The interface between nuclear safeguards and radioactive waste disposal: Emerging issues

Experts are examining requirements and policies for applying safeguards at geological waste repositories and related sites

by Gordon Linsley and Abdul Fattah

A number of questions arise in considering the application of safeguards measures to radioactive wastes, especially in the disposal phase.

The main concern from the waste management side is that safeguards should not disturb the arrangements made to ensure the long-term safety of radioactive wastes, including spent fuel, in a geological repository. The requirement to safeguard certain nuclear materials must be carried through the entire nuclear fuel cycle to the stage where the materials may be considered to be waste from an economic standpoint. Safeguards must be continued for materials still considered to represent a potential target for diversion for undeclared and non-peaceful uses. At this point, the need to continue safeguarding may conflict with the plans to ensure that waste is managed and disposed of in a way that ensures long-term safety.

In 1992, issues concerning the interface between nuclear safeguards and radioactive waste management were discussed at a meeting of the Standing Sub-Group of the International Waste Management Advisory Committee (INWAC) on "Principles and Criteria for Radioactive Waste Disposal". Discussion at that meeting suggested that the full implications of the need to apply nuclear safeguards are not well understood by the radioactive waste management community. The Sub-Group requested that a working paper be prepared to examine the current safeguards position with respect to radioactive wastes, including spent fuel, from a radioactive waste management perspective. This article is based on that working paper,* which should be seen as one input to a dialogue between the radioactive waste management and nuclear safeguards communities.

Safeguards policy for radioactive wastes and spent fuel

In recent years, the IAEA's Department of Safeguards has worked towards defining a safeguards policy on radioactive waste and spent fuel. A basic consideration in relation to radioactive wastes and spent fuel is whether conditions can be met for termination of safeguards or whether safeguards must be continued indefinitely. Agency documents INFCIRC/66/Rev. 2 and INFCIRC/153 state that safeguards can be terminated once the IAEA determines that the material has been consumed or diluted in such a way that it is no longer usable for any nuclear activities or has become practicably irrecoverable. (It is noted that some regional safeguards authorities, such as Euratom, do not allow for termination of safeguards at all.) It has been suggested that there should be more precisely defined technical criteria based on the "consumed", "diluted" or "practicably irrecoverable" attributes relevant to materials from the nuclear fuel cycle.

In 1988, an advisory group was convened to consider the subject of safeguards related to final disposal of nuclear material in waste and spent

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*The participants in the working group were D. Gentsch from Germany; F. Gera from Italy; S. Wingefors from Sweden; and G. Linsley and A. Fattah from the IAEA.

fuel. It recommended that the IAEA should, in consultation with Member States, undertake to define specific criteria for the termination of safeguards on waste other than spent fuel. The criteria for making determinations of "practicably irrecoverable" should include waste material type, nuclear material composition, chemical and physical form, and waste quality (e.g. the presence or absence of fission products). Total quantity, facility-specific technical parameters, and the intended method of eventual disposal should also be considered.

In relation to spent fuel, the group concluded that it does not qualify as being practicably irrecoverable at any point prior to, or following, placement in a geological formation commonly described as a "permanent repository", and that safeguards should not be terminated on spent fuel. Since that meeting, work has continued in the safeguards department towards defining criteria for the termination of safeguards on wastes and on the development of methods for implementing safeguards for spent fuel in geological repositories.

Principles for radioactive waste management

The main objective of radioactive waste management is to design systems for the handling, treatment, and disposal of radioactive wastes which ensure the protection of human beings both now and in the future. The concern for the future arises because of the long-lived radioactive components present in some types of waste, particularly high-level waste and spent nuclear fuel.

This concern for the long-term has led to the IAEA's development of principles such as the following:

"Radioactive waste shall be managed in a way that predicted impacts on the health of future generations do not exceed levels that are acceptable today." This principle is derived from an ethical concern for the health of future generations. In order to achieve this, the wastes should be isolated from the human environment over extended timescales, and while it is not possible to ensure total containment indefinitely, the intent is that there will be no significant impacts when radionuclides enter the environment. In deep geological repositories, isolation will be achieved by a system of barriers surrounding the waste, some engineered (the waste canister, the backfill material) and some natural (the geosphere, the biosphere).

An additional principle is that:

"Radioactive waste shall be managed in a way that limits the burden on future generations." The ethical principle for this is the premise that the generation that produces waste should bear the responsibility for managing it. The responsibility of the present generation includes developing the technology, operating the facilities, and providing funds for the management of radioactive waste. This includes the means for disposal. Long-term management of radioactive waste should, as appropriate, rely on containment without reliance on long-term institutional arrangements as a necessary safety feature. This does not exclude the possible use of institutional control arrangements, such as, monitoring and recordkeeping, but, because of the timescales involved, the primary reliance for safety should not be on such measures.

Interface issues

The main concern from the waste management standpoint is that any intended safeguards measures should not impair the safety of waste management system. Other concerns, not dealt with here, might include consideration of any additional costs associated with the need to implement safeguards measures.

In the following sections, the concerns with respect to safeguards and waste management are discussed for radioactive waste and spent fuel at various stages to final disposal.

Termination of safeguards on wastes

Following the recommendations of the 1988 advisory group, work on the development of criteria for termination of safeguards on different waste types went on through meetings at the IAEA in the period 1989-90. A set of technical criteria was developed although there were divergent views on the quantity limits. Most of the waste which is generated in the nuclear fuel cycle will fall within the criteria but certain wastes do not meet the criteria. For wastes of this type, which have been conditioned to increase their resistance to leaching, it has been proposed that termination of safeguards could be considered on a case-by-case basis.

Depending on the type of waste, conditioning methods in use include bituminization, cementation, and vitrification. One view is that the waste material, being of low grade, would not be very attractive for diversion purposes and once conditioned using one of the above methods, it would be very difficult to use as a basis for generating significant quantities of nuclear material. When such conditioned waste is emplaced and sealed in a geological repository, the likelihood of it being used as a source of nuclear material is still further reduced. A common view among waste management experts is that safeguards should be terminated at this point or before. On the other hand, it can be pointed out that there is no physical form from which nuclear material cannot be recovered if cost is not important. Technological innovations might provide even easier and less costly means to recover material and potentially these could be applied to materials on which safeguards had been terminated at an earlier time.

At present, there is no established consensus on these latter issues and the formal position of the safeguards department is that safeguards would have to be maintained on certain waste types even after conditioning and disposal.

Conditioning of spent fuel

Conditioning of spent fuel involves immobilization or conditioning of the fuel assemblies either in plants located on the site or elsewhere. These operations are generally carried out under dry conditions. After arrival at the conditioning facility, spent fuel is transferred to a hot cell where it is disassembled. The disassembled components are then put into containers which meet final disposal requirements. In some cases it may be necessary to cut the components into pieces. The important concern here is the need to provide assurance that the fuel assemblies have retained their integrity on arrival at the conditioning facility. The major impact on safeguards is the loss of identity of the fuel assembly as a discrete item for accountancy. The material handling operation which changes the content of spent fuel due to such operations should be followed by measures to verify the nuclear material content. Effective safeguards depend on the accounting practices to verify the content and composition of the material placed into final disposal.

Various safeguards techniques have been proposed for application at a spent fuel conditioning facility; generally, they consist of developments of techniques already available. None of the proposed techniques are likely to cause significant problems from the safety point of view. No destructive verification techniques are foreseen. On the contrary, an effective safeguards system would require care in the handling of the fuel itself and of the resulting disposal packages. However, for certain containers, special attention may be needed to ensure that markings made for safeguards purposes do not cause any negative effect on their long-term corrosion resistance.

It is noted that anticipated safeguards will impose certain requirements on the design and layout of the conditioning facility. This issue needs to be considered by national authorities, the implementors, and the IAEA safeguards department.

Operational phase of a repository

A geologic repository is similar to a mine and consists of access corridors and disposal caverns, excavated deep within the geologic formation. Various supporting facilities are located on the surface over the repository. Shafts provide access to the disposal caverns (drifts). At least three separate types of shaft are envisaged to ensure optimum usage. These are a canister transportation shaft; a personnel and ventilation intake shaft; and a ventilation exhaust shaft. The underground facilities at the repository may be designed to allow further excavation of new caverns, receipt and transport of spent fuel, emplacement, and backfilling of the disposal caverns. Mining operations may be performed on a continuous basis. Following excavation of the caverns, vertical access and emplacement shafts would be opened. Spent fuel would arrive at the repository from the conditioning plant in containers which are prepared for final disposal in surface facilities. The containers would be lowered through a shaft to the disposal level, transported to the disposal cavern, and placed in the emplacement shafts. All operations are expected to be remotely controlled. After the canister has been emplaced, the void space would be backfilled with low permeability material.

When the repository has been filled to design capacity and the room has been backfilled, final decommissioning would begin with the backfilling of all corridors and mine level openings. All shafts would be sealed to restore the formation integrity.

The considerations important to safeguards of a repository are the identification of individual canisters that enter the repository and verification that they remain there until the drift is closed and the repository is sealed.

Since the long-term safety provided by the waste disposal system depends upon the multibarrier system surrounding the waste or spent-fuel operating as designed, it is important that none of the safeguards measures taken to identify, trace, and verify impairs the system. The development of safeguards methods suitable for this phase is still under way. The proposed methods place emphasis on identifying and accounting for the containers entering the repository, maintaining a constant check on movements at all accesses into the repository, and on maintaining a complete knowledge of the design of and changes to the geological repository. It has been pointed out that it is not important to know the exact location of emplaced containers within the repository but only to be able to verify that the disposal container has entered and remains within the confines of the repository.

Most of the proposed safeguards methods would not affect the integrity of the waste container and the surrounding material, although there have been suggestions that geophysical techniques could be used for locating packages within the repository. These methods must not be intrusive and must leave natural geological barriers to radionuclide migration undisturbed.

Post-closure phase of a repository

Geological repositories are designed to provide long-term isolation of radioactive waste. Waste isolation is ensured by a combination of engineered and natural barriers. Long-lived radioactive wastes, including spent fuel, require almost complete isolation for time periods of many thousands of years. Since it is not conceivable that human society will be able or willing to maintain controls on repository sites for many thousands of years, isolation systems are designed to be passive in nature. In other words, the safety of the systems depends on the intrinsic properties of the isolation barriers and not on the existence of surveillance and maintenance procedures.

On the other hand, it is admitted generally that public opinion will demand that some form of monitoring be maintained at repository sites for an undefined period of time. The purpose of such monitoring programmes could be to provide reassurance that the system behaves as assumed in the safety assessment and that no unforeseen events are taking place. Any such monitoring programme should not require activities potentially capable of decreasing the performance of the isolation barriers. Drilling to obtain deep samples or to install instruments within the barrier formations are obvious examples of unacceptable activities. Since monitoring activities are not required for technical reasons but can be justified only on social grounds, it is clearly impossible to make predictions on their duration. We can assume that, at some future time, as a result of a cost-benefit analysis, the monitoring programme will be intentionally discontinued or some major disruption of society will eliminate its justification. In the context of shallow land disposal of short-lived radioactive waste — a disposal option for which safe isolation depends on maintaining institutional control of the site — it is generally agreed that it would not be reasonable to expect institutional controls to last for more than a few hundred years.

On the question of safeguarding closed geological repositories containing spent fuel, the 1988 safeguards advisory group took the view that safeguards cannot be terminated even after closure of the repository. This position then poses certain questions, namely how to design an effective safeguards procedure that has no negative impact on the safety of the disposal system; and how long safeguards should last since the spent fuel will remain a potential source of nuclear material for hundreds of thousands of years.

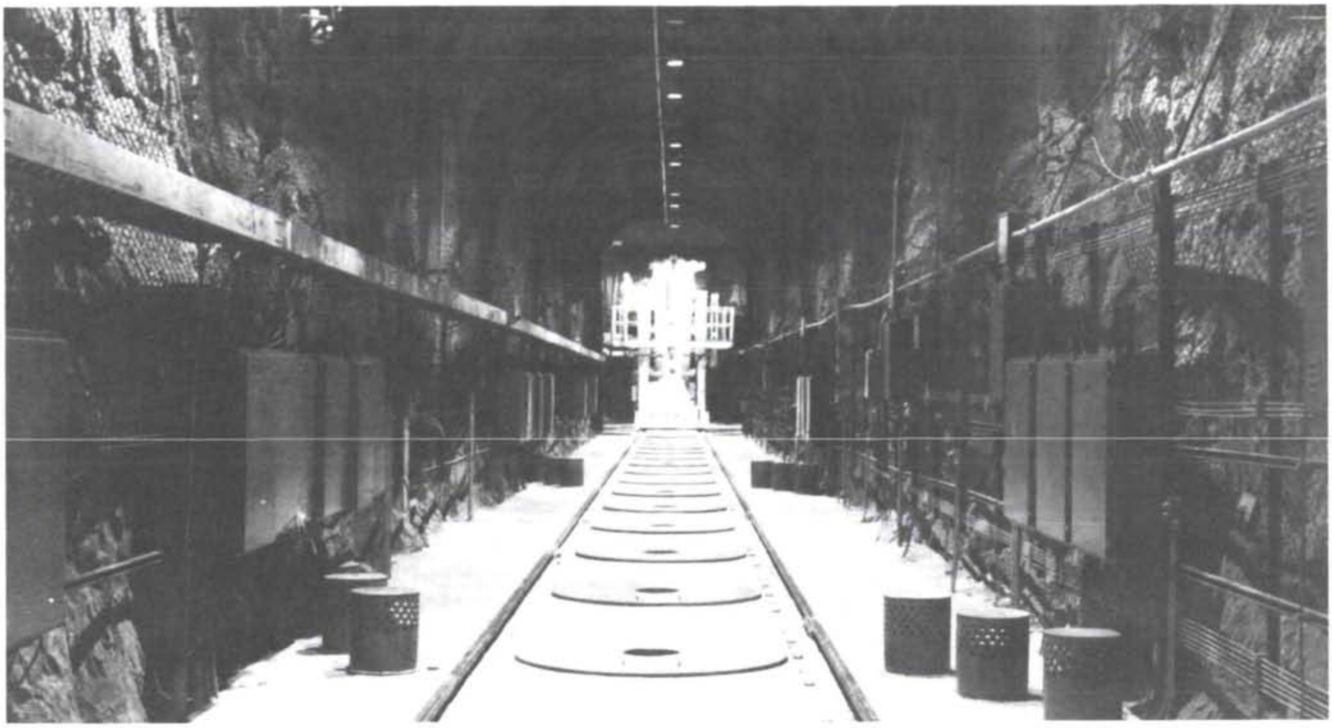
Tentative answers are the following: The repository should be safeguarded without compromising safety features. Since excavation of a sealed repository could not be carried out in a short time, nor made invisible, an obvious approach would be through the analysis of periodically obtained satellite images. Additionally, the above-ground site of the former repository could be subject to periodic inspection by international inspectors. It is also noted that such a safeguards surveillance mechanism would increase the safety of the repository, since it would reduce or remove the possibility of inadvertent intrusion into the repository by humans.

The safeguarding of nuclear material is an important issue for societies today and may continue to be in the future. However, the situation may change in a way which cannot be predicted. Scenarios can be imagined in which the evolution of society makes safeguards an irrelevant issue.

Toward close co-operation

The main purpose of this analysis was to assess the implications of safeguards requirements on the management of radioactive waste and spent fuel. In particular, there was concern that a conflict might exist between safeguards requirements and the main objective of waste management, that is, ensuring that the radioactive substances in the waste are safely isolated from the biosphere as long as necessary to reduce the radiological impacts to acceptable levels.

Provided some conditions are met, the application of safeguards to the management of radioactive waste and spent fuel can be affected without negative impacts on safety. In the first place, it can be observed that the management



Experts are studying safeguards requirements for radioactive wastes destined for disposal in engineered geological repositories. *(Credit: US DOE)*

steps prior to disposal do not appear to present any problem since safeguards procedures are already in effect or could be introduced easily. With respect to disposal, the primary condition is that safeguards procedures must be designed keeping in mind that the safety of the isolation system is an absolute priority. In other words, neither the integrity of the engineered barriers within the repository can be endangered, due to surveillance and control measures during operation, backfilling, and sealing of the disposal zones, nor can the integrity of the natural barriers be threatened, due to surveillance and monitoring after repository closure.

It is assumed that deep geological repositories receiving safeguarded waste material have to be kept under safeguards during the operational phase. From the perspective of waste management, and assuming that the safety system of the planned repository remains intact, safeguarding based on surveillance and control at the surface accesses to the repository (shafts and/or ramps) would cause no difficulties. Similarly, visual inspections underground would be acceptable. However, use of geophysical techniques — which would endanger safety barriers — for locating waste packages inside the repository are to be avoided.

At the present time, no clear safeguards policy for closed repositories containing only wastes exists. Safeguards requirements for the waste-only repositories should therefore be evaluated, taking account of the relatively low concentrations of nuclear materials in the various categories of radioactive wastes and the difficulties of recovering conditioned waste from closed, deep disposal facilities, and then of extracting nuclear material.

For spent fuel in repositories, the IAEA safeguards department's policy is to continue safeguarding after repository closure. In the post-closure period, proposed surveillance techniques such as a combination of satellite imagery and inspections would ensure the continuing integrity of the repository and would not impair its safety system.

The expected duration of safeguards surveillance at the sites of deep geological repositories containing spent nuclear fuel cannot be defined, but, on the basis of spent fuel compositions, safeguarding requirements could last for thousands of years. The acceptance of a requirement for open-ended surveillance of spent fuel repositories raises two issues: 1) a contradiction with one of the objectives of radioactive waste management, that is not to impose a burden on future generations; and 2) the troubling aspect of making economic provisions for an activity of unknown duration and, therefore, with a cost that cannot be estimated reliably.

In order to ensure that safeguards requirements are developed in ways which are compatible with plans involving the long-term isolation of radioactive wastes, experts in safeguards and waste disposal should work in close co-operation. ❐