensive review and consultation process involving individual experts and the competent authorities of Member States, it reflects for the first time an international consensus on the approach to achieving safety in the underground disposal of HLW.

The special attention that has been devoted to considering potential problems to future generations is an important feature of the developing policies for radioactive waste disposal. However, it should be recognized that in the disposal of non-radioactive wastes from many other industrial and agricultural activities the protection of future generations and the environment must also be considered. Many chemical wastes may be rendered harmless by using chemical methods, but unlike radioactive wastes whose potential hazards decay with time, some types of chemical wastes remain toxic for all time.

The following sections describe the main features of the new Agency Safety Standard.

Safety principles

The two overlying objectives of underground disposal of HLW are to isolate high-level waste from man's environment over long time scales without relying on future generations to maintain the integrity of the disposal system, or imposing upon them, significant constraints due to the existence of the repository (responsibility to future generations); and to ensure the long-term radiological protection of man and the environment in accordance with current internationally agreed radiation protection principles (radiological safety).

To meet these two objectives, safety principles have been formulated as follows:

- ***Responsibility to future generations.*** Principle No. 1 (burden on future generations) requires that the administrative, social, and financial burden associated with radioactive waste disposal be borne by the generations which benefit directly from the exploitation of nuclear energy. It recognizes, however, that the timing of the disposal should take due account of a number of technical and socio-economic factors, for example, the technical advantages gained by cooling during interim storage and in the case of spent fuel, the possible recovery of useful constituents from the fuel.

Principle No. 2 (independence of safety from institutional control) states that future generations should not have to take any action to protect themselves from the effects of waste disposal.

Principle No. 3 (effects in the future) states that the future risks to human health and to the environment from the waste repository should be no greater than those which would be acceptable today.

Principle No. 4 (transboundary considerations) states: Where it is possible that HLW disposal could give rise to radiation exposures beyond the frontiers of the country where the disposal takes place, the radiation protection provided to the population in the affected country should not be less than that provided in the country where the release occurs and be in accordance with international standards.

- ***Radiological safety.*** Although the objective of the waste repository is to isolate radioactive wastes from man, it is recognized that there are mechanisms which at some distant time or at some low probability can result in the release of radionuclides. These have to be considered in safety analyses of the repository and it is necessary, therefore, to have radiological and risk criteria against which the results of such safety analyses may be judged.

The mechanisms of radionuclide release from a disposal site are not the same for all environments, but generally the primary cause is likely to be degradation of conditioned waste and its container by water followed by transfer and dispersal of the radionuclides by movement of groundwater, modified by reconcentration processes. These mechanisms are referred to here as "gradual" release processes since they normally lead to a reasonably predictable radiation exposure pattern in space and time.

Gradual release processes are considered to include all evolutionary processes affecting the disposal, whether they be connected with repository construction, operation, and sealing, or with predictable natural phenomena, such as erosion, vertical movements, etc. Changes in groundwater movement can be one consequence of the initiating events.

Other possible processes are not gradual but occur as random events and may have a disruptive effect on the repository and its environment. Processes such as seismic and tectonic phenomena which modify water flows could be important considerations for disposal in some geological formations, and future human activities such as drilling and mineral exploitation could have direct and indirect influences on some repositories. Disruptive processes could, in some situations, dominate the overall safety assessment of disposal.

Principles No. 5 and 6 are, respectively, intended to apply to gradual release processes and disruptive processes. However, it is important to recognize that the principles are linked and have the same overall basis when expressed in terms of risk to an individual.

Principle No. 5 (dose upper bound). This principle requires that for "gradual" processes, the predicted annual radiation dose to a hypothetical most exposed group of individuals in the population is less than the "dose upper bound" (the fraction of the full dose limit

* To be issued as IAEA Safety Series No. 99 (1989).