Evaluation of protection from geological disposal facilities

A deep geological repository is from a radiological protection point of view a planned exposure situation from which, in fact, no public exposure is expected, although exposures in the far future cannot be ruled out. The repository's purpose is to prevent any exposure to the radioactivity contained in waste. During the justification and optimisation process, the potential radiological exposures that might stem from a geological repository are evaluated and expressed in terms of "effective dose" or "risk" to a "reference individual", that is, an individual with certain average physical characteristics, habits and state of health. Present-day habits and health status of populations, and the current level of health protection provided by radiological standards (as well as by other worker safety and/or public health standards) are taken as benchmarks. These terms and benchmarks are then used to evaluate whether the predicted performance of a given repository configuration provides sufficient protection from exposure.

The ICRP considers that the current benchmarks will continue to be meaningful up to and through the time when the repository is fully sealed, and a few centuries beyond. For individuals and populations who may live in the distant future, however, the ICRP prefers not to affirm that these terms and benchmarks will still have the same relevance as for today; people's health and living standards and habits may change far beyond what we imagine. Thus, today's calculations of effective dose and risk that may result in the long term are used not as predictions of potential health detriment, but as tools aiding to compare design options and to get reasonable assurance that a repository will meet, at the very least, the protective benchmarks of today.

THE GOAL OF A GEOLOGICAL DISPOSAL FACILITY IS TO CONTAIN AND ISOLATE THE WASTE IN ORDER TO PROTECT HUMANS AND THE ENVIRONMENT FOR PERIODS THAT ARE COMPARABLE WITH GEOLOGICAL TIME SCALES. GEOLOGICAL DISPOSAL IS RECOGNIZED BY INTERNATIONAL ORGANISATIONS AS ESPECIALLY SUITED FOR HIGH LEVEL RADIOACTIVE WASTE OR SPENT FUEL IN WHICH A HIGH LEVEL OF RADIOACTIVITY IS CONCENTRATED AND WHICH WILL REMAIN SIGNIFICANTLY RADIOACTIVE FOR MANY THOUSANDS OF YEARS. GEOLOGICAL DISPOSAL MAY ALSO BE USED FOR OTHER LONG-LIVED WASTES, ESPECIALLY WHEN THERE IS A SIMILAR NEED FOR LONG TERM PROTECTION. THE ICRP HAS RELEASED NEW RECOMMENDATIONS FOR THE PROTECTION OF HUMANS AND THE ENVIRONMENT FOR THE CASE OF THE GEOLOGICAL DISPOSAL OF LONG-LIVED SOLID RADIOACTIVE WASTE (ICRP PUBLICATION 122). THESE RECOMMENDATIONS REFLECT THE PLEDGE THAT "INDIVIDUALS AND POPULATIONS IN THE FUTURE SHOULD BE AFFORDED AT LEAST THE SAME LEVEL OF PROTECTION AS THE CURRENT GENERATION". ICRP RECOMMENDATIONS ARE TYPICALLY TRANSPOSED INTO NATIONAL AND INTERNATIONAL REGULATIONS AND PRACTICES IN RADIOLOGICAL PROTECTION. THEIR IMPLEMENTATION REQUIRES A MANAGEMENT SYSTEM INTEGRATING HEALTH, ENVIRONMENTAL, ENGINEERING, SECURITY, QUALITY AND ECONOMIC ELEMENTS. THE APPLICATION OF THE SYSTEM OF RADIOLOGICAL PROTECTION TO GEOLOGICAL DISPOSAL TAKES INTO ACCOUNT THE LEVEL OF OVERSIGHT OR 'WATCHFUL CARE' THAT IS PRESENT AT ANY POINT IN TIME.

June 2013

RADIOLOGICAL PROTECTION AND GEOLOGICAL DISPOSAL

THE GUIDING PRINCIPLES AND RECOMMENDATIONS OF THE INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION (ICRP)

AEN NEA NUCLEAR·ENERGY·AGENCY OECD

RWMC Radioactive Waste Management Committee

CRPPH Committee on Radiation Protection and Public Health

ICRP

The protection of humans and the environment from the dangers of radiation is an integral part of the development of deep underground disposal for the categories of radioactive waste that will remain significantly radioactive for centuries to come and in which a high level of radioactivity is concentrated. This flyer succinctly presents the concepts and principles recommended in 2013 by the International Commission on Radiological Protection (ICRP), a gathering of the foremost specialists in radiological protection. Intended for the interested public, the flyer uses plain language. Those wishing to learn more are encouraged to consult the ICRP Publication 122.

ICRP is an independent, international and non-governmental organisation with more than two hundred volunteer members from approximately thirty countries across six continents. They represent the leading scientists and policy makers in the field of radiological protection. Since 1928, the ICRP has been responsible for the ***International System of Radiological Protection*** *used world-wide as the common basis for radiological protection policy, standards, legislation, regulation, guidelines, programmes, and practice. Recognizing the importance of geological disposal as a societal issue, the NEA Committees on Radioactive Waste Management and on Radiation Protection and Public Health offer this flyer jointly with the ICRP.*

Geological disposal of radioactive waste

The goal of geological disposal is to contain and isolate the waste in order to protect humans and the environment for periods of time that can be compared with geological time scales. Several aspects contribute to the protective solution provided by a geological repository. At great distance from the surface, changes are particularly slow, adding to confidence that the facility can fulfil its mission over the very long term. The geological repository is engineered deep underground, away from the human habitat and the biosphere, limiting the potential for human intrusion. Radioactivity will decrease with time, and any release would be delayed and further diluted by a properly chosen geological formation.

For all these reasons, geological disposal is recognized by international organisations as especially suited for the management of high level radioactive waste or spent nuclear fuel which will remain significantly radioactive for very long time periods (on the order of hundreds of thousands of years) and in which a high level of radioactivity is concentrated. Such waste arises →

principally from the operation of nuclear reactors. Many countries that operate nuclear reactors today are planning and moving toward the construction of geological repositories. Geological disposal may also be used for other long-lived wastes, especially when there is a similar need for long term protection.

The safety of a geological repository is first and foremost the responsibility of its designer and operator under the supervision of an independent regulatory body. Society at large is expected to play an influential role in choosing major options that affect safety, such as the location of the facility and how the facility is to be managed over time. Society is also anticipated to actively participate in the surveillance of the disposal facility.

Alongside proper licensed design and construction, and proper management practices by the repository operator, oversight contributes to protecting people and the environment. Oversight is the general term used by the ICRP for "watchful care" and refers to society "keeping an eye" on the technical repository system and the implementation of plans and decisions.

Oversight is accomplished through a variety of actions, such as direct supervision and control by the regulator and the society, monitoring of the pathways (water, air, soil…) through which radiological exposure potentially could occur, preservation of records and of societal memory of the presence of the facility, etc.

Designers of a repository have to take account of the fact that at any given point in time, the waste will be more, or less, accessible and therefore persons and institutions will have more, or less, opportunity to exercise direct control. The ICRP advises that decisions regarding the oversight of the facility should be discussed with the affected or interested publics.

The ICRP points out three periods of oversight:

- **Direct oversight**. This is only possible when repository galleries are not yet sealed and the waste is accessible.
- **Indirect oversight**. This complements direct oversight and gradually replaces the latter as galleries and the whole repository are sealed and the waste may only be monitored remotely.
- **No oversight**. The loss of oversight is not planned, but it is recognised that it may happen at some time in the future after closure. Repository design should ensure that if oversight diminishes or disappears, this will not lessen the protective capability of the facility.

These foreseen periods of oversight correspond to phases in the lifetime of the repository (Figure 1).

To ensure that the repository continues to play its protective role without relying on human actions or oversight, passive controls are built into the facility at the time of its design and licensing. These 'built-in controls' rely on how the waste is conditioned and on the properties of canisters, engineered barriers and natural geological formation.

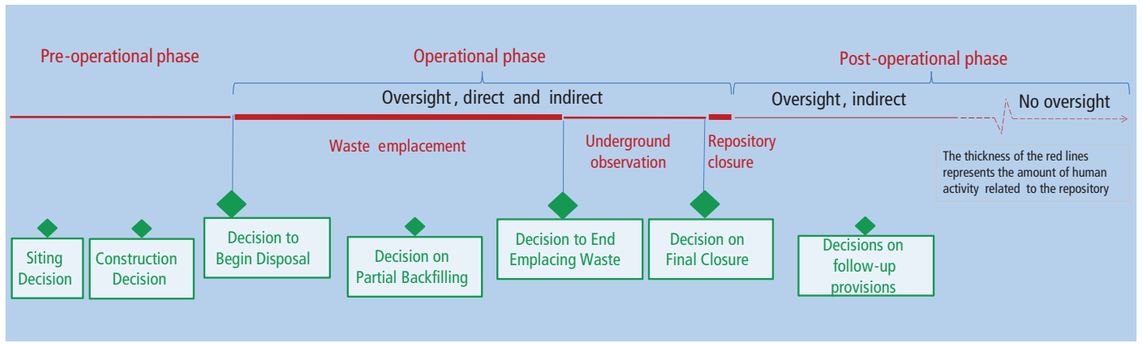

Figure 1: Repository life phases and periods of oversight. The actual duration of each life phase will vary with each national disposal project.

Applying the fundamental principles of radiological protection

The ICRP-122 recommendations reflect the pledge that "*individuals and populations in the future should be afforded at least the same level of protection as the current generation.*"

The ICRP system of radiological protection uses three fundamental principles to address protection now or in the future. Each one of these has a specific meaning in the context of managing radioactive waste:

Justification – *any decision that alters the radiation exposure situation should do more good than harm.*

- This means that, by introducing a new radiation source (starting a new activity), by reducing existing exposure (stopping an activity), or by reducing the risk of exposure (investing resources to achieve protection), sufficient societal benefit should be achieved to offset any detriment caused.
- The ICRP considers that both waste management and disposal are an integral part of the activity that generates the waste. Therefore when the decision to begin or continue operation of nuclear reactors is taken, the justification must also take into account the potential risk to individuals and society from the disposal of radioactive waste generated by the reactors. ICRP advises that this justification should be reviewed periodically over the lifetime of the activity, in particular whenever new and important information becomes available.

Optimisation of protection – *the likelihood of incurring exposures to radiation, the number of people exposed, and the magnitude of their individual doses should all be kept as low as reasonably achievable, taking into account economic and societal factors.*

- This means that the level of protection should be the best it can be under the prevailing economic and societal circumstances.
- The ICRP states that a geological repository must be considered as a functioning nuclear facility throughout its existence. Therefore at the time of design and licensing, its protective capacity must be optimised for all time frames.
- The operator and the regulator must assess the radiation exposures that could result from likely and less likely events that may arise during the facility lifetime under so-called "design-basis" conditions. They must reject any design options that do not allow calculated exposures to remain as low as reasonably achievable below the numerical "constraints" set by the ICRP. The constraint set on effective dose is 0.3 millisievert per year per affected individual; this value is harmonised with the dose constraints for other activities requiring protection from radiation. For assessing less likely events a constraint set on risk is also given, which, again, is compatible with that for other radiological activities. Very unlikely or extreme disruptive events beyond design basis are also taken into account by both the operator and the regulator in their assessments of the future performance of the repository. In addition, the optimisations process has to include features to reduce the possibility of inadvertent human intrusion.
- The optimisation process – namely the process of considering and evaluating options – should be iterative, systematic and transparent. It should include consideration of best available techniques (choice of materials, layout of the tunnels and vaults, etc.) and of economic and societal conditions (e.g., restricted range of potential sites, requirements on retrievability, etc.). The ICRP expects that radiological information will be only one input to a wider decision-making process, which will likely include other societal concerns and ethical aspects and should engage the participation of relevant publics.

Application of dose limits – *the total dose to any individual from regulated sources in planned exposure situations (...) should not exceed the appropriate limits recommended by the ICRP.*

- This is a principle to follow when managing several sources of radiation at the same time. The dose limits recommended by ICRP for the protection of workers is 20 millisievert per year and 1 millisievert per year for the protection of the public. The values set for the dose and risk constraints in ICRP-122 are compatible with these limits.

In the process of justifying and optimising any planned radiological exposure situation, operators and regulators are required to compare scenarios, assessing how much exposure could result under a given set of circumstances, and the health impact that this exposure could produce.