
Ways of ensuring short/long term safety

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Abstract:

Various strategies have been adopted among countries to manage radioactive waste. The present publication gives to this respect a broad overview of the policies and strategies adopted by Germany, Belgium and France. It appears that these may show remarkable differences, but motivated mainly by political and societal considerations. With regard to safety, practices for waste management are consistent and reflect the broad international consensus that has been progressively established. As an illustration, safety practices and possible specificities for the storage and geological disposal of spent fuel and high level radioactive waste from reprocessing are shortly described.

1 INTRODUCTION

Radioactive waste arises in nuclear power plants, nuclear fuel cycle and waste management facilities, research institutes, industrial plants, decommissioning of facilities and in connection with medical applications. The various kinds of waste differ in volume as well as in their physical, chemical and radioactive properties and characteristics.

Radioactive waste can pose a hazard for man and the environment. Therefore, strategies have been developed to ensure its safe management with due account for providing solutions that are commensurate with the time dependent hazard potential of the waste.

The intent of the present publication is to give a broad overview of the national policies for waste management carried out in three countries, namely, Germany, Belgium and France, with the aim of identifying whether the various options adopted may entail specific issues and difficulties for achieving a high level of safety for waste management. For practical reasons (only some examples can be given here), this publication only addresses waste arising from electricity production, reprocessing as well as from miscellaneous activities (research, medical use, etc.) and focus is given to high level waste and spent fuel when addressing safety issues.

For the purposes of this publication, safety means the protection of people and the environment against radiation risks now and in the future, without imposing undue burdens on future generations. In this sense facilities and activities that give rise to radiation risks are also in the focus of safety. Safety as used here includes nuclear safety, radiation safety, the safety of radioactive waste management ; it does not include non-radiological aspects of safety. As shown in the following, national policies may be different with regard to reprocessing options, management of very low level waste or distribution of waste streams in disposal channels. However safety principles to apply to waste management remain

consistent and reflect the broad international consensus that has been progressively established on this matter.

2 NATIONAL POLICIES FOR WASTE MANAGEMENT

2.1 Waste management policy in Germany

The radioactive waste arising in Germany is, in consistency with recommendations from the International Atomic Energy Agency (IAEA) on the classification of such waste, subdivided into low- and medium-active waste (divided yet again into long-lived and short-lived waste, depending on its half-life) and in high-active waste. However, with regard to final disposal, a further distinction is made in Germany between heat-generating radioactive waste and radioactive waste with negligible heat generation.

The national policy for managing these wastes [1,2] has been greatly influenced by the evolution of the political situation over the last 6 years. The basic document on the use of nuclear energy for electricity production in Germany was issued on 11 June 2001. According to this document, the former Federal government and the utilities agreed to limit the future utilisation of the existing nuclear power plants allowing only an average of 32 years of operation of a nuclear power plant, starting at the beginning of its commercial use. The new policy was enforced by the latest amendment of the Atomic Energy Act which became effective on 27 April 2002. Since, a new political situation has occurred as a result of the latest federal elections that took place on 18 September 2005 and a political coalition came into power. This new coalition however agreed (11 November 2005) to continue a policy of phasing-out of nuclear energy, while acknowledging that the safe disposal of radioactive waste was a national responsibility. A decision on how to progress in radioactive waste disposal within this legislative period (which ends in 2009) must be taken.

According to present day options, spent nuclear fuel is to be directly disposed of in an appropriate facility. Indeed, subsequent to 01 July 2005, shipments of spent nuclear fuel elements to reprocessing facilities are legally prohibited. Thus, only the high level waste coming from the reprocessing of spent fuel which was shipped to foreign reprocessing facilities in France and Great Britain prior to this date is to be managed. As a consequence of Germany abandoning reprocessing strategies and minimizing shipments of spent nuclear fuel, the utilities must construct and operate new engineered storage facilities at the sites of the nuclear power plants or near them (decentralised storage).

Since the early sixties, i. e. from its very beginning, radioactive waste disposal in Germany is based on the Federal Government decision that all types of radioactive waste (short-lived and long-lived) are to be disposed of in deep geological formations within the country. Only solid or solidified waste is accepted for disposal; liquid and gaseous wastes are excluded from the emplacement in a geological repository. The Federal Government is required to provide the resources for disposal.

In line with this objective, the Federal Government is not pursuing any plans for constructing near-surface repositories. In May 2002, the licensing procedure for the Konrad repository - to take in radioactive waste with negligible heat generation - was concluded, but pending legal proceedings are currently delaying emplacement operations. Concerning, the high level waste and spent fuel, the German radioactive waste management concept is being reviewed since 1998. The Federal Government is aiming at establishing a repository in deep geological formations for the disposal of all kinds of waste, including spent fuel assemblies, by 2030. Until 2000, the Gorleben salt dome was explored with regard to its suitability as a

repository, especially for heat-generating waste. But, since then, a moratorium, running for 3 to 10 years, has suspended investigation work until safety-related and conceptual issues regarding final disposal is clarified. This clarification process has not yet been concluded.

Radioactive materials subject to regulatory control may be released from the radiological protection system if their use presents only a minor radiological risk. This procedure is called “clearance” and the corresponding levels of radioactivity concentration are called clearance levels. Details are given in section 29 of the Radiation Protection Ordinance. The clearance may be restricted to certain conditions or specific uses or management routes (conditional clearance) or may be without restrictions (unconditional clearance). The different options for the management of residues and waste from a licensed practice are summarised in Table 1. A criterion for “triviality” for each clearance option is defined in section 29 of the Radiation Protection Ordinance as an effective dose of 10 μSv per year for individual members of the general public, in conformity with the regulations according to Guideline 96/29 Euratom.

Under regulatory control			Conditional Clearance			Unconditional Clearance
Disposal	Recycling	Reuse	Disposal	Recycling	Reuse	
Deep geological disposal of radioactive waste	Production of waste containers and shielding plates used in the nuclear field	Equipment, tools and components in nuclear facilities	As conventional waste (incineration or municipal landfill disposal)	As secondary raw material (e.g., use of scrap for general melting or special products; recycling of building rubble)	Equipment, tools and components	No conditions on treatment or use after clearance (incl. reuse, recycling, disposal)

Table 1 :Management of residues and waste from a licensed practice

2.2 Waste management policy in Belgium

The Belgian classification of radioactive waste derives from considerations of predisposal operations and long term management (disposal) [3].

For predisposal purposes, the following categories were identified :

- *Low level waste* is radioactive waste whose contact dose rate (dose to which an individual is exposed when in contact) is less than 5 milliSieverts per hour. This category arises from nuclear power plants operations, from the use of radioactive sources in medicine, agriculture and industry, and in particular from the decommissioning of nuclear facilities that have been closed down. These include filters, resins, protective equipment (clothing, gloves, and so on), paper, biological waste, activated concrete, residues from the processing of waste water in nuclear power plants and also decommissioning waste that has been in contact with radioactive substances.
- *Medium-level waste* is radioactive waste whose contact dose rate is between 5 milliSieverts and 2 Sieverts per hour. Most of this category comes from the production and reprocessing of nuclear fuel and from decommissioning activities. Some filters and resins from nuclear power plants also belong to this category.
- *High-level waste* is radioactive waste whose contact dose rate is greater than 2 Sieverts per hour. This type of waste emits heat.

The objective for waste treatment and conditioning is the transformation of radioactive waste into a stable end product, ready for intermediate storage and/or final disposal. It requires the use of appropriate technical processes involving incineration, pre-compaction, super-compaction, mechanical and thermal size reduction techniques for solid wastes and flocculation and evaporation for liquid wastes. Residues from the treatment of the various radioactive waste categories are encapsulated in one of three possible matrices: cement,

bitumen or glass. The discharge of effluents produced, such as the flue gas of the incinerator or wash water of filters is based on the dilution in the immediate neighbourhood of the very small fraction of radioactivity present in the discharged effluents in accordance with the specifications applied to it.

All the conditioned waste that is produced in Belgium will be stored on the site of Belgoprocess (region Mol-Dessel), until a long-term solution is implemented.

For disposal purposes, ONDRAF/NIRAS has adopted a classification of radioactive waste based on three categories depending on its activity level and life span : *Category A waste* (low or medium-level and short-lived waste) is conditioned waste of sufficiently low activity level and with a sufficiently short life span (= 30 years) to allow surface disposal ; *Category B waste* (low or medium-level and long-lived waste) consists of conditioned low and medium-level waste contaminated by long-lived alpha emitters in quantities that are too great for this waste to be classified as category A, but which emit too little heat to belong to category C. This waste may also contain varying quantities of beta and gamma emitters ; *Category C waste* (high-level short or long-lived waste) includes all conditioned high-level waste containing significant amounts of beta and gamma emitters with a short life span and large quantities of long-lived alpha emitters. Because of the high activity level, most waste in this category emits considerable amounts of heat (more than 20 Watt/m³).

In May 2006, ONDRAF/NIRAS has issued a report allowing the government to take an informed decision concerning the disposal of low and medium active short-lived waste. The council of ministers of 23 June 2006 decided that the low and medium active short-lived waste may be disposed of in a surface disposal installation on the territory of Dessel municipality. This decision makes possible to engage the next phase of the program so that a disposal installation may be realized concretely. The disposal of category B and C waste has been a matter of investigation for over 25 years. The research carried out by ONDRAF/NIRAS, with the collaboration of SCK•CEN (the Belgian nuclear research centre in Mol) and several engineering offices and universities, must determine whether disposal in the poorly indurated layers of clay (such as the Boom clay in the north-east of the country) can guarantee protection of man and his environment in the long term. Although first conclusions on the matter are positive, research will continue for several years before a decision can be taken and a social dialogue must be started.

Clearance of waste is permitted by the Belgian regulation. Clearance levels are defined in the Royal Decree of 20 July 2001 (in conformity with the levels of document RP 122 from the European Commission). Other levels may be authorized by the Federal Agency for Nuclear Control (FANC), in particular for decommissioning. The procedures for clearance and measurement techniques will have to comply with the directives of FANC, which are presently under development.

2.3 Waste management policy in France

France has adopted a classification of waste that comprises categories that are fairly comparable to the Belgian A, B, C classification scheme. There is however a subdivision of these waste according to their activity level and half- life, leading to identify 6 different categories of waste at present time, as shown in table 2 (extract from [4]). These categories are not defined upon generic levels of activity but with respect to their management channel. Hence, the characteristics of the waste belonging to each category depend on the waste acceptance criteria derived from safety assessments of the facilities that may receive the waste.

Half-life / Activity level	Very short lived (half-life < 100 days)	Short-lived (half-life < 30 years)	Long-lived	
Very low level (VLLW)	Management by radioactive decay	Dedicated surface repository (Morvilliers repository) recycling technologies		
Low level (LLW)			Dedicated subsurface repositories under study	
Intermediate level (ILW)		Surface disposal (Aube repository) except tritiated waste, sealed sources (under study)	Technologies under study under article L.542 of the Environment Code (law of 30 December 1991)	
High level (HLW)		Technologies under study under article L.542 of the Environment Code (law of 30 December 1991)		

Table 2 : Radioactive waste classification scheme in France

The spent fuel is not considered to be waste since it contains valuable energetic resources and France has opted already in the early seventies for the reprocessing and recycling of spent fuel. Options for direct disposal of spent fuel have nevertheless been studied so as to account for possible changes of reprocessing policy in future, though not envisaged at present.

Due to its large nuclear energy programme, France has the full spectrum of radioactive waste to be managed. Very low level waste (VLLW) and low and intermediate short lived waste (LILSLW) benefit today of disposal channels in surface repositories, however of different design so as to provide for the different hazard potential of these two categories (simple “trench like” design of the Morvilliers centre that receives VLLW, of activity levels fairly comparable to internationally recommended clearance levels, engineered design for Centre de la Manche and Centre de l’Aube that receive LILSLW and that must provide for containment over a 300 year period). The intermediate long lived waste and the high level waste have not yet disposal channels available. Policy for their management was defined by the Law of 30 december 1991. This Law considered that a 15 years period was to be allowed for progresses and researches to be implemented on HLW management possibilities. The law required to carry out in parallel investigations on three possible directions for HLW management : a search for solutions enabling the separation and transmutation of long-lived radionuclides contained by the wastes (direction 1) ; a study on the possibilities of reversible and irreversible disposal in geological formations, in particular through the construction of underground laboratories (direction 2) ; a study on processes for the conditioning and long-term storage of HLW in near surface facilities (direction 3).

The government was to report every year on the progresses and researches made in these three directions and to address to the parliament a global report of evaluation in 2006 at the latest with, if appropriate, a project of law on the creation of a Centre for the disposal of HLW. Besides directions 1 and 3, the law brought new perspectives for HLW disposal, accounting for the reversibility of a disposal on one hand, and implicitly positioning underground laboratories as a distinct and preliminary phase in the process of qualifying a possible HLW repository in a geological formation. Within the time frame set by the law, one underground laboratory was constructed in eastern France to study the feasibility of a deep geological disposal in a clay formation. The process has come to an end in mid 2006 and a new law on radioactive waste management was recently adopted (28 june 2006: *Programme Act on the sustainable management of radioactive materials and wastes*). This law sets a new road map

for waste management, establishing in particular a milestone in 2015 for the creation of a deep disposal facility that would be set in operation in 2025, the assessment in 2012 of industrial prospects for transmutation (studies on this matter should be made in close connection to those carried out on reactors of new generation), the creation in 2015 of new storage facilities or the modification of existing ones so as to provide appropriate capacity with regard to the implementation of the adopted waste management policy. Among other issues, the new law also set plans for the creation in 2013 of a new disposal centre for graphite and radium bearing waste. It finally establishes the need for implementing a national plan for the management of all radioactive materials and waste.

The volumes of waste and spent fuel to be managed in the three countries are indicated in table 3.

The former presentation of national situations shows significant differences in preferred policies for waste management. It should be made clear however that these differences are driven by political and social concern but not by safety, which can be ensured whatever policy is implemented if internationally agreed safety principles are applied to the various steps of waste management, as shown in the next section.

	VLLW	LILSLW	ILLW (B)	HLW (C, heat emitting)	Spent Fuel
Germany	3 10 ⁵			3700	24000
Belgium	70500		8900	250 to 2100	0 to 4450
France	6.5 10 ⁵	1.5 10 ⁶	80 000	2500 to 7500	0 to 10 ⁵

Table 3: Orders of magnitude of waste volumes (m³) to be managed in Germany, Belgium and France (projection over life time of power plants installed at present)

3 SAFETY ISSUES FOR WASTE MANAGEMENT

The waste management safety strategy recommended internationally and applied in the three countries addressed in the present publication is to concentrate and contain the waste, meaning that it is kept apart from man and his environment.

This strategy offers two alternatives. The waste can be placed and stored in a suitable facility where its separation from man and the environment is ensured by a series of barriers which require controls, maintenance and supervision. However, for high level and long lived waste, a very long period of containment and separation is required to allow decay of the waste to levels that would not lead to unacceptable consequences if containment is lost. For ethical and technical reasons, a system for the safe management of radioactive waste that requires active measures and maintenance by future generations over a very long time period cannot be considered to be a sound practice. Thus, storing the waste can only be a temporary solution. Thus, the waste after a possible period of storage will have to be shipped to a disposal facility, which involves placing the waste within a series of barriers, both engineered and natural, in a way that achieves the necessary containment without a requirement for active controls, maintenance and supervision in the long term. Such a disposal solution is said to provide 'passive safety'. Disposal is accepted at international level in conventions and resolutions as a necessary end phase in the safe long-term management of radioactive waste. While disposal implies that there is no intention to retrieve the waste beyond a given

point in time, it needs not preclude the option of retrieving the waste over a certain period. For the sake of completeness an option that involves destroying the radioactive waste, e.g. by transmutation of the radionuclides, is viewed by some as a possible management solution for high-level and long-lived waste, but at present time, there is no evidence that transmutation can be a complete substitute for the other options, as addressed further in this publication.

Whatever stage of waste management is considered (treatment, conditioning, transport, storage and disposal) the overriding safety principle that applies is defence in depth. This principle consists in ensuring containment through the implementation of multiple “lines of defence” that can either be physical barriers and operational dispositions (control, maintenance, supervision), so that radioactivity and radiation stays contained even if one or several lines fail. Designing facilities upon this principle thus implies that all processes and events that may lead to dysfunction of the system are analysed and that appropriate means are implemented to compensate the possible loss of lines of defence.

For storage facilities, this requires the systematic analysis of hazards of internal and external origin such as associated to waste handling, fire and explosion, criticality, gas emission, thermal output, corrosion, mechanical disorders, irradiation and contamination, loss of dynamic confinement as well as linked to disruptive events (earthquakes, flooding, extreme weather conditions). It is usually required from the waste package itself to provide for containment for a series of perturbations associated to the events and processes previously mentioned, and to show favourable properties so as to minimise the occurrence, extent and consequences of these perturbations. These favourable properties are described in [5]. Among the main issues of safety to be dealt with for high level waste are the waste handling that must be remote for all waste to avoid irradiation, with a particular attention paid to the reliability of systems to avoid dropping waste and the necessity for high efficiency filtration in case of activity release, fire and explosion protection but mainly from external source (except for some waste that may produce hydrogen from radiolysis), heat evacuation for spent fuel and vitrified waste and criticality. One essential matter is to provide adequate design and control to avoid the loss of tightness of the waste package since this waste must be contained for a given period of time e.g. as a legal requirement or for retrieval. Finally, the radioactive content is such that an adequate design of the facility against disruptive events is required.

An important feedback on waste storage exists today and shows that safety issues mentioned above can be adequately managed, whatever waste type is considered. The “long term storage” that may be required for some waste or spent fuel to allow their thermal decay does not really bring new issues (even if enhanced robustness of waste package and facility design maybe looked for so as too reduce maintenance needs over a long period, studies that were conducted did not identify a specific issue that could not be dealt with when applying present practices of storage, nor that a new facility is specifically needed for this purpose). Whatever period of time is set for designing the facility, there will always be an obligation to control and periodically reassess the safety of the facility so as to make sure that at anytime, the waste can be retrieved safely from the facility.

For the disposal of the high level waste and spent fuel, the same considerations as above are to be accounted for but long term safety requirements entail specific design issues. There is indeed the need to find optimal design options allowing for safe operations, including needs for control and for preserving the possibility to retrieve waste during a certain time (“operational” period or extended “reversibility” period) together with the emplacement of barriers of particularly high tightness to ensure containment of the waste over thousands of years. The latest studies of deep disposal feasibility and expert reviews [6,7] have raised the following issues :

- *heat evacuation and limitation*: as for storage, the heat from spent fuel and vitrified waste must be evacuated with a particular constraint in limiting temperature in disposal vaults (today's studies for host rocks clay and salt indicate that this temperature should remain below 100°C in clay and 200°C in salt so as to minimise perturbations and stay within conditions for which the knowledge of facility evolution is accessible). This calls for special dispositions that must be efficient over some thousand years. It necessitates a dilution of thermal power of the waste inside the underground vaults that has strong effects on the design. Thus, it is not the volume of waste that is the major parameter governing the surface area of the facility needed for safe disposal of these waste but the thermal characteristics. Due to this need for diluting power, a facility for the disposal of spent fuel only would not be much smaller than one for reprocessed waste. Also, the temperature criteria cannot be met readily for disposal of spent fuel coming out directly from cooling pools or vitrified waste from the process unit. There is a need for interim storage to cool the waste in a more appropriate way than could be offered by the disposal facility and this for a period of 30 up to a hundred years. Mox fuel is to that respect the most constraining material and the trend to increase burn up will not relax this constraint. This shows that respecting a safety criteria on temperature in disposal has strong influence on the industrial aspects of waste management prior to disposal, particularly for spent fuel,
- *handling aspects*: there are common requirements to storage and disposal on this aspect but the recovering of waste that may drop incidentally in a drift or a vault is more difficult, due to the lack of easy access to the infrastructures. This may lead to develop new remote control equipment and specific design of waste package. The preservation of some ability to retrieve waste together with obtaining a high confinement capacity of the vault over the long term necessitates particular development for handling of vitrified waste and spent fuel and may lack feedback from other facilities (in particular horizontal handling),
- *the gas evacuation* from ends and hulls and technological waste is also an issue that is more constraining than for storage. It may lead to specific waste package requirements, especially for waste from reprocessing,
- *the resilience to corrosion* is essential and more constraining than for storage. In particular, the requirement for retrievability over some hundred years (without easy monitoring of the evolution of waste package inside the vault) and the requirement for water tightness of canister during the thermal phase (some thousand years) calls for particularly robust design and also needs elements of demonstration that are not fully available today. The requirement is slightly more stringent for spent fuel,
- *the resilience to leaching* is of course a feature that is favourable for ensuring long term safety. To this respect, vitrified waste and spent fuel show obviously very good properties, spent fuel leaching being nevertheless somewhat more complex to assess and comprising a part of activity that might be instantly released if the canister breaches. The intermediate level reprocessing wastes show rather large uncertainties in their long term performances that require at the time being very conservative values to be selected for assessing a source term. However, they contain less activity so they finally are not necessarily major contributors to releases in and outside the facility in the long term,
- *criticality* in the long term is also a new issue and requires specific studies (though not considered today as being a first rank risk). It concerns mostly spent fuel.

Long term safety assessment that have been realised at present raise also new issues when compared to the experience acquired in other nuclear facilities (in terms of chemical

interactions, temperature interactions, rock damage, sealing of infrastructures, effects of natural events). These cannot be assessed generically but are specific to a site. They are thus future key issues for ensuring safety of deep disposal and require specific in situ validation of knowledge. They are nevertheless not specific to a particular waste type and thus not dependant of strategies chosen for managing waste prior to disposal.

Finally, results from long term assessments available today tend to show that spent fuel would be the main contributor to the radiological impact of the facility (due to its comparatively high content of long-lived β - γ emitters) but only by a factor of 10 when compared to the projected impact from reprocessed waste. Considering the large uncertainties related to long term dose calculation, this cannot be considered to be an issue that would motivate specific choices of strategies with regard to waste management.

4. PARTITIONING AND TRANSMUTATION

Partitioning and transmutation (P&T) has the potential to open new avenues for long term waste management and to reduce the radiological hazard (in terms of magnitude and duration), to weaken the decay heat evolution history (e.g. by eliminating long lived heat producing actinides) and to reduce the quantities of the fissile and/or fertile radionuclides that pose proliferation concerns. The application of P&T would, if fully implemented, result in a significant decrease in the transuranic inventory to be disposed of in geologic repositories. Currently, it is believed that the inventory and radiotoxicity can be reduced by a factor of 100 to 200 and that the time scale required for the radiotoxicity to reach reference levels (natural uranium) will be reduced from over 100 000 years to between 1000 and 5000 years. To achieve these results it is believed that it would be necessary for plutonium and neptunium to be multiple recycled and for americium and curium to be incinerated in a single deep burn step [8].

Currently, P&T is at the R&D stage. Concerning partitioning, the scientific feasibility of the separation of americium, curium and of caesium from the waste has been demonstrated. The partitioning of neptunium, soluble technetium and iodine can be achieved by modifying the Purex process. However, the demonstration of the technical feasibility of separating the actinides just began in 2005. So, the possibility of industrial application is not proven. Concerning transmutation, it has been shown that it is not practically possible with the current thermal neutrons PWRs. Even if the scientific feasibility of transmutation of few radionuclides has been experimentally proven, this has been done only at a very small scale within the experimental fast neutrons reactor Phoenix.

Two different ways are today studied for transmutation: the fast breeder reactor (FBR) and the accelerator driven system (ADS), but both are still at the concept stage (except for the sodium cooled FBR). No FBR system of the IV generation is yet available and, if the international research is progressing as expected, a demonstrator could be ready maybe in 2020-2030. The studies of the ADS (neutron flux produced by a proton accelerator), performed for example for the MYRRHA project in Belgium, have identified the principal technological problems but the solutions are not operational today. A European decision for the realization of a demonstrator is not expected before 2008.

Partitioning and transmutation have to be considered together: if transmutation needs partitioning, partitioning by itself, not immediately connected to transmutation, could lead to significant technological and safety problems such as workers protection, specific conditioning and specific storage or disposal not yet studied or available.

The scientific, technical and economical efforts needed to lead to a potential industrial realization would not be possible without a large international cooperation. On the other hand, an industrial deployment will depend on many other factors such as the energy context, the importance of the nuclear option and, in the end, of the economic relevance and viability of P&T. It will not be justified without a nuclear long term persistency policy. Transmutation will not be applied for current nuclear wastes and will not eliminate all the long-lived nuclides: it can not be seen as a management option by itself; a final disposal will be anyway necessary.

5. CONCLUSIONS

The national policies for waste management in Germany, France and Belgium show some remarkable differences, but when looked at in detail, it becomes clear that these differences have more to do with the impact of public perception than with real differences in the safety level. In Germany only deep geological formations are felt to be acceptable for disposal. Near-surface repositories are excluded as final solution. Therefore a clearance policy is useful to limit the amount of waste to be disposed of in an underground facility. In France there is a very low level waste category which can be disposed of in a surface repository. This makes the need for a clearance policy much less crucial. In Belgium there is no very low level waste category, but low and medium active short-lived waste may be disposed of in a dedicated surface installation. A clearance policy is being developed. In all three countries, adequate protection of man and environment is the overriding concern.

To ensure the safety of radioactive waste storage and disposal facilities, the overriding safety principle to apply is defence in depth. This principle consists in ensuring containment through the implementation of multiple "lines of defence" that can either be physical barriers and operational measures, so that radioactivity and radiation stays contained even if one or several lines fail. Designing facilities using this principle implies that all processes and events that may lead to dysfunction of the system are analysed and that appropriate means are implemented to compensate the possible loss of lines of defence. Past experience shows that storage and disposal facilities can be safely designed along those lines.

The ways to ensure safety for spent fuel or reprocessed waste management are fairly comparable for storage and benefit from a large feed back of experience. There is no particular new arising from long term storage safety option, but much more from deep disposal which show more specific aspects whether you consider spent fuel or reprocessed waste. However, it appears from feasibility studies that no adverse issues arise that would discount reaching an appropriate level of safety for deep disposal in future, the multi-barrier system being robust enough to tolerate quite large uncertainties. Though issues specific to the type of waste are to be addressed, the same studies do not show that reprocessing or spent fuel direct disposal should be preferred with regard to short or long term safety. The new processes under study are at a too preliminary stage to infer this conclusion. Indeed, if partitioning and transmutation (P&T) has the potential to open new avenues for long term waste management and to reduce the radiological hazard, to weaken the decay heat evolution history and to reduce the quantities of the fissile and/or fertile radionuclides that pose proliferation concerns, it is currently still at the R&D stage. Much work remains to be done, and the scientific, technical and economical efforts needed to lead to a potential industrial realization will not be possible without a large international cooperation. P&T will not be applied for current nuclear wastes and will not eliminate all the long-lived nuclides. Thus, it can not be seen as a management option by itself; a final disposal will be anyway necessary.

Finally, it comes that choosing a strategy cannot be justified today on the sole appraisal of the pros and cons of waste management safety, but must be considered globally, over all the aspects of energy production.

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