

### 3 Generating and organising knowledge: scientific and technical achievements

The ONDRAF/NIRAS current programme of methodological research and development basically comprises two main branches. First, there are the studies and research projects to generate and organise all of the scientific and technical knowledge required to be able to *design and implement* a deep disposal solution capable of safely isolating radioactive waste from the biosphere in the long term (the subject of this chapter). Second, there is the *indirect assessment* of the long-term radiological safety of the developed solution (the subject of Chapter 4). The ONDRAF/NIRAS work programme focuses on the study of a reference host formation and a reference site (the Boom Clay under the Mol–Dessel nuclear zone) and has, so far, given only preliminary consideration to the study of an alternative host formation (the Ypresian Clays beneath the Doel nuclear zone).

Chapter 3 summarises the scientific and technical findings of the second phase of the ONDRAF/NIRAS programme of methodological research and development (1990–2000) in eight sections. These can be linked to eight of the questions that the design of a deep disposal facility ultimately poses.

- *Which waste is intended for deep disposal, and what is its volume?* (Section 3.1)
- *What are the geological and hydrogeological characteristics of the reference host formation and how does water move through and around that formation?* (Section 3.2) (The geomechanical characteristics of the Boom Clay are discussed in Section 3.6.2.)
- *What does the studied deep disposal facility look like, and how does ONDRAF/NIRAS propose to construct, operate, and ultimately close it?* (Section 3.3)
- *How can the disposed waste and the materials that make up the facility be expected to behave under disposal conditions?* (Section 3.4)
- *What are the mechanisms by which the radionuclides present in the disposed waste are likely to migrate through the clay?* (Section 3.5)
- *What disturbances can the construction of the facility and the disposed waste induce in the host formation, and to what extent must they be limited?* (Section 3.6, which also covers the, as yet, exploratory study of the migration of chemotoxic species present in the disposed waste.)
- *How should the transfer of radionuclides to the biosphere be dealt with?* (Section 3.7)
- *What are the principal characteristics of the alternative host formation?* (Section 3.8)

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### 3.1 Conditioned waste

To be suitable for adequate long-term management, the radioactive waste must meet a number of preconditions that can be summarised as follows. It must

- be chemically inert and capable of being handled, and so must have been conditioned in a solid form;
- be sufficiently well known, radiologically and chemically, so that the safety of the repository in which it will be emplaced can be assessed;
- satisfy certain quality criteria to ensure that it does not put the proper functioning of the disposal system at risk;
- have undergone thorough studies of its degradation modes under disposal conditions.

The diversity of the radiological characteristics of the waste has, of course, necessitated the development of an appropriate classification system.

#### 3.1.1 Classification of conditioned radioactive waste

For the purpose of its safe management in the short and long term, radioactive waste, which possesses extremely diverse characteristics, is classified according to certain similarities. The classification systems used internationally—those of the IAEA and the European Union—make no distinction between conditioned and non-conditioned radioactive waste. They comprise two levels, groups and categories respectively, which classify waste according to its activity and half-life (Table 3.1).

**Table 3.1** Characteristics of the three categories of radioactive waste according to the international classification.

	Low level	Medium level	High level
<b>Short half-life</b> (30 years or less)	A	A	C
<b>Long half-life</b> (over 30 years)	B	B	C

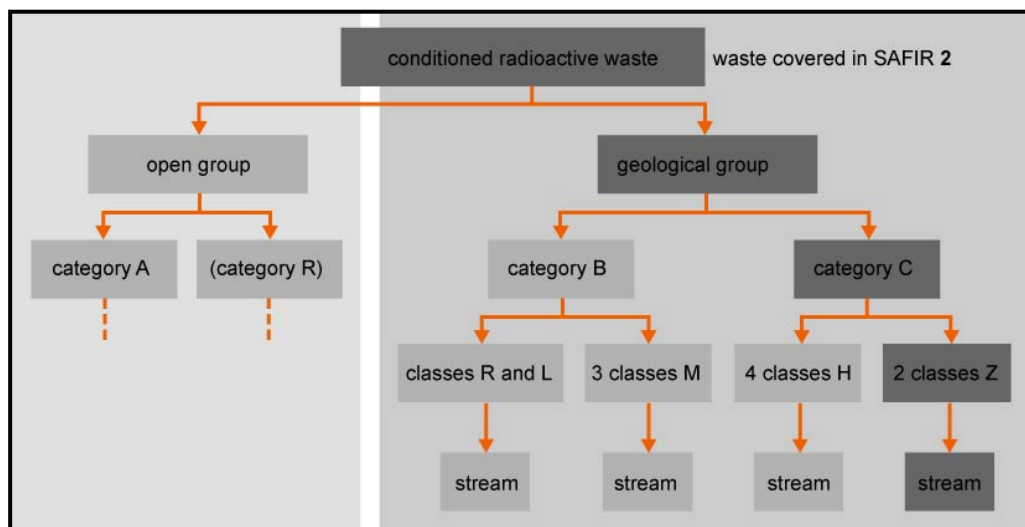
The countries faced with the issue of radioactive waste management have, however, evolved their own classification systems, which are more detailed and more suited to their management modes. In Belgium, for example, ONDRAF/NIRAS has since 1997 adopted a four-level hierarchical classification system for conditioned radioactive waste. This system is compatible with the main international classification systems and can, if necessary, be adapted to take account of changes that may occur in the management of the waste. This system, based on the characteristics of the waste at the time of conditioning, represents a significant achievement since the SAFIR report and is a major contribution to the technical, administrative, and financial management of the waste (Fig. 3.1).

The **groups** of conditioned radioactive waste, two in total, are defined as a function of the possible disposal solutions for the waste in question.

- The *geological* group, which forms the subject of the SAFIR 2 report, includes the conditioned radioactive waste whose radiological characteristics, that is to say the

activity concentrations of the radionuclides that it contains and their half-life, make it imperative that it is permanently isolated from the biosphere. Permanent isolation, which is thus the sole conceivable solution for the long-term management of the waste, is currently judged to be achievable by disposing of it into deep and stable geological layers.

- The *open* group, which is not considered in the SAFIR 2 report, contains the conditioned radioactive waste whose radiological characteristics are such that alternative solutions to geological isolation can be considered, since its activity will decrease to an insignificant level by radioactive decay over a period of time compatible with the period over which control can be exercised, i.e., a maximum of 200 to 300 years.



**Figure 3.1** Classification of conditioned radioactive waste in Belgium. While the SAFIR 2 report covers all of the waste in the geological group, it deals more specifically with the long-term management of very high-level vitrified waste and non-reprocessed spent fuel, that is, waste from the Z-classes, these being the most demanding classes in radiological and thermal terms.

The three main **categories** of conditioned radioactive waste are defined by a radiological criterion and by a thermal power criterion. Category A belongs to the open group, and categories B and C to the geological group. Category R is more recent and more specific; it has no international equivalent and has been provisionally assigned to the open group.

- The *category A* waste is the one whose radionuclides present specific activities low enough and half-lives short enough to permit surface disposal, i.e., a maximum of 400 to 4000 Bq·g<sup>-1</sup> of alpha activity according to the generic recommendations of the IAEA and the European Union.
- The *category B* waste is waste that does not meet the criterion for belonging to category A, but does not generate enough heat to belong to category C.
- The *category C* waste contains very high quantities of alpha and beta emitters and generates a thermal power of over 20 W·m<sup>-3</sup>, a figure that marks the limit between categories B and C for disposal into clay. It must, therefore, be allowed to cool down during a period of interim storage, and its residual thermal power at the time of

disposal requires either limiting the number of packages per linear metre of disposal gallery, or increasing the distance between galleries.

- Finally, the *category R* waste covers the waste contaminated with radium and stored on the site of the old Olen refinery of the Union Minière. The fate of this waste is still uncertain.

The twenty **classes** of waste are defined as a function of the type of interim storage and the type of disposal for which the waste packages are intended, and sometimes as a function of their origins or technical characteristics. Radioactive waste intended for deep disposal, most of which comes from operations associated with the fuel cycle, is divided into 11 classes (Table 3.2).

- The *class Z* waste (category C, very high level, highly heat-emitting) is the result of the nuclear fuel cycle. The ZAGALC class is the very high-level *vitrified waste* from the reprocessing of spent commercial fuel by the French company COGEMA (activation and fission products and minor actinides, liquid effluents). The ZAGALS class will appear if Belgium abandons the reprocessing option, and will consist of the commercial *spent fuel* assemblies. All of this waste initially generates a large amount of heat, primarily due to the radioactive decay of  $^{90}\text{Sr}$  and  $^{137}\text{Cs}$  in the case of the ZAGALC class waste, and to the radioactive decay of  $^{241}\text{Pu}$  and  $^{241}\text{Am}$  in the case of the ZAGALS class waste. For the purpose of deep disposal into clay, this heat emission means that the waste must be allowed to cool down on the surface for some time to avoid compromising the containment capability of the clay. The thermal power per unit of length of the ZAGALC class waste is  $378 \text{ W}\cdot\text{m}^{-1}$  at 50 years after discharge from the reactor. This is the period of interim storage prior to disposal that is currently being considered, although it could be increased to 60 years.
- The *class H* waste (category C, high level, moderately heat-emitting) is the result of the reprocessing of spent fuel. The HAGALC2 class consists of structural materials (*hulls, endpieces, springs, etc.*) of the spent fuel assemblies reprocessed by COGEMA and so-called 'technological' waste comprising mainly equipment items and laboratory instruments. All of this waste is compacted. The three HAGALP classes are the result of vitrification and, for a small proportion of them, the result of cementation by Belgoprocess in the PAMELA facility of the reprocessing waste produced by Eurochemic between 1966 and 1974.
- The *class M* waste (category B, medium level, low heat-emitting) is more varied in origin than the waste of classes Z and H. The MAGALC class consists of bituminised sludge from the reprocessing of spent fuel by COGEMA. The MAGALE class comprises various types of bituminised waste, mainly liquid Eurochemic reprocessing waste (Eurobitum waste). The generic MAGAL class is made up of waste packages whose contact dose rate is above  $5 \text{ mSv}\cdot\text{h}^{-1}$ ; it contains mainly waste from the research conducted by SCK·CEN prior to 1989 and dismantling waste, all cemented in PAMELA.

**Table 3.2** Inventory of radioactive waste intended for deep disposal. The figures in normal print in the column 'Expected no. of packages' correspond to the complete reprocessing option and should be replaced by the figures in *italics* in the case of the direct disposal option (1999 estimates). The activity levels, doses, and powers shown are those at the time of conditioning. (\*: the material used to fill the watertight packagings is sand; \*\*: production discontinued)

Category and level	Class	Principal waste streams	Matrix	Expected no. of packages	Ext. vol./ pack. [m <sup>3</sup> ]	Activity [Bq/pack.]	α	βγ	Contact dose [Sv h <sup>-1</sup> ]	Power [W/pack.]
<b>C</b> <b>very high level</b>	ZAGALC	Reprocessing waste	glass	3915 / 420	0.180	1.3·10 <sup>14</sup>	1.3·10 <sup>14</sup>	9.1·10 <sup>15</sup>	> 10 <sup>4</sup>	602
	ZAGALS	Spent fuel:	UO <sub>2</sub> * (Doel 1 and 2)	1669	0.326	1.7·10 <sup>14</sup>	1.7·10 <sup>14</sup>	1.5·10 <sup>15</sup>	≈ 10 <sup>3</sup>	188
		UO <sub>2</sub> (Tihange 1 and 2 / Doel 3)	4780	0.444						
		UO <sub>2</sub> (Tihange 3 / Doel 4)	3266	0.517						
<b>C</b> <b>high level</b>	HAGALC2	MOX: UO <sub>2</sub> / PuO <sub>2</sub> (Tihange 2 / Doel 3)	UO <sub>2</sub> /PuO <sub>2</sub> *	144	0.444	9.9·10 <sup>14</sup>	9.9·10 <sup>14</sup>	2.3·10 <sup>15</sup>	≈ 10 <sup>3</sup>	905
		Compacted structural and technological waste	-	6410 / 820	0.180	7.9·10 <sup>11</sup>	7.9·10 <sup>11</sup>	1.7·10 <sup>14</sup>	> 2	20
		Liquid reprocessing waste from the ex-Eurochemic	glass	1501**	0.070	8.2·10 <sup>11</sup>	8.2·10 <sup>11</sup>	1.3·10 <sup>14</sup>	> 2	5
		Liquid reprocessing waste from the ex-Eurochemic	glass	700**	0.195	2.6·10 <sup>11</sup>	2.6·10 <sup>11</sup>	7.1·10 <sup>13</sup>		
HAGALP3	Solid reprocessing waste from the ex-Eurochemic	cement	160**	0.195	6.0·10 <sup>11</sup>	6.0·10 <sup>11</sup>	3.6·10 <sup>13</sup>	> 2	3	
<b>Total category C waste 12686 / 13460 2132/4642 m<sup>3</sup></b>										
<b>B</b> <b>medium level</b>	MAGALC	Reprocessing waste (coprecipitation sludge)	bitumen	480**	0.238	1.8·10 <sup>10</sup>	1.8·10 <sup>10</sup>	2.6·10 <sup>12</sup>	0.750 to 2	0.1
	MAGALE	Liquid and solid waste from the ex-Eurochemic	bitumen	13406	0.245	2.0·10 <sup>10</sup>	2.0·10 <sup>10</sup>	2.6·10 <sup>12</sup>	0.005 to 2	0.1
	MAGAL	Secondary waste from PAMELA and its dismantling	cement	186	0.245	8.6·10 <sup>9</sup>	8.6·10 <sup>9</sup>	2.2·10 <sup>12</sup>	0.005 to 2	0.2
		Waste from the HRA/Solarium	cement	1200	0.500	pm	pm			
Waste from the HRA/Solarium		cement	142	2.500	pm	pm				
<b>B</b> <b>low level</b>	LAGAL	Waste from the dismantling of industrial reactors	cement	2075	0.500	pm	pm	1.1·10 <sup>15</sup>	< 0.005	0.02
		Waste from the dismantling of reactors of SCK-CEN	cement	67	0.500	5.1·10 <sup>5</sup>	2.6·10 <sup>13</sup>			
		Waste from the current production of MOX	cement	1459	0.500	4.6·10 <sup>11</sup>	1.0·10 <sup>13</sup>			
		Waste from the dismantling of MOX facilities	cement	1901	0.500	2.7·10 <sup>10</sup>	2.7·10 <sup>11</sup>			
<b>B</b> <b>low level</b>	RAGAL	Waste from the dismantling of the ex-Eurochemic	cement	642	0.500	3.5·10 <sup>11</sup>	3.5·10 <sup>11</sup>	1.2·10 <sup>9</sup>	< 0.005	0.3
		Miscellaneous waste from the ex-Waste department	cement	170	0.500	1.7·10 <sup>11</sup>	1.7·10 <sup>11</sup>	3.3·10 <sup>12</sup>	< 0.005	0.2
<b>Total category B waste 21728 7556 m<sup>3</sup></b>										

- The waste of the generic *classes L and R* (category B, low level, low heat-emitting, long lived) have a contact dose rate less than or equal to  $5 \text{ mSv}\cdot\text{h}^{-1}$ . The LAGAL class contains mainly waste from the current production of MOX fuel, historical waste, and dismantling waste containing large quantities of alpha emitters, all cemented. The RAGAL class includes all of the radium-contaminated waste that results from the radium production operations of the old Olen refinery (Union Minière) and from the actinium programme of SCK·CEN. (It does not therefore include the category R waste.)

Finally, the waste classes are divided into over 100 waste **streams**. These are defined as groups of packages with homogeneous physical, chemical, and radiological characteristics, produced using the same process to condition the same kind of raw waste.

### 3.1.2 Inventory of conditioned waste intended for deep disposal

The main achievements with regard to the inventory are the development of waste production forecasts and the acquisition, and systematic and coherent grouping, of a large quantity of data about the waste, especially in terms of qualitative and quantitative radiological content, i.e., the radionuclides contained and the concentration of each (Tables 3.2 and 3.3).

Unlike the inventory given in the SAFIR report, which assumed a complete reprocessing of all types of spent fuel, the inventory given in the SAFIR 2 report, which dates from 1999, looks at two distinct options: an option in which all spent fuel types is reprocessed, and one in which spent fuel is disposed of without reprocessing. These two options are based on the same assumptions regarding the fuel that is, or will be used:

- the seven Belgian commercial nuclear reactors, with a total installed power of 5.7 GWe, will be shut down after an operating period of 40 years each;
- before irradiation, the enriched uranium fuel contains 4.0 %  $^{235}\text{U}$  and the mixed-oxide fuel (MOX) contains 4.93 %  $^{239}\text{Pu} + ^{241}\text{Pu}$ ;
- the fuel is irradiated for 1450 days and its reference burn-up is  $45 \text{ GWd}\cdot\text{tHM}^{-1}$ , or  $45\cdot 10^9$  watt-days per tonne heavy metal (uranium or MOX).

Based on these assumptions, the total consumption of conventional uranium fuel is estimated to be 4860 tHM, to which some 70 tHM of MOX fuel must be added. The total inventories for the two options are therefore as follows:

- *complete reprocessing option*: reprocessing of all of the 4860 tU. This option involves the production of 3920 containers of very high-level vitrified waste (ZAGALC class waste) and 6410 containers of structural waste from spent fuel assemblies (HAGALC2 class waste), plus some 70 tHM of existing MOX.
- *direct disposal option*: reprocessing stops after the reprocessing of the 630 tU under existing contracts. This option entails the production of 420 containers of very high-level vitrified waste and 820 containers of structural waste from spent fuel assemblies, plus about 4230 tU non-reprocessed spent fuel and the existing 70 tHM of MOX.

The forecasts of waste production based on the two options and information about the other waste streams indicate a sharp reduction in the waste volume intended for deep disposal. This volume stood at approximately 27 000 m<sup>3</sup> in the SAFIR report (1989), but is now only about 10 000 m<sup>3</sup> for the complete reprocessing option and some 12 500 m<sup>3</sup> for the direct disposal option. As a result of developments in the conditioning processes, the SAFIR 2 report also includes new types of waste, while other waste types have disappeared.

**Table 3.3** Inventory, in becquerels per package, of the radionuclides considered in the long-term safety assessments for the most demanding waste in radiological and heat emission terms (see also Section 4.3.2.1). (For the safety assessments, the inventory of <sup>36</sup>Cl has been estimated from foreign data. In addition, although <sup>59</sup>Ni, <sup>94</sup>Nb, and <sup>147</sup>Sm have half-lives that should lead to their consideration in safety assessments, the very low intrinsic radiotoxicity of the first radionuclide makes it non-critical, while the radiological impact of the other two according to these same assessments is negligible. They are, therefore, not shown below.)

	<sup>14</sup> C	<sup>79</sup> Se	<sup>93</sup> Zr	<sup>99</sup> Tc	<sup>107</sup> Pd	<sup>126</sup> Sn	<sup>129</sup> I	<sup>135</sup> Cs
<b>Vitrified waste</b>	–	1.7·10 <sup>10</sup>	9.1·10 <sup>10</sup>	7.1·10 <sup>11</sup>	5.2·10 <sup>9</sup>	2.9·10 <sup>10</sup>	1.5·10 <sup>8</sup>	2.3·10 <sup>10</sup>
<b>uox fuel</b>	8.9·10 <sup>9</sup>	9.4·10 <sup>9</sup>	4.5·10 <sup>10</sup>	2.9·10 <sup>11</sup>	2.9·10 <sup>9</sup>	1.8·10 <sup>10</sup>	7.4·10 <sup>8</sup>	1.0·10 <sup>10</sup>
<b>MOX fuel</b>	4.3·10 <sup>9</sup>	8.0·10 <sup>9</sup>	3.3·10 <sup>10</sup>	2.8·10 <sup>11</sup>	5.9·10 <sup>9</sup>	2.5·10 <sup>10</sup>	9.2·10 <sup>8</sup>	9.4·10 <sup>9</sup>
<b>Hulls and endpieces</b>	5.0·10 <sup>7</sup>	3.9·10 <sup>7</sup>	5.6·10 <sup>9</sup>	4.0·10 <sup>9</sup>	–	–	5.6·10 <sup>7</sup>	2.0·10 <sup>8</sup>
	<sup>226</sup> Ra	<sup>229</sup> Th	<sup>230</sup> Th	<sup>231</sup> Pa	<sup>232</sup> Th	<sup>233</sup> U	<sup>234</sup> U	<sup>235</sup> U
<b>Vitrified waste</b>	–	1.8·10 <sup>3</sup>	3.8·10 <sup>4</sup>	1.4·10 <sup>5</sup>	3.1·10 <sup>0</sup>	8.6·10 <sup>1</sup>	6.3·10 <sup>5</sup>	3.9·10 <sup>5</sup>
<b>uox fuel</b>	4.9·10 <sup>5</sup>	3.1·10 <sup>3</sup>	2.5·10 <sup>6</sup>	8.4·10 <sup>5</sup>	1.4·10 <sup>1</sup>	1.9·10 <sup>6</sup>	1.0·10 <sup>10</sup>	2.6·10 <sup>8</sup>
<b>MOX fuel</b>	1.0·10 <sup>6</sup>	1.8·10 <sup>4</sup>	1.1·10 <sup>7</sup>	2.2·10 <sup>5</sup>	9.3·10 <sup>5</sup>	4.4·10 <sup>10</sup>	4.4·10 <sup>10</sup>	4.1·10 <sup>7</sup>
<b>Hulls and endpieces</b>	–	–	–	–	–	–	–	–
	<sup>236</sup> U	<sup>237</sup> Np	<sup>238</sup> U	<sup>242</sup> Pu	<sup>244</sup> Pu	<sup>248</sup> Cm		
<b>Vitrified waste</b>	4.7·10 <sup>6</sup>	1.5·10 <sup>10</sup>	5.5·10 <sup>6</sup>	8.0·10 <sup>7</sup>	4.3·10 <sup>0</sup>	3.7·10 <sup>4</sup>		
<b>uox fuel</b>	5.6·10 <sup>9</sup>	9.1·10 <sup>9</sup>	5.4·10 <sup>9</sup>	5.1·10 <sup>10</sup>	1.2·10 <sup>4</sup>	1.5·10 <sup>4</sup>		
<b>MOX fuel</b>	3.9·10 <sup>8</sup>	7.3·10 <sup>9</sup>	5.2·10 <sup>9</sup>	2.4·10 <sup>11</sup>	7.8·10 <sup>5</sup>	1.1·10 <sup>5</sup>		
<b>Hulls and endpieces</b>	–	5.0·10 <sup>6</sup>	–	5.3·10 <sup>10</sup>	–	–		

Although assessments of the long-term radiological safety of deep disposal indicate a safety level that is adequate and largely insensitive to the inventories that are used (see Section 4.3.2), these results have yet to be confirmed. Such confirmation is based mainly on a more detailed knowledge of the waste and calls, among others, for the following four types of action:

- on the basis of information that is available—mainly with waste producers—, to identify the inventory of critical radionuclides of the different waste classes, the physical properties of this waste (heat emission in particular), and its chemical characteristics (especially the presence of heavy metals and other chemotoxic elements);
- as part of a transparent system of quality management and assurance, to improve the documentation of knowledge about the waste inventory, so as to make it easier to find back the assumptions and calculation codes used or the measurements carried out (see Section 2.4);

- to refine the waste production scenarios on the basis of a more detailed description of the nuclear fuel cycle and the various changes that it could undergo;
- to study ways of verifying the fundamental characteristics of the waste before it is disposed of.

### 3.1.3 General rules for waste acceptance and acceptance criteria

To be in a position to ensure the short-term and long-term management of the radioactive waste that is placed in its charge, ONDRAF/NIRAS must be confident enough that the intrinsic characteristics of the waste will not, in principle, threaten the safety of one or more stages of its management. ONDRAF/NIRAS must, therefore, be assured that the waste conforms to a range of criteria that it has established in advance. Under the provisions of the Royal Decree of 30<sup>th</sup> March 1981 as amended by the provisions of the Royal Decree of 16<sup>th</sup> October 1991, ONDRAF/NIRAS has laid down the general rules to be used as a reference framework for the development of criteria to be satisfied by the radioactive waste packages before ONDRAF/NIRAS agrees to accept them, and has then established the actual acceptance criteria proper. These general rules and acceptance criteria may be modified at the initiative of ONDRAF/NIRAS or the competent authority in response to changes in, for instance, the repository design, national and international legislation and recommendations, and processing and conditioning techniques. They represent one of the most significant advances in the management and quality assurance of radioactive waste (see also Section 2.4). All radioactive waste packages accepted by ONDRAF/NIRAS must also meet the applicable legal and regulatory requirements. These include the requirements of the operating licences of the nuclear facilities involved, and the international transport regulations.

The *general rules*, which were approved by the competent authority and came into force on 10<sup>th</sup> February 1999, consider all of the aspects (essentially mechanical, physical, chemical, radiological, and biological) that must be subject to acceptance criteria, and lay down a range of administrative requirements. These include a duty to document all waste packages individually and identify them uniquely, a procedure for package acceptance, obligations for nuclear operators who condition the waste to prove the conformity of their packages with the acceptance criteria, possible alternatives in the case of non-conformity of the packages, technical and administrative arrangements for monitoring their characteristics over time, and revisions of the acceptance criteria.

The *acceptance criteria*, which currently cover the bulk of conditioned radioactive waste production, are established separately for each waste class and are all subject to systematic documentation and justification procedures. Besides certain administrative specifications, they specify the mainly technical requirements for minimum quality that packages must meet before they can be accepted by ONDRAF/NIRAS. Each primary package must satisfy a number of requirements. These relate to its mechanical strength, the maximum percentage of void it can contain, its resistance to radiation, its level of surface contamination and its hazardous substance content, in particular, its radiological content and, more specifically, its content of critical radionuclides. It must not be the source of chemical reactions that could jeopardise the safety of waste management. Moreover, the

conditioned waste must form a solid whole with no free fluids. It must be compact, chemically stable, non-dispersible, and unlikely to crack, and it must satisfy a number of criteria that vary according to the type of matrix used to immobilise it. It must not contain putrescible materials. It must not contain complexing agents in quantities large enough to have a significant adverse effect on the behaviour of radionuclides near to the repository. There must be no risk of damage or excessive distortion to the waste packages from the production of gas from the waste. Finally, the packages must satisfy requirements governing their geometrical, mechanical, and corrosion resistance characteristics and, more generally, relating to the maintenance of their integrity.

Compliance with the acceptance criteria is determined primarily by the waste processing and conditioning stage, which is the stage that most broadly controls the physical quality of the waste. The processing and conditioning facilities, and the processes carried out in them, must therefore be qualified by ONDRAF/NIRAS. There are four steps in this *qualification* process. First, the operator who processes and conditions the waste (the producer or a sub-contractor of ONDRAF/NIRAS) submits a technical qualification report to ONDRAF/NIRAS. This describes the operation of the facility, and formalises and justifies the arrangements to guarantee that the conditioned waste packages meet the applicable acceptance criteria. ONDRAF/NIRAS then verifies, possibly with the assistance of an authorised organisation, that the facility fully complies with the conditions of the qualification report by conducting regular technical audits. Then, again assisted by an authorised organisation, it verifies the processes and facilities used by the operator to characterise the radiological composition of the waste conditioned in the facility that is to be qualified. Finally, ONDRAF/NIRAS examines the documentation showing the conformity of the conditioned waste with the acceptance criteria and the conformity of the process used with the data in the qualification report for the facility concerned. Provided all of these checks are satisfactory, ONDRAF/NIRAS qualifies the process and the processing and conditioning facility concerned, as well as the characterisation method and facility. This qualification is then valid for a given period.

The *acceptance procedure* for the packages of conditioned radioactive waste is the administrative process by which ONDRAF/NIRAS uses both administrative and technical checks to satisfy itself that the conformity report that accompanies the waste which the operator asks ONDRAF/NIRAS to accept has been properly prepared and that the waste conforms to that report and, therefore, to the applicable acceptance criteria. Since this operation has technical, financial, and safety implications, each of its phases must be documented in accordance with previously established procedures. In practice, and in simple terms, when ONDRAF/NIRAS receives an application to collect conditioned waste, it first examines the accompanying production file. This file contains the results of calculations of radiological and physico-chemical characterisation carried out by the operator to verify the conformity of his waste with the acceptance criteria in force at the time of production. ONDRAF/NIRAS then carries out physical spot checks on the packages to ensure that they really do conform to the information given in the file, and issues a collection inspection report setting out the results of its checks and any reservations. It then arranges transport for the packages and issues the acceptance report, which certifies the conformity of the packages with the criteria, or sets out the conditions by which they have been accepted, and the transfer report. The packages are then transferred to the interim storage facility that ONDRAF/NIRAS has designated and where it examines them

physically and issues the storage inspection report. Under the regulatory provisions that require the party who conditioned the waste to remain liable for 50 years for any hidden defects that might be found, ONDRAF/NIRAS is currently developing a plan for regular checks on the continued conformity of the packages with the acceptance criteria during their interim storage, and, hence, on their compatibility with the reference repository. If a package ceases to be compatible with its ultimate destination, then corrective action must be taken, the most extreme case being reconditioning.

### 3.2 The host formation and the environment of the disposal system

Long-term radiological safety assessments having repeatedly stressed the dominant role of the natural barrier in the performance of a deep disposal system in the Boom Clay (see Chapter 4), ONDRAF/NIRAS intensified its work on the characterisation and understanding of the Boom Clay beneath, and in the immediate vicinity of, the Mol–Dessel nuclear zone during the period 1990–2000. In accordance with the recommendations of the SAFIR Evaluation Commission (1990), it focused its methodological research and development programme on

- characterising the lithological heterogeneities of the Boom Clay;
- identifying structural discontinuities (faults, etc.) affecting that clay;
- improving the understanding and modelling of the regional and local hydrogeology of the aquifers both above and below the Boom Clay.

It also set about establishing the natural radiological background of the clay and studying the behaviour of the naturally-occurring radionuclides.

(The geomechanical behaviour of the Boom Clay is discussed in Section 3.6.2 dealing with disturbances. Also, given the preliminary nature of the investigation of the Ypresian Clays and the significant difference in the level of progress between the reference option and the alternative option in terms of the development of a deep disposal facility, the body of information relating to the Ypresian Clays is dealt with separately from the information concerning the Boom Clay, in Section 3.8.)

#### 3.2.1 Selection and status of the host formations studied in Belgium

There has been a significant evolution in the approaches proposed at an international level for the selection of geological formations or appropriate sites for deep disposal. This evolution has involved a move away from an approach that applied exclusion criteria associated with the host formation towards a global approach of assessment and optimisation of the performance and safety of the disposal system as a whole. This integrated and system-oriented approach to the selection of host formations and the development of the disposal system and its assessment, however, casts no doubt on the fundamental importance of the geological barrier in guaranteeing long-term radiological safety.