COMMISSION OF THE EUROPEAN COMMUNITIES

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COMMUNICATION FROM THE COMMISSION

Present situation and prospects in the field of radioactive waste management in the European Community

ANALYSIS OF THE PRESENT SITUATION AND
PROSPECTS IN THE FIELD OF RADIOACTIVE
WASTE MANAGEMENT IN THE EUROPEAN COMMUNITY

Second Report

COMMUNICATION FROM THE COMMISSION TO THE COUNCIL

SUBJECT: Present situation and prospects in the field of radioactive waste management in the European Community.

I. PREFACE

In its resolution of 18 February 1980,* the Council approved a Community plan of action in the field of radioactive waste. The plan refers to the problems posed by radioactive waste from nuclear installations and, in particular, those concerning the management and storage of high level and/or long-lived waste. It runs from 1980 to 1992 and is reviewable every three years.**

Point 1 of the plan provides for continuous analysis of the situation as regards radioactive waste management in the Community with a view to adoption of the necessary solutions. This analysis must cover:

- the techniques available and installations already in existence or planned by the Member States for the various stages of radioactive waste management, including processes and practices for final disposal;
- technological research and development work which the Member States and the Community intend to carry out;
- management practices which have been, or are to be, defined in the Member States for the various categories of waste;
- the estimated implementation dates and schedules.

The information and results obtained from the analysis are to be used "to keep the Community and the Member States constantly up to date on work and achievements in the management and storage of radioactive waste, having regard to nuclear programme requirements".

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* O.J. No C 51 of 29 February 1980.

** In the light of the situation described herein after and in accordance with the opinion of the competent Advisory Committee on programme management (O.J. No C 51 of 29 February 1980 and O.J. No L 177 of 4 July 1984, p. 25) delivered on 12 November 1985, the Commission considers that there are no reasons to modify the plan of action for the time being. This Commission decision will be the subject of a further communication.

In 1983, the Commission forwarded to the Council a first report* on the situation in 1982 and prospects in the management of radioactive waste in the Community Member States up to the end of the century. The appended report, which describes the situation in 1986 and was drawn up on the basis of information supplied by the Member States, is now being forwarded. The Commission intends to keep the Council regularly informed throughout the duration of the plan by presenting further reports.

II. PRESENT SITUATION AND PROSPECTS IN THE FIELD OF RADIOACTIVE WASTE MANAGEMENT

The Commission wishes to draw the Council's attention to the following points:

A) As already pointed out in the 1983 report, the high level of development in the Member States results in the production in the Community of radioactive waste of many different categories and origins (see Chapter I of the report).

In terms of the radioactivity it contains, waste from nuclear power stations and the associated fuel cycle plants accounts for the most of the waste produced. This applies only to States that possess nuclear power programmes. The present estimates of the volume of cumulative waste arisings over the 1986-2000 period are lower than those made in 1983, but the order of magnitude remains unchanged. This decrease chiefly reflects a downward revision by about 25% in this report of the estimated installed nuclear power capacity in the Community of the Twelve in the year 2000 as compared with the forecasts made in the Community of the Ten in 1983.

In terms of volume, a considerable proportion of radioactive waste consists of waste arising from medical uses, non-nuclear industry and research. This is true of all Member States.

B) The situation as regards radioactive waste has therefore to be analysed by category, each category covering similar types of waste. From the technical standpoint, the situation in the Community at present can be described as follows (see Chapters II and III of the report):

. Some 30 years' experience has been acquired with the management of low- and medium-level waste; roughly one million m^3 of waste has already been definitively disposed of, a quantity which is approximately equivalent to the volume likely to be produced in the Community as a whole between now and the end of the century. Land disposal, mainly by shallow burial, has accounted for 94% of this volume and sea dumping for the remaining 6%.

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* Communication from the Commission to the Council "First report on the present situation and prospects in the management of radioactive waste in the Community" doc. COM(83)262 final of 16 May 1983.

The international suspension of sea dumping since the last such operations were carried out in 1982 has obliged several Member States to concentrate their efforts on adaptation to land disposal. In its 1983 communication, the Commission had already drawn the Council's attention to the need for further development of land disposal in the Community. Any slow-down in new or existing programmes in this field, particularly as regards opening up new sites, should be avoided. It is also advisable for this option to benefit continuously from technological progress, and, when the need arises, for exchanges of know-how between the national organisations involved to be promoted.

. Basic technologies for the management of long-lived waste (waste contaminated mainly by alpha-emitters, producing little heat, and high-activity waste, generating a considerable amount of heat) are available and some of them have reached the stage of industrial application (waste vitrification) (see Chapter II). Nevertheless, development work should be continued, particularly on treatment and conditioning processes to render alpha-contaminated waste suitable for disposal in deep-lying geological formations.

. Waste containing alpha-emitters has hitherto been stored pending disposal. It was initially believed that sites for the geological disposal of such waste would be available by 1990 (see 1983 Communication), but it is now evident that this will be true of only one site, others becoming available towards the year 2000. Since nothing is to be gained by delaying the disposal of this type of waste, efforts should be made to avoid further delays in selecting and operating disposal sites.

. Disposal of high-level waste and/or spent fuel at great depths in suitable geological formations is being studied in all Community countries which possess or intend to possess a nuclear power programme. Such formations, for example salt, clay and crystalline rock, are widely present in the Community. The 1983 communication indicated that the feasibility of this type of disposal seemed to be proven. The knowledge already acquired is now being supplemented and verified through research in several deep underground laboratories. The feasibility of the concept will be demonstrated further through the operation of several experimental underground installations, existing or planned, as the forerunners of industrial-scale installations. In view of the need to allow highly active waste - and possibly spent fuel - to cool down over storage periods lasting up to several decades before disposal is carried out, the present situation may be said to be satisfactory.

It should be pointed out that experience has shown that several decades are likely to elapse between the initiation of research and the start of industrial-scale operation of deep disposal facilities. It is thus hence imperative that the work in progress be continued unremittingly.

Finally, it must be emphasised that this research work as a whole forms an integral part of the 3rd Community R&D programme, and the Community both provides significant support for the financing and coordination of the research and promotes information exchange.

. The safety of disposal cannot be verified easily, since extremely long-term assessments (several centuries in the case of low- and medium-level waste and thousands of years in that of alpha waste, high-level waste and spent fuel) are required which are beyond the realm of direct experience.

Hence, in addition to legal, regulatory and administrative provisions covering the peaceful use of nuclear energy in the Community Member States, specific provisions are necessary to ensure safe disposal. Such provisions already exist or are in preparation and can be divided into two categories.

The first category covers the definition and evaluation of radioactive packages and the associated quality-control criteria and procedures, the underground disposal facilities and the storage sites in order to ensure that disposal is carried out with the requisite level of safety. All national procedures make provision for a public inquiry regarding the selection of the final sites.

The second category covers the structures required for the preparation and execution of disposal operations. All Community Member States which possess nuclear power programmes now entrust all or part of these tasks to executive organizations or special agencies on the basis of the polluter-pays principle. Substantial progress has been achieved in comparison with the situation described in the 1983 Communication.

Harmonization of these provisions at Community level would be desirable, but, in view of the importance of the characteristics specific to a given disposal site, the scope of the provisions will have to be limited essentially to qualitative basic principles, which are, in fact, already harmonized to some extent.

III. RESULTS OF THE COMMISSION'S ACTIONS

In its 1983 communication, the Commission put forward the course of action which it considered should be adopted in the field of radioactive waste management and which has been pursued as follows:

- As regards R&D activities, the research programmes in question (Joint Research Centre 1984-1987 and shared cost research programme 1985-1989) were presented to the Council in 1983 and 1984, respectively, and are being implemented.

- As regards the promotion of demonstration activities, studies and/or projects on geological disposal at experimental or pilot-plant level are in progress in Belgium, Spain, France and the Federal Republic of Germany; these activities are covered by a special chapter of the abovementioned shared-cost Community programme.

- As regards promotion of cooperation between Member States, arrangements have been made to enable national organisations which wish to do so to participate in research relating to the underground experimental installations. The Netherlands is participating in the German project and France in the Belgian project. Participation by other countries is under study.

IV. RECOMMENDATIONS

In the light of the analysis set out in the appended report, which is summarized in Section II above, the Commission wishes to draw the Council's attention to the following points:

- radioactive waste management is an important feature of safety and environmental protection. Immediate priority must be accorded to the adoption of management practices, particularly the selection and opening-up of disposal sites (for permanent disposal);

- the Community action which has been successfully undertaken for several years with the support of the Community institutions must be energetically continued, both with regard to R&D and along the lines laid down in the Community plan of action in the field of radioactive waste. This mainly implies the encouragement of technical cooperation between Member States; concerted action on management practices and criteria and harmonization where necessary; information for the public etc.

COMMUNITY PLAN OF ACTION
IN THE FIELD OF RADIOACTIVE WASTE

ANALYSIS OF THE PRESENT SITUATION AND PROSPECTS IN THE FIELD OF RADIOACTIVE WASTE MANAGEMENT IN THE EUROPEAN COMMUNITY
Second Report

Commission of the European Communities

ANALYSIS OF THE PRESENT SITUATION AND PROSPECTS IN THE FIELD OF RADIOACTIVE WASTE MANAGEMENT IN THE EUROPEAN COMMUNITY: SECOND REPORT

CONTENTS

EXECUTIVE SUMMARY

1. The Community plan of action in the field of radioactive waste for 1980-92 provides for continuous analysis by the Commission of the situation regarding radioactive waste management in the Community.

   A first report was forwarded to the Council in 1983. The present report updates and supplements the information presented in the first report; it also provides information on the situation in the countries which joined the Community in 1986, namely Spain and Portugal.

2. All Member States produce radioactive waste from medical and non-nuclear industrial activities and research; this waste accounts for a significant proportion of the total arisings. Member States with nuclear power programmes also have to cope with waste from nuclear power plants and the installations of the associated fuel cycle, which, in terms of the radioactivity it contains, accounts for most of the waste produced.

   The present estimates of cumulative waste arisings over the 1986-2000 period are lower in terms of both volume and radioactivity than those made in 1983. This decrease chiefly reflects a downward revision by about 25% of the estimated installed nuclear power capacity in the Community of the Twelve in the year 2000 as compared with forecasts made in the Community of the Ten in 1983.

   Nevertheless, the foreseeable order of magnitude of cumulative arisings of radioactive waste for the Community as a whole over the 1986-2000 period remains unchanged: about one million m^3 of low- and medium-level waste, several tens of thousands of m^3 of waste containing alpha emitters and several thousand m^3 of high-level vitrified waste. These volumes are small in comparison with the arisings of non-nuclear industrial waste which, if not adequately stored and disposed of, can be dangerous to man.

3. Some 30 years' experience has been acquired with the management of low- and medium-level radioactive waste; roughly one million m^3 of waste has already been definitively disposed of, a quantity which is approximately equivalent to the volume likely to be produced in the Community as a whole by the end of the century. Land disposal, mainly by shallow burial, has accounted for 94% of this volume and sea dumping for the remaining 6%.

   The international suspension of sea dumping since the last such operations were carried out in 1982 has obliged several Member States to concentrate their efforts on adaptation to land disposal. New sites on land will hence have to be opened up.

4. Basic technologies for the management of alpha and high-level waste are now available and some of them have reached the stage of industrial application. Nevertheless, development work should be continued, particularly on treatment and conditioning processes to render alpha-contaminated waste suitable for disposal in deep-lying geological formations.

5. Waste containing alpha emitters has hitherto been stored pending disposal. Although it was initially expected that sites for the geological disposal of such waste would be available early in the last decade of the century, it is now evident that only one will be ready before half of the decade has elapsed. That exception is the German disposal site KONRAD: the decision to grant an operating license is expected to be taken towards 1990. Since nothing is to be gained by delaying the disposal of this type of waste, efforts should be made to avoid further delays in selecting and opening up disposal sites.

6. Disposal of high-level waste and/or spent fuel at great depths in suitable geological formations is being studied in all Community countries which possess a nuclear power programme. Such formations, for example salt, clay and crystalline rock, are widely present in the Community. The knowledge already acquired is now being supplemented and verified through research in several deep underground laboratories. The feasibility of the concept will be demonstrated further through the operation of several experimental underground installations, existing or planned, as the forerunners of industrial-scale installations. The Member States concerned have scheduled the start of construction or the entry into service of such facilities for the beginning of the next century, in view of the need to allow highly active waste - and possibly spent fuel - to cool down after storage periods which are determined, in particular, by the intended host rock; in the case of some types of geological formation, decades may be required.

7. This research as a whole forms an integral part of the Community's R&D programme, and the Community both provides significant support for the financing and coordination of the research and promotes information exchange. Cooperation between Member States is on the increase and is furthered, in particular, by arrangements which enable organisations and research workers in one Member State to participate in research in underground pilot installations in other Member States under the Community's R&D programme.

8. The safety of disposal cannot be verified easily, since long- of very long-term assessments are required which are beyond the realm of direct experience. Progress is being made in evaluating the performance of isolation systems, particularly at Community level within the framework of the PAGIS project (Performance Assessment of Geological Isolation Systems).

Specific provisions are hence necessary to ensure safe disposal, and can easily be divided into two categories:

The first category covers the definition and evaluation of radioactive packages and the associated quality-control criteria and procedures, the storage installations and the underground repositories in order to ensure that disposal is carried out with the requisite level of safety. All national procedures in this field make provision for a public inquiry regarding the selection of the final sites.

The second category covers the structures required for the preparation and execution of the disposal operations. All Community Member States which possess nuclear power programmes now entrust all or [illegible] on the basis of the polluter-pays principle. Substantial progress has been achieved in comparison with the situation described in the 1983 Communication.

Efforts are being made under the Community Plan of action in the field of radioactive waste to harmonise some of these provisions, where such harmonization seems feasible and necessary.

9. Radioactive waste management is important to safety and environmental protection. In consequence, it is imperative that current projects be successfully completed BY continuing R&D work at both national and community levels. The highest priority must be accorded without delay to the selection and opening-up of disposal sites.

PREFACE

The Community plan of action in the field of radioactive waste for 1980-92, approved by the Council of Ministers of the European Communities in February 1980*, provides under point 1 for continuous analysis by the Commission of the situation regarding radioactive waste management in the Community.

To enable the Community and the Member States to make use of the results of such an analysis, the Commission reports periodically to the Council of Ministers.

The first report was forwarded to the Council in 1983**. The present report is thus the second of its kind; it updates and supplements the information presented in the first report and for the first time provides information on the situation in the countries which joined the Community in 1986, namely Spain and Portugal.

The report incorporates only in abridged form, and to the extent necessary for an understanding of the text, the general information on radioactive waste set out in the first report, to which the reader will hence have to refer when the need arises.

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* Council Resolution of 18 February 1980, OJ No. C 51, 29.2.1980, p. 1.

** Communication from the Commission to the Council of Ministers of the European Communities, Doc. COM(83) 262 of 16 May 1983 "Analysis of the present situation and prospects in the field of radioactive waste management in the Community".

CHAPTER I

Production of radioactive waste and spent fuel in the European Community

I.1. Sources of radioactive waste production

Three types of activity which generate radioactive waste can be considered within the European Community*:

- nuclear power production,
- research activities,
- industrial and medical activities involving the use of radionuclides.

The relative importance of these sources varies considerably from one Community country to another; all Community countries commonly use radioactive elements for research, industrial and therapeutic purposes. It is the countries with nuclear power programmes which generate waste containing most of the radioactivity produced and accounting for the greater part of the radioactive waste arising in the Community as a whole.

I.2. Radioactive waste categories

Radioactive waste comprises a great variety of materials. These materials can have different physical/chemical states, can emit several types of radiation** and can have radioactivity levels ranging over several orders of magnitude.

Clearly, this diversity results in widely differing potential hazards and therefore necessitates different types of management. Radioactive waste must hence be classified by categories.

The classification described below has already been used in the first report (1983) and was chosen because it is the best way of presenting, in the case of the Community, quantitative data on the treated and conditioned radioactive waste produced in the Member States (and by the Community's Joint Research Centre). It also possesses the advantage of grouping the radioactive waste into categories which correspond to the disposal options applied at present or contemplated in the Member States (see Chapter III).

* Military activities do not come within the scope of this report.

** Mainly alpha, beta and gamma radiation.

Four main waste categories are distinguished:

- low-level waste,
- medium-level waste,
- alpha waste,
- high-level waste.

These categories, and the inclusion of a "type" of waste in one category rather than in another, are obviously not of a regulatory or normative nature. Moreover, the management practices in some Member States may be such that categories or types of waste identical to those considered in this report may not exist at national level.

(a) The low-level waste category covers waste (mainly technological) containing or suspected of containing beta-gamma emitters and mainly naturally occurring alpha emitters in low concentrations (and therefore of low activity) produced by research centres and arising from industrial and medical uses of radioactive elements and from the operations conducted in various installations involved in the nuclear fuel cycle. The concentration of the other alpha emitters (plutonium, americium, etc.) in this waste category is very low and is very strictly monitored. The radioactivity of such wastes becomes negligible through natural decay after several centuries at most. The waste produces only negligible amounts of heat.

(b) The medium-level waste category* comprises waste containing mainly beta-gamma emitters in relatively high concentrations. This waste originates, for the most part, in nuclear power stations (ion-exchange resins, filter cartridges, evaporator concentrates, etc.). The alpha-emitter concentration in waste of this category is extremely low, as in the case of low-activity waste. Only negligible amounts of heat are generated.

(c) The waste in the alpha waste category* comprises technological and process waste from nuclear laboratories conducting research on transuranics, plants fabricating uranium-plutonium mixed-oxide fuel elements and spent-fuel reprocessing plants. Some of this waste is low-level waste containing only alpha emitters. The remainder is medium-level waste containing alpha, beta and gamma emitters which arises at reprocessing plants and includes hulls, caps and fines from fuel elements. The radioactivity in such wastes persists for very long periods because long-lived alpha emitters are present. Only small amounts of heat are generated.

* In the Federal Republic of Germany, medium-level waste and alpha waste which produce only negligible amounts of heat are combined with waste in the low-level category in view of the fact that deep-lying geological formations will be used for the disposal of all categories of waste.

(d) The high-level waste category comprises, for the purposes of this report, solely vitrified waste* containing the "ashes" arising from nuclear combustion (fission products and transplutonium elements which are alpha and beta-gamma emitters). These ashes are separated from the unburnt nuclear fuel (uranium and plutonium) in radiochemical installations (reprocessing plants) which treat the spent fuel discharged from the nuclear power stations. Such waste contains the greater part of the radioactivity; it remains dangerous for very long periods and emits an appreciable amount of heat for several centuries.

(e) If the decision is taken not to undertake reprocessing of the spent fuel discharged from the nuclear power stations, it is declared to be waste and constitutes a category separate and distinct from high-level waste. The spent fuel from the THTR reactor** in the Federal Republic of Germany and that from the light-water reactors in Spain are examples of such waste.

Discharges of liquid and gaseous effluents into surface waters and the atmosphere, which take place with due regard to the radiation protection regulations in force and are adequately monitored, are communicated to the Commission of the European Communities and form the subject of periodic Commission reports; they are not dealt with in this report.

A special category of low-level waste which is not covered by the scope of this report, since it is not relevant to the Community as a whole, is made up of the residues from the extraction and processing of uranium ores. The quantities produced at the extraction site are very great, and the natural radionuclides present release a radioactive gas called radon (^{222}Rn). Discharges containing such waste undergo special treatment to reduce the radiological risk to the public.

I.3. Nuclear power programmes

The production of radioactive waste associated with nuclear power programmes is directly proportional to the scale of those programmes. It also depends on the type of nuclear installation under consideration***. It is therefore appropriate to recall how such programmes were developed and to assess their future development prospects.

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* In the Federal Republic of Germany, this category is defined as a waste producing a significant amount of heat.

** THTR: Thorium Hochtemperaturreaktor in Hamm/Uentrop.

*** It will be noted, in particular, that the GCR reactor type, which is installed chiefly in the United Kingdom, and its associated fuel-cycle installations (reprocessing plants, etc.) produce almost four times as much waste per unit of electricity generated as the LWR reactor type with its fuel-cycle installations.

Several Community countries have installed nuclear power plants since the late 1950s. The installed nuclear power capacity in the Community rose gradually to reach about 77.5 GWe* in 1985.

As regards the future, the 1986 end-of-year forecasts relating to the development of nuclear power programmes up to the year 2000 are summarized in Table I.1, which shows, country by country and for certain key years, the net nuclear power capacity installed, committed and planned at the end of each year.

The estimates are obviously subject to a number of uncertainties, linked, on the one hand, with economic developments in the various countries, and, on the other hand, with political decisions concerning energy sources.

For the sake of comparison with the 1983 report, note should be taken of the Danish decision not to adopt nuclear power production, of a slowing-down in the rates of development forecast for the Federal Republic of Germany and France, and of the Italian and Dutch forecasts regarding certain projects for the construction of nuclear power stations by the end of the century. Taken as a whole, the estimate of the net nuclear power capacity installed, committed or planned up to the year 2000 is about 30% (in order to obtain comparable values, the Spanish capacity has not been taken into account) below what it was in the first report in 1983.

I.4. Future production of waste in the Community Member States

The estimates given below refer to the annual production of treated and conditioned** radioactive waste produced by nuclear power programmes and the various fuel-cycle installations*** and to radioactive waste resulting from research and the production and utilization of radioactive elements in industry, medicine, etc. They are based on information from national sources supplied by Member States' delegates on the Commission's Advisory Committee on Programme Management "Management and Storage of Radioactive Waste", which is responsible for advising the Commission of the European Communities during the implementation of the Community plan of action in the field of radioactive waste.

These estimates cover a period of 15 years, from 1986 to 2000.

Furthermore:

- As a result of technological progress in general and of the research and development work undertaken in certain Member States, processes for the treatment and conditioning of waste

* This figure includes the Spanish capacity (5.6 GWe), which was not included in the figures of the previous report.

** Estimated volumes after treatment and conditioning by means of current methods, despite the fact that some of this waste, in particular alpha and high-level waste, will not be conditioned for several years.

*** Except for the low-level waste arising during the extraction and processing of uranium ores.

TABLE I.1.

Nuclear power programmes in the Member States of the European Community

COUNTRY		Net power installed at the end of the year (GWe) (a) = power stations in operation, committed and planned (b) = only power stations in operation or committed			
		1985	1990	1995	2000
BELGIUM	(a)	5.4	5.4	5.4	6.8
	(b)	5.4	5.4	5.4	5.4
FED. REP. GERMANY	(a)	16.2	23.6	24.9	27.5
	(b)	16.2	23.6	23.6	23.6
SPAIN	(a)	5.6	7.5	8.4	9.3
	(b)	5.6	7.5	7.5	7.5
FRANCE	(a)	38.8	57.3	65.0	70.0*
	(b)	38.8	57.3	61.0	61.0
ITALY**	(a)	1.3	3.3	6.1	9.5
	(b)	1.3	1.3	3.3	3.3
NETHERLANDS	(a)	0.5	0.5	0.5*** (+ 2 to 4)	0.5*** (+ 2 to 4)
	(b)	0.5	0.5	0.5	0.5
UNITED KINGDOM	(a)	9.6	11.8	15.0****	18.7****
	(b)	9.6	11.8	10.0	8.7

* Estimate not covered by the 9th Energy Plan.

** Forecasts for Italy might be modified.

*** Forecasts of nuclear capacity are to be revised in the Netherlands. The additional quantities of waste that would arise in the event of greater capacity were estimated by COVRA.

**** According to a moderate growth scenario put forward by the CEGB.

which enable better volume reduction factors to be obtained will be available during the coming years. Any advance in this field will reduce the quantities of waste to levels lower than those set out in the following tables;

- the choice of the type and the extent of the treatment and conditioning to be applied to the waste depends in large measure on the disposal options adopted and must be optimized with those options in mind. Since several Member States have so far not made definitive choices, the quantities of waste to be treated and conditioned are beset by uncertainty;

- the reactor operating modes, the fuel loading/unloading patterns and the burn-up rates are regularly adjusted with a view to more effective economic optimization, and, inter alia, with the aim of decreasing the quantities of waste produced by the nuclear power programmes.

As regards waste arising from nuclear research activities and from industrial and medical use of radioelements, which is of relevance to all the Community Member States, it should be pointed out that the production of such waste was presumed to be constant over the three five-year periods under consideration in that report*. In the case of Community countries with increasing nuclear power production, and hence an increasing quantity of waste, the proportion of the total volume which they generate is inevitably decreasing (see Table I.2.). Nonetheless, the quantities of that waste which are produced amount for the time being to a considerable proportion of the total amount of waste arising in Member States which, at present, have a small installed nuclear power capacity, such as Italy and the Netherlands. By the end of the century, however, the actual quantity of such waste will represent only a small percentage of the total amount of waste produced, in France and the United Kingdom in particular.

As regards radioactive waste from nuclear power programmes, the situation hitherto can be summarized as follows:

The radioactive waste produced before 1986 is either awaiting conditioning or has been conditioned and stored in a monitored interim-storage facility, or has already been definitely disposed of. Table I.3. presents, country by country, the quantities of waste awaiting disposal; in order to make the figures uniform, the conditioned-volume equivalent is indicated even if the waste has not yet been conditioned. Table I.4. presents, country by country, the method of disposal, the disposal site and the volume of waste already disposed of.

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* It is to be expected that production of this waste will increase over the three periods; it is, however, very difficult to make reliable estimates. Moreover, better volume reduction factors can be expected in this field as well.

TABLE I.2.

Percentage of waste arising from activities not linked to nuclear power generation

COUNTRY	Percentage by volume of waste arising from research activities and uses of radionuclides in relation to the total amount of waste produced (illustrative values)	
	1981 - 1985	1995 - 2000
BELGIUM	25	15
SPAIN	6	4
FRANCE	20	6
FED. REP. GERMANY	25	21
ITALY	50	12*
NETHERLANDS	40	40**
UNITED KINGDOM	12	8

In the case of Denmark, Greece, Ireland, Luxembourg and Portugal, which do not have nuclear power programmes, the proportion is obviously 100%.

* See footnote ** to Table I.1.

** See footnote *** to Table I.1.

It should be noted that, in the case of countries which possess nuclear weapons, the quantities indicated in Table I.4. contain an unspecified percentage of waste of military origin. It would appear that about 1,000,000 m^3 of waste, mainly of low activity, has been disposed of by a variety of means since the beginning of the nuclear era and with reference to the present Community as a whole.

The present and future situations can be evaluated on the basis of the nuclear-power-programme estimates in Table I.1. The data concern the net power capacity, installed at the end of the year and based on power stations in operation, committed and planned, given in point (a) of that table. However, and more particularly in the case of waste produced during reprocessing, account was taken in some cases of a certain lapse of time to enable treatment and conditioning of the waste to be carried out. These estimates are beset by the same uncertainties as those concerning the nuclear programmes themselves.

The estimates relating to each Member State have been divided among the four waste categories described in Section I.2. and are presented, accumulated per five-year period, in Tables I.5., I.6., I.7. and I.8. for low-level, medium-level, alpha and high-level waste, respectively. The increase in the quantity of waste produced over the years is not quite proportional to the growth in installed nuclear power capacity. This is due mainly to the volume reduction allowed for in anticipation of the gradual introduction of new treatment and conditioning techniques. In the case of the United Kingdom, the greatest influence in this connection results from the gradual shutdown of GCR (Magnox) reactors and their replacement with AGR or LWR reactors (see Section I.3., footnote concerning the GCR reactor type).

As regards waste arising from the decommissioning of nuclear installations, for which an estimate was in preparation when the first report was published in 1983, it would seem that, during the period under consideration (1986 - 2000), it would be produced through the dismantling of a small number of reactors of quite low power, mainly in the Federal Republic of Germany, France and the United Kingdom. The corresponding overall production of low-level waste can be estimated at several thousand cubic metres per reactor.

The dismantling of large power reactors should give rise to greater quantities of waste (of the order of 25 000 m^3 in the case of a PWR with a capacity of at least 800 MWe and of the order of 40 000 m^3 in the case of an AGR).

Low- and very low-level waste will make up 80% to 90% of the waste arising from dismantling, the remainder being chiefly medium-level waste; only a small quantity of steel from the areas near the reactor core will have been sufficiently activated to be considered as waste requiring deep geological disposal.

The production of such waste will remain extremely low in the Community during the 1986-2000 period under consideration, although some ten medium-sized reactors have already been definitely shut down and some 50 nuclear power stations will probably be taken out of service by the year 2000. A policy of delayed

TABLE I.3.

Waste in interim storage which was produced before 1986, treated and conditioned or presumed to have been conditioned*

COUNTRY	Quantities of waste in interim storage (m^3)				
	Low-level	Medium-level	Alpha	High-level	Remarks
BELGIUM	3,500	-	3,000	260	Medium-level waste included in the low-level waste
FED. REP. GERMANY	36,200**	-	-	200	Medium-level and alpha waste included in the low-level waste
SPAIN	8,075	-	-	-	Medium-level waste included in the low-level waste
FRANCE	0	0	20,000	715***	
ITALY	1,780	350	75	25	Waste presumed to be conditioned****
NETHERLANDS	2000		0	0	
UNITED KINGDOM	0	7,000	37,000	700	
Other countries	Small quantities of waste arising from medical, industrial and R&D activities				
TOTAL	51,600	7,400	60,100	1,900	Totals are rounded off

* Most of the alpha and high-activity waste (stored in liquid form) has not yet been conditioned. For uniformity of presentation, the volumes indicated in this table are those which could be obtained by conditioning the waste with the methods available at present.

** Of which 7 000 m^3 unconditioned, taken into account with a post-conditioning reduction factor of 1.5.

*** Quantities arising from the reprocessing of fuel from the national reactors.

**** The unconditioned quantities in interim storage are 8 900 m^3, 1 760 m^3, 376 m^3 and 124 m^3, respectively; a volume reduction factor of 5 is expected to result from conditioning.

TABLE I.4.

Low- and medium-level waste disposed of before 1986
with conditioning products and lost package included

COUNTRY	Quantities of waste (m³)			
	Low-level	Medium-level	Type of disposal	Site
BELGIUM	15,000		Sea dumping*	North Atlantic
FED.REP. GERMANY	96		Sea dumping*	North Atlantic (1967)**
	42,000	260	Deep burial (salt mine)	Asse***
SPAIN	-	-		
FRANCE	2,700	7,200	Sea dumping*	North Atlantic (1967 and 1969)
	190,000	80,000	Shallow burial	Centre de la Manche
ITALY	23		Sea dumping*	North Atlantic (1967)**
NETHERL.	8,700		Sea dumping*	North Atlantic
UNITED KINGDOM	26,000		Sea dumping*	North Atlantic
	630,000	-	Shallow burial	Drigg

* Moratorium on sea dumping since 1983.
** As part of a joint operation organized by the OECD.
*** In operation between 1967 and 1978.

TABLE I.5.

Production of low-level waste of any origin, treated and conditioned, in various Community Member States (power stations in operation, committed and planned - assumptions (a) in Table I.1.)

COUNTRY	Quantities of waste accumulated per five-year period (m³)				
	1986-1990	1991-1995	1996-2000	TOTAL	REMARKS
BELGIUM	6,000	7,000 (1)	7,000 (1)	20,000	(1) These quantities include waste originating from fuel reprocessed abroad and medium-level waste.
FED.REP. GERMANY	41,000	60,000	91,000	192,000	These quantities include medium-level waste and alpha waste which does not produce heat.
SPAIN	12,000	18,000	22,000	52,000	These quantities include medium-level waste.
FRANCE	87,000	86,000	92,000	265,000	
ITALY*	10,000	11,500	13,500	35,000	
NETHER-LANDS**	4,000	4,000	4,000	12,000	
UNITED KINGDOM	120,000	130,000	130,000	380,000	
GRAND TOTAL	280,000	316,500	359,500	956,000	

* see footnote ** to Table I.1.

** see footnote *** to Table I.1.

TABLE I.6.

Production of medium-level waste of any origin, treated and conditioned, in various Community Member States (power stations in operation, committed or planned - assumptions (a) in Table I.1.)

COUNTRY	Quantities of waste accumulated per five-year period (m^3)				
	1986-1990	1991-1995	1996-2000	TOTAL	REMARKS
BELGIUM	-	-	-	-	In accordance with management practices applied in Belgium, waste of this category is accounted for as low-level waste.
FED.REP. GERMANY	-	-	-	-	In accordance with management practices applied in Germany, waste of this category is accounted for as low-level waste.
SPAIN	-	-	-	-	In accordance with management practices applied in Spain, waste of this category is accounted for as low-level waste.
FRANCE	58,000	57,000	61,000	176,000	
ITALY*	1,300	3,000	4,500	8,800	
NETHER.**	250	250	250	750	
UNITED KINGDOM	2,500	2,500	3,000	8,000	Waste with an alpha activity of less than 10 GBq/m^3***
GRAND TOTAL	62,050	62,750	68,750	193,550	

* See footnote ** to Table I.1.

** See footnote *** to Table I.1.

*** 1 GBq = 10^9 Bq (1 Becquerel corresponds to one disintegration per second)

TABLE I.7.

Production of alpha waste, treated and conditioned, in various Community Member States (power stations in operation, committed or planned - assumptions (a) in Table I.1.)

COUNTRY	Quantities of waste accumulated per five-year period (m^3)				
	1986-1990	1991-1995	1996-2000	TOTAL	REMARKS
BELGIUM	300	850(1)	650(1)	1,800	(1)These quantities mainly comprise waste originating from fuel reprocessed abroad.
FED.REP. GERMANY	-	-	-	-	The alpha waste is accounted for in waste of the low-level category.
SPAIN	-	-	-	-	No alpha waste originating from reprocessing abroad before the year 2000.
FRANCE	4,000	7,500	11,500	23,000	
ITALY*	850	850(2)	200(2)	1,900	(2)These quantities also include waste originating from fuel reprocessed abroad.
NETHER-LANDS**	-	50	50	100	Waste originating from fuel reprocessed abroad.
UNITED KINGDOM	14,000	11,000	7,000	32,000	
GRAND TOTAL	19,150	20,250	19,400	58,800	

* See footnote ** to Table I.1.

** See footnote *** to Table I.1.

TABLE I.8.

Production of high-level waste, treated and conditioned*, in various Community Member States (power stations in operation, committed or planned - assumptions (a) in Table I.1.)

COUNTRY	Quantities of waste accumulated per five-year period (m^3)				
	1986-1990	1991-1995	1996-2000	TOTAL	REMARKS
BELGIUM	-	30	40	70	This is waste originating from fuel reprocessed abroad.
FED.REP. GERMANY	-	250	375	625	These quantities include waste originating from fuel reprocessed abroad.
SPAIN	-	-	-	-	No high-level waste before year 2000.
FRANCE	210	400	720	1,330	Waste originating solely from the reprocessing of national fuel.
ITALY**	-	125	135	260	These quantities also include waste originating from fuel reprocessed abroad.
NETHERLANDS***	-	5	15	20	Waste originating solely from fuel reprocessed abroad.
UNITED KINGDOM ****	120	170	170	460	Waste originating solely from the reprocessing of national fuel.
GRAND TOTAL	330	980	1,455	2,765	

* Or presumed to have been conditioned.
** See footnote ** to Table I.1.
*** See footnote *** to Table I.1.
**** Originating from the reprocessing of Magnox fuel and of 1 850 MTHM of fuel from AGRs.

dismantling will probably be applied to these nuclear installations in order to benefit from the natural decay of the radioactivity with time, which will postpone the production of waste from decommissioning beyond the year 2000. As far as waste arising from dismantling of nuclear fuel cycle installations is concerned, it will account for less than 4% of the waste from normal reactor operation during the 1986-2000 period. The increase in the quantities of waste arising from decommissioning was taken into account in the assessment of the required disposal site capacities that will be required.

I.5. Quantities of spent fuel discharged from power stations

The quantities of spent fuel discharged from nuclear power stations reflect the effective production of nuclear power. It is of relevance to this report insofar as the proportion of the spent fuel which is not reprocessed constitutes a special type of high-level waste (see Section I.2. (d) and (e)). Table I.9 indicates the total quantities that will be discharged either for reprocessing purposes or to be stored. The quantities to be reprocessed are accounted for as vitrified high-level waste in Table I.8.

It should be stressed that the fuel consumption per unit of electricity produced varies from one type of reactor to another. For that reason, quantities of fuel per reactor type have been given, and the totals have not been calculated.

I.6. Conclusions

Waste classification at national level does not always follow the same pattern in each country, since it is an operational classification closely linked with the types of disposal chosen (see Chapter III). The types of waste are hence not directly comparable from one country to another. With these reservations in mind, the following illustrative conclusions can be drawn:

a) The total production of conditioned low-level, medium-level and alpha waste is at present about 70 000 m^3/year for the Community as a whole and should still be well below 100 000 m^3/year at the end of the century. The alpha waste accounts for 7% to 8% of that total, the medium-level waste for about 15%* and the low-level waste for the remainder, or over 75%.

b) Almost all of the radioactivity generated by the use of nuclear energy is concentrated in the spent fuel discharged from the nuclear power stations, which amounts to about 3 500 MTHM per year at present and will increase to about 4 600 MTHM per year by the end of the century in the Community as a whole. The reprocessing scheduled for a considerable proportion of this fuel will reduce very appreciably the volumes to be stored by producing several dozen cubic metres of vitrified waste per year, as at present, and several hundred cubic metres per year by the end of the century in the Community as a whole.

* This fraction varies from 2% to 37% according to country, reflecting the differences in classification resulting from the type of disposal chosen and the difference between the types of waste produced by the different types of reactor.

TABLE I.9.

Spent fuel discharged in the Member States of the European Community

COUNTRY	Reactor type	Quantity of fuel discharged per five-year period (MTHM)* - Power stations in operation, committed or planned (assumptions (a) in Table I.1.).		
		1986-1990	1991-1995	1996-2000
BELGIUM	LWR	650	550	550
FED. REP.	LWR	2,516	3,000	3,250
SPAIN	LWR GGR	695 400	850 400	975 400
FRANCE	LWR GGR FBR	5,800	6,700	6,600
ITALY**	LWR GGR	200 200	350 200	500 200
NETHERLANDS***	LWR	75	75	75
UNITED KINGDOM (1)	GCR AGR	5,900 1,200	4,500 1,880	920 2,870
UNITED KINGDOM (2)	GCR AGR LWR	5,900 1,200 0	4,500 1,520 270	920 1,560 950

* MTHM: Metric tons of heavy metal.
** see footnote ** to Table I.1.
*** see footnote *** to Table I.1.
LWR: Light water reactor.
GGR: Gas-graphite reactor.
GCR: Gas-cooled reactor.
AGR: Advanced gas-cooled reactor.
FBR: Fast breeder reactor.
(1) If reactors of the advanced gas-cooled type are constructed in the future.
(2) If pressurized-water reactors are constructed in the future.

c) The quantities of waste involved are small in comparison with the quantities of non-nuclear industrial wastes which are generated and are also capable of harming man if they are not stored and disposed of with care. Consequently, only small-capacity storage facilities and repositories will be required, and it is unlikely that, even in the case of a large-scale nuclear programme, more than one or two sites will be needed in any country.

Finally, it should be recalled that the volume of waste indicated in the foregoing tables comprises both the actual volume of the radioactive materials constituting the waste and that of various inert materials (cement, bitumen, polymers, glass, etc.) necessary for waste conditioning. The latter volume accounts for a considerable proportion of the final volume of conditioned waste. Furthermore, the numerical values in the tables also take into account the volume of the containers (metal drums, concrete containers, etc.) used as receptacles for the conditioned waste. In the storage and disposal facilities, the containers, which are basically cylindrical, are arranged by rows; as a result of the free space between the drums, the space required to accommodate the waste is greater than the volumes indicated in the tables.

CHAPTER II

Techniques and installations for the treatment and conditioning of radioactive waste and spent fuel in the European Community

II.1. Introduction

The management of radioactive waste comprises the collection, sorting, treatment, conditioning, transport, storage and, finally, disposal of the waste. These activities are closely linked through numerous interactions between them. However, for the sake of simplicity, two main groups of activities are distinguished below*:

a) activities relating to treatment and conditioning, which are industrial conversion operations intended to impart to the waste a form appropriate to handling, storage and disposal;

b) activities relating to disposal, which can be carried out either on land (shallow land burial, disposal in continental geological formations) or at sea (sea dumping and, possibly at some future date, burial in the sea bed).

The activities relating to treatment and conditioning are the subject of this Chapter, while those relating to storage and disposal are described in Chapter III.

Finally, the administrative and regulatory measures intended to enable waste management to attain its main objective in the Community Member States, namely the safety of present and future generations and environmental protection, are studied in Chapter IV.

Concern to keep the radiological risks as low as reasonably achievable (ALARA principle**) guides the choice of techniques and the design of the treatment and conditioning installations, account being taken of technical and economic factors.

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* The transport operations are a special case in the context of the transport of nuclear materials in general and do not fall within the specific ambit of radioactive waste management.

** "As low as reasonably achievable, economic and social factors being taken into account".

II.2. Treatment and conditioning of low- and medium-level waste

Almost 93% of the volume of radioactive waste currently produced in the Community is accounted for by low- and medium-level waste (see Chapter I).

Processes for the treatment and conditioning of such waste are available and the corresponding industrial installations have been applying them successfully since the early 1950s. A general description of these processes and installations was given in the 1983 report.

The treatment prepares the waste, as produced at source, for conditioning; it chiefly takes the form of:

- Compaction or incineration in the case of solid waste;
- Evaporation, insolubilization or chemical precipitation followed by filtration in the case of aqueous waste.

As regards solid waste, note should be taken of the recent advances achieved in the field of supercompaction, thanks to the development of high-performance presses, and in the field of incineration, thanks to the raising of temperatures, which allows for fuller combustion of the products to be treated. Installations of these different types are already in operation or are planned in several Member States.

To these advances can be added the efforts to minimize waste production at source which are being made in the nuclear installations concerned (for example by adapting the reactor's mode of operation or by increasing the lifetime of certain contaminated components, such as filters, so that replacements can be less frequent). This set of measures has already resulted in a considerable reduction in the volume of waste treated for a given production of electricity of nuclear origin and contributes to limiting the growth of waste volume (see Table I.5.) in comparison with the quantities estimated in the 1983 report.

As regards liquid waste, numerous processes designed to achieve high decontamination factors have recently been adopted for use in certain major nuclear installations; for example, the new installation for the decontamination of low-level liquid waste (called SIXEP, the construction of which began in 1979) at the British reprocessing plant at Sellafield entered service in 1985. That very large installation makes use of an ion-exchange process which now enables the amount of radioactivity discharged into the sea to be reduced to only a few per cent of that discharged in the 1970s. Flocculation/coprecipitation decontamination processes have been used for several years at CEN/SCK Mol. Other very effective processes are being developed, such as ultrafiltration (membrane separation processes) or processes which make use of selective action on the most important radioelements (selective complexing agents). The introduction of these processes will make it possible to reduce the volume of the sludges through improved separation and result in lower residual activity in the discharges.

Conditioning imparts to the treated waste forms which reduce to a minimum the risk of dispersion of the radioelements in the waste during handling and transport operations or in the event of attack by external agents (mainly water) after disposal. To that end, the treated waste is most frequently incorporated in matrices which solidify into blocks or structures possessing, with or without external containers, the requisite safety features (good mechanical strength, resistance to fire, a low leaching rate, satisfactory long-term behaviour, etc.).

The matrices most often used in the Community are as follows:

- cements, which have been employed since the 1950s mainly for low-level waste; a considerable effort has been made to improve their characteristics, either by changing their composition or by adding polymers, ...
- bitumens, which were introduced between 1960 and 1965, are used by several Member States;
- polymers, which were recently introduced.

This aspect of radioactive waste management would seem, on the whole, to meet satisfactorily the current requirements of the nuclear power programmes and the safety requirements. Although such operations have been carried out for several decades, they benefit significantly from technological advances.

The principal characteristics of the treatment and conditioning installations in the Community are presented in Table II.1.

II.3. Treatment and conditioning of alpha waste

Of the radioactive waste produced in the Community, 7 to 8% consists of products contaminated by long-lived alpha emitters, the radioactivity of which remains at a significant level over long periods. Most of such waste remains untreated at present, pending the development of treatment and conditioning processes and the availability of underground disposal facilities. The basic technologies are available and the current R&D activities are focused on techniques for the treatment of liquid and solid waste contaminated by alpha emitters and on the conditioning of the hulls of spent fuel elements. The objective of these activities is to develop conditioning processes which would ensure safe storage and disposal over long periods. New processes have been developed and tested up to the pilot-installation stage, chiefly for solid plutonium-contaminated waste (see Table II.2.). These processes have fields of application which vary according to the plutonium content of the waste. Where liquid alpha waste is concerned, and despite the fact that a number of advanced processes (inorganic ion exchange, selective chemical precipitation, electrical processes, etc.) have been studied, only the ultracentrifugation process combined with chemical precipitation (developed at Harwell in the United Kingdom) is far enough advanced to be used in an active-waste pilot installation with a capacity of 5 m^3/day. The treatment generally applied in Europe to such waste is of the conventional type (chemical precipitation, evaporation, ion-exchange resins, etc.). The separation of long-lived radioelements (actinides), either with a view to recycling them or to degrade most of such waste into waste of other categories, is also under study.

TABLE II.1.

Principal characteristics of installations for the treatment and conditioning of low- and medium-level waste

Nature or type of waste	Management phase	Principal characteristics
Solid (sometimes also liq.) Combustible	Treatment by incineration	20 to 150 kg/h, reduction factors up to 100
Solid Compactable	Treatment by compacting presses	16 to 1500 tonnes, volume reduction factors of 2 to 5
Solid Non-compactable	Treatment by shearing	70 to 400 m^3/year
Metals	Treatment by melting	1200 tonnes/yr, volume reduction factors greater than 3
Solid	Encapsulation (mainly with cement)	150 to 2000 220-litre drums per year
Low- and medium-level effluent	Treatment, mainly by filtration and evaporation	Capacities typically around 4 m^3/h, max. 200 m^3/h.
Sludges resulting from treatment	Encapsulation in bitumen and cement	650 m^3/year
Ion-exchange resins	Encapsulation in polymers and cement	2 - 5 m^3/8 h
Low- and medium-level effluent	Chemical precipitation	5 m^3/h
Low- and medium-level effluent	Treatment by two-stage evaporation	0.5 - 10 m^3/h
Low- and medium-level effluent	Treatment by concentration/drying	100 l/h
Low- and medium-level effluent	Ion exchange	About 150 m^3/h
Liquid organic waste	Treatment by incineration	40 l/h
Liquid and solid organic waste	Treatment by pyrolisis	15 - 30 kg/h

TABLE II.2.

Pilot installations for the treatment of plutonium-contaminated waste

Type of installation	Capacity	Recovery percentage	Start of operation with active waste	Place
Incineration	1 kg/h	-	1971	Marcoule (F)
Incineration	5 kg/h	-	1973	Windscale (UK)
Incineration (pyrolisis)	1 kg/h	-	1978	Valduc (F)
Acid digestion	1-1.5 kg/h	95	1983	Dessel (B)
Washing	1-2 kg/h	75-95	1984	Hanau (FRG)
Slag-forming incineration	100 kg/h	-	1984	Mol (B)
Cryogenic crushing	6 m^3/h	> 45	1985	Cadarache (F)
Incineration	50 kg/h	-	1986	Karlsruhe (FRG)

II.4. Treatment and conditioning of high-level waste

Of the volume of radioactive waste produced in the Community, 0.3% is made up of high-level waste (also containing alpha emitters) which is or is to be vitrified. This waste contains almost all the radioactivity in waste arising from the nuclear power programmes. The release of heat due to radioactivity is in consequence a major concern in the management of such waste.

Radioactivity and heat emission decrease until levels similar to those of alpha waste are reached after several hundred years. At that moment, the high-level waste is similar to alpha waste.

Most of the high-level waste is nowadays temporarily stored in the liquid state in tanks provided with special cooling and safety systems. The objective of the treatment and conditioning processes is to immobilize this waste in solid matrices, such as glasses, which maintain satisfactory integrity in the long term. Industrial development of various conditioning processes is at present under way in the Community. Of such processes, the French vitrification process (AVM)* is available on a commercial scale and is being applied in several major facilities. In the Germano-Belgian installation PAMELA, high-level liquid waste from the Eurochemic reprocessing plant has also been successfully vitrified by means of the PAMELA process. The vitrification installations in operation, under construction or planned in the Community are presented in Table II.3.

It can be seen that all sources of production of high-level liquid waste (mainly reprocessing plants) in existence or planned in the Community will be provided in due course with vitrification facilities in order to ensure that the waste is immobilized and adequately conditioned with a view to its final disposal.

Alternative second-generation processes are being studied in several countries; they are intended to meet very specific requirements (for example spent-fuel solid residues from dissolution processes during reprocessing operations) or to develop the capacity of the immobilization matrix to confine the radioactivity of the waste until it approaches that of the geological disposal medium itself; the containment capacity of the geological medium is considered to be tens, and even hundreds of thousands, of years (Chapter IV).

Of the most promising processes under study, immobilization in ceramic matrices (France, Federal Republic of Germany, United Kingdom) or vitro-ceramic matrices may be mentioned.

II.5. Spent-fuel conditioning with a view to disposal without reprocessing

The spent-fuel sub-assemblies discharged from a reactor, after spending several years in the reactor storage pond, must undergo interim storage for one or more decades in order to complete their cooling-down process before disposal (see Chapter III). Preconditioning may in consequence be necessary, especially in the case of dry interim storage. Such preconditioning, which provides as a minimum requirement leak-tightness to prevent

* Atelier de Vitrification de Marcoule

TABLE II.3

Industrial-scale installations for the vitrification of high-level waste arising from reprocessing (in service and planned)

Site	Year of commissioning	Vitrification process	Capacity kg glass/year	Type of reactor
Marcoule (a) (France)	1978	AVM	72,000	UNGG + military
Mol (b) (Belgium)	1985	PAMELA	12,000	LWR + MTR + special fuel
La Hague (c) (France)	1988	AVM	300,000	LWR
Sellafield (d) (United Kingdom)	1988	AVM	240,000	Magnox + AGR + LWR
Wackersdorf (e) (Fed.Rep.Germany)	1996	PAMELA or AVM	206,000	LWR

(a) The Atelier de Vitrification de Marcoule (AVM) treats waste arising from the reprocessing of fuel elements from reactors of the gas-graphite natural-uranium (UNGG) type.

(b) The vitrification installation in Mol, which has been dealing with active waste since November 1985, has treated liquid waste from water-cooled reactors (LWR), which had been stored at Mol; liquid waste from the Material Test Reactor (MTR) and special fuel elements is being treated at present; the PAMELA process (liquid-fed Joule-heated ceramic melter) was developed by KfK, DWK, HMI and Eurochemic.

(c) The Atelier de Vitrification de la Hague makes use of the AVM process which has been adapted to deal with waste from pressurised-water reactors.

(d) The WVP plant will vitrify waste arising from past and future reprocessing of metal fuel from reactors of the Magnox type (a reactor type in which the fuel cladding is made of a magnesium alloy) and from the reprocessing of oxide fuel in the Thorp plant (fuel from light-water reactors (LWRs) and advanced gas-cooled reactors (AGRs)).

(e) The WAW (Wiederaufarbeitungsanlage Wackersdorf) plant will be treating 200 tonnes in 1996 and then 350 tonnes per year up to 2001; there are plans to expand the capacity to 500 tonnes per year after 2002.

radioactive gases from escaping from the fuel rods and facilitates the removal of the residual heat, is used as a means of conferring upon the package of radioactive fuel the long-term integrity which makes it suitable for disposal in a deep-lying geological formation. Final conditioning for disposal must make the fuel capable of resisting rock-formation pressures and corrosion for several centuries. Finally, protection against radiation, often of the type called "lost packaging", will enable the final product to be transported to and installed in the disposal repository.

The type of conditioning is chosen in strict accordance with the parameters of the final repository: type of formation, method of placing the waste in position, dimensions of and permissible load in the access shafts and the galleries, depth of repository chamber, etc.

Various types of conditioning are undergoing design studies in several Community Member States: simply placing several assemblies in a leak-tight cylindrical container to be loaded into a thick metal container, volume reduction by disassembling and cutting up the pins and then embedding the pieces in a matrix, chemical dissolution of the sub-assembly followed by vitrification, etc.

Of the Community countries, only the Federal Republic of Germany (which is planning to dispose of sub-assemblies from high-temperature reactors without prior reprocessing and intends to study the feasibility of disposing of special fuel elements from other reactor types without reprocessing) is preparing to set up a conditioning plant; this pilot unit, with a capacity of 35 tonnes per year, is scheduled to be built in Gorleben; the application for a construction permit was submitted in May 1986.

II.6. Conclusions

Treatment and conditioning processes for radioactive waste of the low- and medium-level categories, which account for most of the total volume (93%), are available in the Community on an industrial scale. Over the years, technological advances have constantly brought about substantial improvements in the field of waste processing.

Most of the other waste which contains radioisotopes with long or very long half-lives will remain in the untreated and unconditioned state for the time-being, despite the fact that applicable processes exist. Such waste is stored in safe interim storage facilities which are continuously monitored pending the availability of disposal repositories in geological formations (see Chapter III).

Furthermore:

a) As regards low- and medium-level waste, management action to decrease waste production at source and the increasingly widespread application of improved volume-reduction processes are already resulting, in certain Member States, in less waste to be stored for any given nuclear programme; current research and development work concerns improvement of the long-term resistance of conditioned solid products and reduction of the radioactive contamination of liquid effluents.

b) Waste of the alpha waste category has not yet been conditioned to any great extent, although the requisite basic processes exist, since these processes must be suited to the characteristics of the disposal installations, which have not yet been selected. This state of affairs leaves room for research into even more efficient processes; in some cases, the separation of long-lived radioactive elements might make it possible to achieve considerable volume reduction of part of the waste.

c) The vitrification of high-level waste has reached the stage of industrial-scale application, and large-scale vitrification installations will enter into service in various Member States over the next few years; other promising processes are still being developed.

d) The conditioning of spent fuel with a view to disposal without reprocessing, despite the decision of most of the Member States to reprocess spent fuel, is being studied intensively at present; the Federal Republic of Germany is planning to construct a pilot conditioning plant.

CHAPTER III

Storage and disposal of radioactive waste and spent fuel in the European Community

III.1. Introduction

"The disposal of radioactive waste in the Community is currently confined essentially to low- and medium-level waste. For the time being, alpha and high-level waste are stored. Means of disposal are being studied or developed...". The foregoing statements, reproduced from the 1983 report, are still valid.

However, governmental awareness of public unease concerning the nuclear industry has not been without consequences to the development of the policies pursued with regard to the storage and disposal of radioactive waste.

This is illustrated by the revision of the strategy for disposal of low- and medium-level waste in Belgium and the Netherlands and, to a lesser extent, in the United Kingdom following the moratorium* on the sea disposal of radioactive waste recommended by the parties to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (called the "London Convention") in February 1983 and confirmed in 1985.

The complex processes for the selection of future disposal sites continue to be applied cautiously, and are often slowed down by a wide range of political and social factors. Furthermore, many R&D results indicate that, although several geological formations (salt, crystalline rock and clay) may be suitable for deep disposal, the specific characteristics of the sites under consideration are also important. As a result, there exists in several Member States a situation justifying the construction and operation of experimental or pilot underground installations.

Finally, the economic data (stagnation in the demand for energy, the low price of oil and uranium) provide no incentive to adopt rapid and widespread reprocessing of spent nuclear fuel.

To these reasons can be added the technical requirement that high-level vitrified waste (or possibly spent fuel) should be allowed to "cool-down" for a period which is determined also by

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* Although not legally binding, that moratorium did in fact lead to the suspension of all sea dumping since 1983; it was confirmed in 1985 pending additional studies on the political, legal, economic and social aspects which are intended to supplement the scientific evaluation (positive) presented in 1985.

the nature of the geological formation chosen for disposal (and may amount to decades in the case of some host rocks), so that we would now seem to be traversing somewhat of a waiting period with regard to the disposal of such waste. In this context, interim storage has become a matter of importance, as will be seen below.

All countries have a common objective in ensuring that waste will be stored and disposed of safely and without harm to the environment. However, there are many ways in which this objective can be attained, and various approaches have been adopted:

- France and the United Kingdom reprocess spent fuel, including fuel from other countries, practice land disposal of low-level waste by shallow burial and are studying ways and means of disposing of other types of waste.

- the Federal Republic of Germany has decided to bury all its waste in deep-lying geological formations; for this reason, only two waste categories are distinguished: waste which produces significant amounts of heat and will be buried in a salt dome and other waste, most of which will be buried in an iron-ore mine and/or a salt mine.

- the option adopted by <u>Belgium</u> is to dispose of its high-level and alpha waste by deep burial in clay formations. Research activities already in progress for a number of years have resulted in the drilling of a shaft 237 m deep and the setting-up of an underground laboratory.

- <u>Italy's</u> Magnox fuel discharged from the Latina power plant is reprocessed in the United Kingdom; fuel from LWR type reactors is not reprocessed, but stored at the production site or in centralized ponds.

- the other waste-producing countries are preparing, at various rates of progress, the disposal of their waste; most of their spent fuel is reprocessed in France and/or the United Kingdom.

- one Community country, Spain, has decided not to reprocess the spent fuel from its LWR reactors and to make provision for direct disposal after an appropriate cooling-down period.

Despite these somewhat differing approaches, a very pronounced convergence of these policies in the future is taking shape, as can be seen from Figures III.1. and III.2., which present the estimates for the Member States:

- Fig. III.1. shows how the construction and operation of disposal facilities for low- and medium-level waste have evolved and are likely to evolve in the future;

- estimates for waste containing long-lived emitters are presented in a similar way in Figure III.2.

FIGURE III.1.

Installations for the disposal of low- and medium-level waste

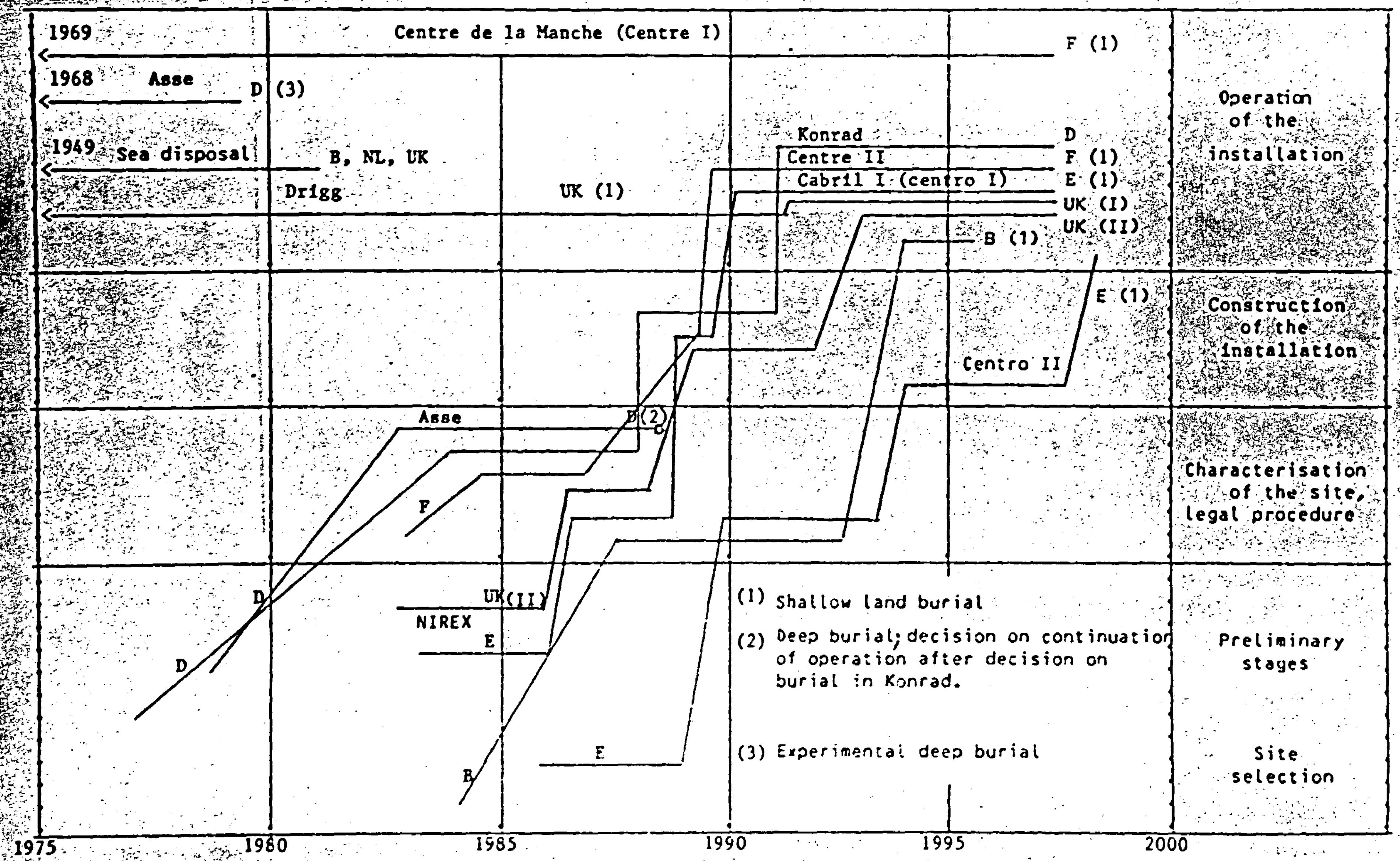
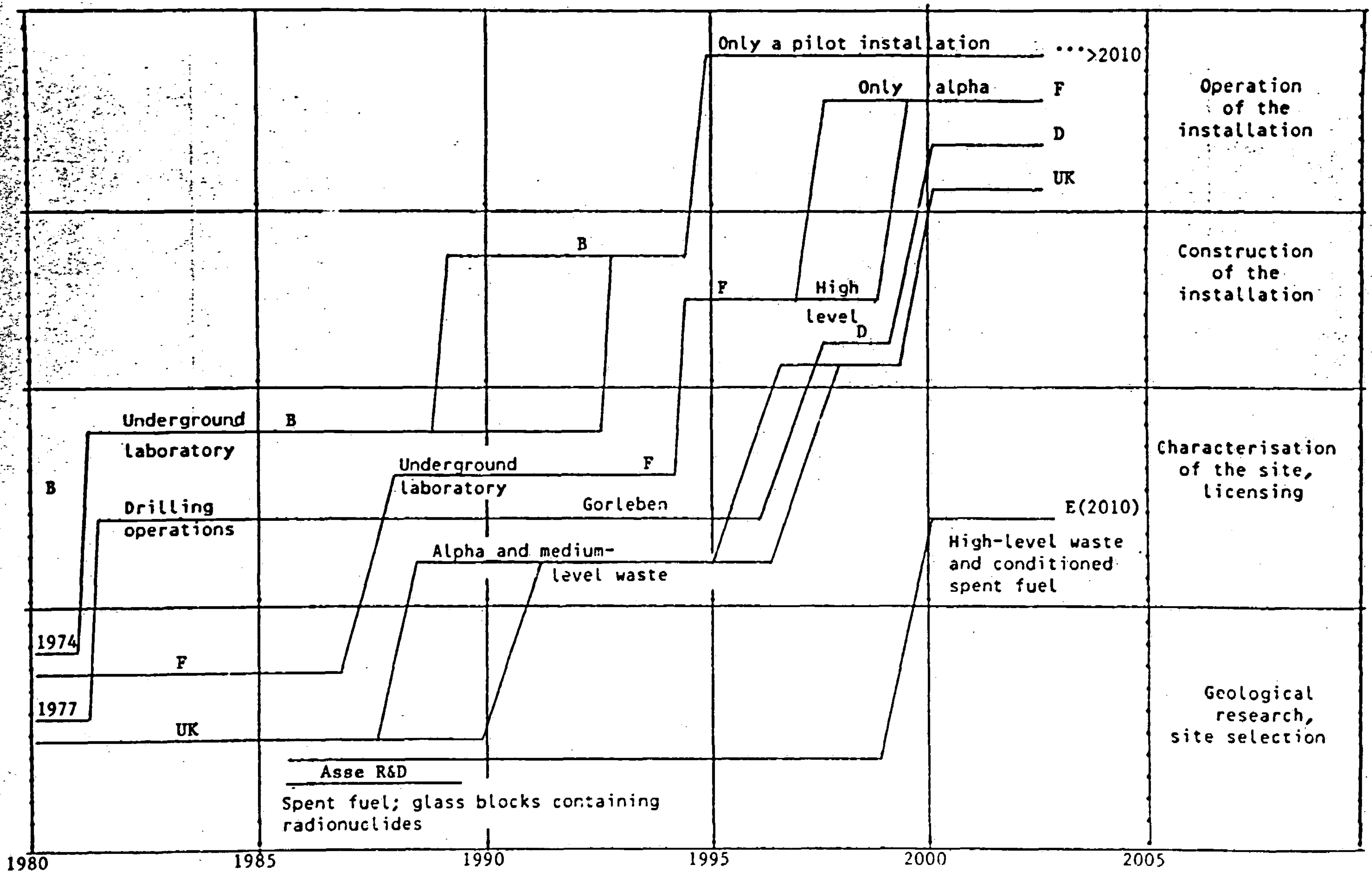


FIGURE III.2.

Disposal of high-level and alpha waste in deep-lying geological formations



Considerable advances have been achieved in the field of R&D, and the use of underground galleries on a pilot scale makes it possible to approximate the actual operating conditions of disposal facilities in deep-lying geological formations. Most of these activities are conducted under the Community's R&D programme, which provides a framework for the exchange of scientific information and promotes the exchange of technological know-how.

As regards assessment of site suitability, the Community PAGIS (Performance Assessment of Geological Isolation Systems) group demonstrated that the sites currently under consideration are fully capable of providing the requisite effective isolation of waste over tens of thousands of years.

III.2. Low- and medium-level waste

Low- and medium-level waste contains fission products which virtually disappear after several hundred years through decay, and very small quantities of radionuclides with a long half-life, of which the maximum specific content or the content with reference to a site as a whole is defined by the national authorities in accordance with the data specific to the site. The principles of radiation protection are applied throughout the management process and, generally speaking, optimization of the process should be the determining factor when making a choice in respect of a specific category.

This waste is generally treated and conditioned quite soon after it has been produced.

Interim storage takes place:

- either at the production site, which sometimes possesses quite a large storage capacity;

- or in a centralized storage facility, which is often close to the disposal site and is protected and monitored.

Quite a wide range of disposal options exist, and many of them have been and are being put into practice; it seems that, for the foreseeable future, shallow land burial will continue to be the method applied in most Member States (see Fig. III.1.)

Land disposal is carried out:

- either by burial close to the surface, a great variety of repositories being used in accordance with the type of waste and the geological formation, ranging from a simple trench to an artificial underground structure;

- or by deep burial, often in disused mines known to be free of water intrusion; the feasibility of injecting certain waste in liquid form into very deep boreholes is being studied in the Federal Republic of Germany (tritiated waste).

As regards sea disposal, the dumping of waste at sea, which was practised regularly up to 1983, has been suspended for the time being; that type of disposal would appear to be the best possible option from an environmental standpoint for some types of waste such as tritiated waste. One option which has been studied is the temporary or final storage of waste in artificial structures on the sea surface.

The situation in and the estimates for the principal countries are as follows:

- Belgium practised sea dumping up to 1983 (29 700 tonnes were dumped between 1960 and 1982); since then, the waste has accumulated on the Mol-Dessel site, where an appropriate temporary storage infrastructure is under construction; a study on disposal by shallow burial is in progress;

- the Federal Republic of Germany practised deep land disposal in the disused Asse salt mine up to 1978; the waste, in 200- and 400 litre drums, was placed in large caverns at depths ranging from 450 to 715 m; the feasibility of reopening the Asse salt mine as a disposal site is being studied, and an opinion in this regard will be delivered as soon as a decision has been reached on the entry into service, of the Konrad mine, probably towards 1990;

- in Spain, about 7,000 m^3 of waste in temporary storage in 200- and 400-litre drums at the nuclear power plants; the remainder of the waste is stored at the El Cabril site, where there is a disused uranium mine. About 6 000 drums (mostly 200-litre drums) containing conditioned waste from other activities are stored at this site in a surface storage facility; about 700 drums which have so far been stored in the mine will be transferred to the surface facility, which has a maximum capacity of about 15 000 drums. Expansion of the capacity of the El Cabril facility by shallow land burial is under study. Preliminary studies concerning an additional capacity of 38 000 m^3 are already in progress. Site selection studies for a second facility have also been initiated in case the need for a second site arises;

- France participated in sea dumping projects in 1967 and 1969 (14 200 tonnes of waste); since then, shallow land disposal has been practised exclusively; the Centre de la Manche (Normandy), where well over 270 000 m^3 of waste has already been disposed of, can accommodate 450 000 m^3 of waste; a project to set up a facility to be called the Centre de l'Aube (Champagne) is being examined (1,000,000 m^3);

- Italy, which participated in the 1969 sea dumping project with a very small quantity of waste (50 tonnes), is continuing to practise interim storage at the production site and in regional centres; the Italian system as a whole (ENEL-ENEA-industry) has defined a programme for reducing the volume of radioactive waste arising from the operation of nuclear power stations, with particular regard to future power stations; to this end, new technologies now available in a number of countries will be applied in order to optimise the management of low- and medium-level waste from this source; studies on disposal sites are in progress;

- the Netherlands disposed of almost all its waste of this type at sea up to 1983 (about 19 200 tonnes from 1967 to 1982); since those operations ceased, interim storage in a storage facility near the Petten Centre (North Holland) has been practised; the decision to construct a centralized storage facility near the Borssele nuclear power station was taken in 1986. Studies on the disposal of all categories of waste in geological formations are in progress;

- the United-Kingdom has been burying low-level waste in trenches at Drigg since 1971: about 600 000 m^3 of waste has been buried. Four possible new sites (Elstow, Bradwell, Fulbeck and South Killingholme) are currently being studied with a view to starting disposal of low-level waste in 1993. The sea dumping of waste was practised until 1982; a total of 57 600 tonnes was disposed of in this way. Medium-level waste and alpha waste are at present held in interim storage. Most such waste will be treated and disposed of in a deep underground facility from the year 2000 onwards.

The other Community countries are currently using interim storage facilities to hold their waste, which is produced in quite small quantities.

III.3. Alpha waste

Alpha waste contains appreciable quantities of radionuclides with a long-half life, but heat generation is virtually negligible.

Since a very long period of isolation is necessary in order to prevent the radionuclides from re-entering the biosphere and such isolation can be ensured only by disposal in deep-lying geological formations or possibly in the sediments of the seabed at great depths, waste of this type is often combined with high-level waste for the purposes of disposal.

In the Federal Republic of Germany, low- and medium-level waste are to be combined with alpha waste and disposed of in deep-lying geological formations. In this connection, a decision on the entry into service of the KONRAD mine as a deep disposal facility is expected to be taken towards 1990. As no advantage is to be gained from the interim storage of alpha waste, the United Kingdom is planning deep disposal of such waste in a specific underground installation while France is according priority to the disposal of alpha waste in a disposal facility which is still at the planning stage (see Fig. III.2.). Sites for the disposal of high-level waste are by no means readily available (see also Chapter III.5. and Fig. III.2.). Almost all alpha waste in the Community Member States is thus held in interim storage in the untreated and unconditioned state. Studies are in progress to determine an optimum treatment and conditioning strategy with a view to the disposal of such waste.

III.4. Interim storage of spent fuel

The interim storage of spent fuel for periods of 20 to 50 years is being contemplated in several Member States. Throughout the world, considerable experience has been acquired over more than 20 years with the storage of spent oxide fuel in ponds. Less experience with dry storage* is available, but the technical feasibility of this method has been confirmed and, in the long term, dry storage could prove to be more advantageous than pond storage.

It is important to note that reprocessing has to be carried out quite soon after discharge from the reactor in the case of fuel from reactors of the graphite-gas type, which is not sufficiently resistant to corrosion to withstand prolonged storage in a pond**.

Before storage practices in the Member States are reviewed, a description should be given of the available options:

- storage at the reactor site (AR = at reactor site) is necessary, for several months at least, in order to allow the waste to cool down before it can be transferred to another storage facility; the storage capacity of the ponds has been considerably increased by the introduction of compact fuel-element storage, made possible by placing absorbent materials between the elements; the equivalent of up to 10 years' production can thus be stored at the reactor sites;

- centralised storage away from the reactors (AFR = away from reactor) at the sites of the reprocessing plants has been used for several years in countries which practise reprocessing; in view of the quantities of spent fuel accumulated at power stations, other countries will be obliged to construct centralized storage facilities, the available options being storage in ponds, modular dry storage in containers (dry-cask storage) and dry storage in special buildings (the last-mentioned solution requires quite a high initial investment and seems to be advantageous in the case of capacities well above 1 000 tonnes of heavy metal).

It is clear that safe storage (in which the principles of radiation protection are observed) must be practised without allowing the fuel to deteriorate significantly; research is hence in progress for the purpose of studying likely cladding corrosion and deterioration mechanisms.

The situation country by country (see Table III.1.) is as follows:

In Belgium, a capacity of 1 100 MTHM is available at the reactor sites; that capacity could be expanded up to 2 000 MTHM by the year 2000.

In the Federal Republic of Germany, the existing capacity of 4 250 MTHM will be increased to 9 800 MTHM by the year 2000. At present, most of that capacity consists of ponds inside the

* Dry storage is characterized by the use of the ambient air to remove the residual heat emitted by the fuel elements.

** One exception is the Wylfa nuclear power station in the United Kingdom, where the spent fuel is stored in the dry state, first of all under CO_2 for 150 days and then in air.

TABLE III.1.

Storage capacities for spent oxide fuel
(tonnes of heavy metal)

COUNTRY	YEAR			
	1985	1990	1995	2000
BELGIUM	1 100	1 400	2 000	2 000
FED.REP.GERMANY	4 250	7 400	9 200	9 800
SPAIN*	1 580	1 960	2 420	2 880
FRANCE	13 900	19 900	23 050	26 250
ITALY**	450	1 202	2 216	4 582
NETHERLANDS	87	87	87***	87***
UNITED KINGDOM	4 100	6 750	6 750	6 750

N.B. These capacities include those of on-site (AR) and centralized (AFR) storage facilities.

* Only in reactor ponds, whole core storage capacity not included.
** See footnote ** to Table I.1.
*** See footnote *** to Table I.1.

reactor buildings, which are already, or are about to be, equipped with compact storage racks. As regards centralized storage, the Federal Republic of Germany chose the option of modular storage in cast-iron containers, which also serve as transport containers and can accommodate nine PWR fuel elements or 16 BWR elements. The first storage facility of this type, the construction of which was completed in 1985, has a capacity of 1 500 MTHM and is located in Gorleben. A second facility of the same capacity is being constructed (work began in 1984) in Ahaus. Finally, an initial construction permit was issued in 1985 for a facility for the storage of 1 500 MTHM to be attached to the future reprocessing plant in Wackersdorf. Consequently, the centralized storage capacity will be 3 000 MHTM in 1990, rising to 4 500 MTHM from 1995 onwards.

In Spain, the spent LWR fuel is stored in the reactor ponds, which have a compact storage facility capable of accommodating ten years' spent-fuel production on average. These capacities will be exhausted by 1992/93, and a centralized storage facility, which is currently at the design stage, will be accommodating an excess quantity of 700 MTHM between that date and the year 2000. The spent fuel from the Vandellos I reactor (natural uranium metal) is regularly dispatched to France for reprocessing.

In Italy, existing capacities of 450 MTHM will probably increase to 4 582 MTHM by the year 2000. The reactor ponds will suffice until 1992; studies on a centralized storage facility are in progress. The fuel from the Latina Magnox reactor is reprocessed abroad.

In France, the capacity will increase from 13 900 MTHM in 1985 to 26 250 MTHM by the year 2000. Since a systematic reprocessing policy is being implemented, the capacities consist of storage in tanks either at the reactor sites or at the site of the reprocessing plant. In La Hague, where the LWR fuel is reprocessed, the storage pond of the NPH (Nouvelles Piscines de La Hague) plant, with a capacity of 2 000 MTHM, has been in service since 1981; by 1987, three additional ponds of the same capacity, tanks C, D and E, will be added.

In the Netherlands, the capacity of the reactor ponds is 87 MTHM; depending on future decisions on the development of nuclear power in the Netherlands, it could be increased to possibly 400 MTHM. The future policy under consideration is interim storage at a central site at Borssele.

The United Kingdom, where storage capacity (excluding that of Wylfa) is scheduled to increase from 4 100 MTHM to 6 750 MTHM by the year 2000, is at present practising the systematic reprocessing of spent fuel and, in consequence, the storage ponds at the Sellafield reprocessing plant serve solely as a buffer capacity. However, a study is in progress on dry storage, which would make it possible to accommodate fuel in excess of the reprocessing capacity of the new Thorp plant. Any future PWR power stations will have to be capable of storing the equivalent of 18 years' production of spent fuel.

III.5. Vitrified high-level waste

High-level waste contains virtually all of the fission products and long-lived radionuclides; furthermore, it releases considerable amounts of decay heat*.

The geological formations considered suitable for the disposal of such waste are subject to limitations as regards the maximum temperature they are capable of withstanding in contact with the waste, and a site as a whole can accept only a limited heat injection if the entire structure is not to deteriorate. Interim storage of vitrified waste over periods up to 50 years is hence advantageous. Installations for this purpose either exist (Marcoule, Mol) or are planned (La Hague, Sellafield, Wackersdorf) at existing or planned vitrification plants (see Table II.3.).

The basic safety principle is that safety has to be intrinsic to the entire disposal operation: when the repository has been shut down and access has been closed off, the disposal conditions must be such as to ensure protection of the environment and of the public without any need for human intervention.

Disposal in deep-lying geological formations (several hundred metres) is being studied by several Member States with emphasis on clay, salt and granite formations.

One possible alternative solution is disposal in seabed sediments at great depths, either by the drilling of boreholes or by using free-fall penetrators to put the waste in place; this solution is being studied at international level by the Seabed Working Group under the auspices of the Nuclear Energy Agency of the OECD.

Disposal in clay formations is of interest to several Member States. Belgium is studying disposal in a clay stratum below the Mol research centre (HADES project) which is between 110 and 270 metres deep. An underground laboratory was constructed at a depth of 225 metres and hydrogeological, geomechanical and technological tests have been under way there since 1984.

A pilot test installation for disposal in a salt dome is in operation in the Asse mine in the Federal Republic of Germany. Also in Germany, the Gorleben salt dome is undergoing qualification as a definitive disposal site.

In France, where granite, shale, salt and clay formations are at present being investigated, a site for opening an underground laboratory intended for the in-situ study of conditions suitable for setting up a storage centre will shortly be proposed.

The plans for disposal of this type of waste are presented in Figure III.2.

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* Somewhat over 1 000 watts per tonne of uranium from spent fuel ten years after discharge from the reactor, dropping to about 100 watts after 100 years of decay.

The programmes and strategies of the Member States in this field are supported by, and to some extent integrated through, the Community programme on the management and disposal of radioactive waste. Coordination includes such areas as geological research, experimental drilling and experiments in underground caverns. The Community programme combines the work of national laboratories with that of the Community's Joint Research Centre through coordinated projects and cost-sharing actions by providing financial contributions.

III.6. Disposal of spent fuel without reprocessing

There are plans to practise what is called the "direct" disposal of spent fuel in a number of non-Community countries (the United States, Sweden, Canada, Finland, etc.), in the Federal Republic of Germany (a certain category of fuel) and in Spain.

The main differences as compared with disposal after reprocessing are as follows:

- the volume of high-level waste will be much greater (by at least a factor of 3), but the volumes of low- and medium-level waste and alpha waste, which are quite considerable after reprocessing, will be much smaller;

- the thermal load is much greater and, in consequence, the available space in the disposal site must be 10 to 30% greater, according to the period of interim storage;

- the radiotoxicity of the waste will always remain greater over long periods.

Specific studies on the behaviour of conditioned waste under the conditions projected for a disposal site (corrosion studies, leaching studies, etc.) will be necessary.

In the Federal Republic of Germany, direct disposal has been under study since 1979 as an adjunct to the setting-up of the fuel cycle with reprocessing. A research programme, "Andere Entsorgungstechniken", coordinated by the Karlsruhe Research Centre and implemented between 1981 and 1984, made it possible to demonstrate the technological feasibility of that option and to develop a design for a conditioning plant and for disposal containers. The comparison of the two options, with and without reprocessing, clearly showed that, in the Federal Republic of Germany, the technique with reprocessing is more advanced.

The Federal Government, after concluding that direct disposal would not bring about any decisive advantages, decided in 1985 to retain the cycle with reprocessing as the reference procedure for the management of spent fuel. However, development work to bring the option without reprocessing up to technical maturity is continuing so that it will be possible to dispose of fuel assemblies in respect of which reprocessing is not technically feasible or is too costly. The elements in question are the spherical fuel elements from the THTR reactor, but certain other special assemblies are also possible candidates for disposal without reprocessing.

III.7. Conclusions

a) Shallow land burial of suitable types of waste is, and has been from the outset, standard practice in France and the UK. Most of the countries which practised sea dumping in the past are now also considering shallow land burial. One exception is the Federal Republic of Germany, where preparations are under way for the disposal of low- and medium-level waste in specific or dual-purpose (also capable of accommodating long-lived waste) underground facilities in iron or salt mines. In view of the considerable volume of waste of these types, no time sould be lost in opening up the new disposal sites required. Another exception is the Netherlands, where a central facility for long-term interim storage above ground is being prepared, and studies on ultimate disposal in geological formations in the Netherlands, or in cooperation with other countries, are in progress.

b) No advantages from the standpoint of activity decay and heat removal are to be gained from the prolonged interim storage of alpha waste, which remains to a large extent untreated and unconditioned pending the availability of disposal sites. R&D programmes are being implemented in several countries with a view to reducing the volume of such waste and determining the best method of confining the radioactivity. In Belgium, for example, slag-forming incineration is being studied. Disposal-sites selection should proceed according to schedule, since the waste-treatment processes, which have to be suitable for specific disposal conditions, will be chosen on the basis of the sites selected.

c) Existing capacities for the storage of spent fuel, mainly in ponds, are adequate for the time being; it may become necessary to construct centralized storage facilities in certain countries between 1990 and 2000.

d) Studies on the disposal of vitrified high-level waste in suitable deep-lying geological formations, are being conducted in all Community countries which possess or intend to possess nuclear power generation programmes. Any decision regarding this means of disposal has to be preceded by trials and experiments, in particular the operation of pilot installations in deep-lying geological formations. The storage period is determined on the basis of several factors, particularly the nature of the host rock; in the case of certain geological environments, it may be necessary for several decades to elapse before the waste has cooled down sufficiently for disposal. Advantage should be taken of this interval to undertake preparatory work, since the period between initiation of research and the entry into service of an industrial-scale installation can also last for several decades.

e) Several countries have been attentively studying the disposal of spent fuel without reprocessing, and a number of experiments and trials are in progress. That option has been adopted by Spain for spent fuel from LWR reactors and is being considered most particularly for certain types of spent fuel discharged in small quantities (for example, from research or prototype reactors).

CHAPTER IV

Existing or planned structures and arrangements in the European Community for ensuring safe storage and disposal of radioactive waste

IV.1. Introduction

Laws and regulations in the nuclear field cover:

- The production and use of nuclear energy.
- The construction and operation of installations required for that purpose.
- Protection against the hazards of ionizing radiation and of uncontrolled energy releases.
- The disposal of radioactive substances.

The regulations relating to the first three points concern all nuclear activities and apply to radioactive waste management in particular. This being the case, waste processing installations, for example, are subject, like other nuclear installations, to a procedure under which a construction permit and an operating licence are granted. Such permits and licences specify the conditions which must be met in respect of operating safety and protection of the public and the environment.

The fourth point, on the other hand, necessitates the adoption of additional specific structures* and arrangements in view of the permanent nature of disposal. The safety of waste disposal is based on the concept of "multiple barriers", developed at international level; according to this concept, the radioactive packages to be disposed of (the conditioned waste), the repository installation (mine, cavern, trenches, etc.) and, to an extent appropriate to the radioactive lifetime of the waste, the geological formation accommodating the repository (salt, crystalline, clay and other formations) must all participate in confining the radioactivity which the waste contains. The design, the setting-up and the monitoring of such a system, which must remain effective for several centuries (in the case of low- and medium-level waste) to several millenia (in the case of alpha and high-level waste and of spent fuel), must be based on adequate structures and arrangements in the Member States, and these are examined below.

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* The structures which, in the various Member States, are associated with the use of nuclear energy in general and with radioactive waste management in particular were briefly described in the 1983 report.

IV.2. Management structures

Since the very nature of radioactive waste requires that it be isolated from the biosphere for long periods, public bodies or undertakings have been made responsible for waste management. The accumulation of radioactive waste over several decades, particularly in certain Member States with nuclear power programmes, has prompted those States to set up executive bodies responsible specifically for the storage and/or disposal of all or some of the radioactive waste, that is to say, for the design, the setting-up and the monitoring of the relevant system (see Section IV.1. above). Note should be taken, in particular, of the creation, since the publication of the 1983 report, of the "Centrale Organisatie Voor Radioactief Afval" (COVRA) in the Netherlands in December 1982 and of the "Empresa Nacional de Residuos Radioactivos, S.A." (ENRESA) in Spain in July 1984.

The extent of the tasks of these bodies varies with the level of nuclear development in the countries concerned and with the policies on radioactive waste management implemented by the governments.

In the Netherlands, for example, where the nuclear industry is not very extensive and the national policy is to store all categories of waste provisionally for a period of 50 to 100 years, the present task of COVRA is to manage low- and medium-level waste with a view to storing it for lengthy periods. Preparations are being made for the long-term interim storage of high-level waste.

On the other hand, in Belgium, France, the Federal Republic of Germany and, quite recently, in Spain, national agencies and a federal body have been given wider responsibilities in order to determine what conditions are required for the safe disposal of waste produced by more developed nuclear industries.

In the United Kingdom, where the Governement decided in 1982 not to dispose of high-level waste until periods ranging from 50 to 100 years had elapsed, NIREX is responsible mainly for the disposal of low- and medium-level waste.

This situation is summarized in Table IV.1.. It can be seen that:

- Community Member States with nuclear power programmes are faced with identical problems and have adopted similar approaches in order to cope with them. Nowadays, all these States possess executive bodies or "Agencies", to which the tasks of managing all or part of the radioactive waste and, in particular, of disposing of it have been assigned.

- The characteristics of the structures which have been set up vary from one Member State to another (legal status and extent of tasks) so that the specific needs of each country can be met in the most effective manner.

TABLE IV.1.

Executive bodies responsible for all or part of radioactive waste management in the Community Member States (see Annex for meaning of acronyms)

COUNTRY	EXECUTIVE BODY	WASTE CONDITIONING	LAYING-DOWN OF SPECIFICATIONS AND QUALITY CRITERIA	QUALITY CONTROL	SITE STUDIES, DESIGN, CONSTRUCTION AND MANAGEMENT OF DISPOSAL CENTRES	STUDIES ON MANAGEMENT STRATEGIES	TRANSPORT OF WASTE	INTERIM STORAGE AWAY FROM THE PRODUCTION INSTALLATIONS
BELGIUM	ONDRAF/NIRAS public set up 80-81	In parallel with the industrial operators	X	X	X	X	X	X
DENMARK	The RISØ national laboratory, by agreement with the National Health Service, is responsible for collecting and storing radioactive waste from hospitals and industry.							
			Tilsynet med Nucleare Anlaeg and RISØ					
FEDERAL REPUBLIC OF GERMANY	PTB The "waste" task was assigned to this Federal body in 1976	- (Responsibility of the industry)	X	X	X (DBE acts on behalf of PTB)		Performed by industry after permit from PTB	By industry and/or federal centres (Landessammelstellen)
FRANCE	ANDRA public set up on 07.11.79	- (Responsibility of the industry)	X	X	X	X	X (partially)	X
SPAIN	ENRESA (1) public set up in 1984	X (in particular cases and circumstances)	X	X	X	X	X	X
GREECE	The control of storage is the task of the ministries concerned in co-operation with the Atomic Energy Commission and the Demokritos Research Center.							

(1) Including spent fuel!

TABLE IV.1. (continued)

Executive bodies responsible for all or part of radioactive waste management in the Community Member States

COUNTRY	EXECUTIVE BODY	WASTE CONDITIONING	LAYING-DOWN OF SPECIFICATIONS AND QUALITY CRITERIA	QUALITY CONTROL	SITE STUDIES, DESIGN, CONSTRUCTION AND MANAGEMENT OF DISPOSAL CENTRES	STUDIES ON MANAGEMENT STRATEGIES	TRANSPORT OF WASTE	INTERIM STORAGE AWAY FROM THE PRODUCTION INSTALLATIONS
IRELAND	The Nuclear Energy Board is responsible for the regulation of the storage and disposal of radioactive waste arising from industry, research laboratories and hospitals in accordance with Statutory Instrument 166/1977.							
ITALY	NUCLECO (1) <u>Semi-public</u> set up in 1981	X not including nuclear power stations			Site management		X (2)	X (2)
NETHERLANDS	COVRA <u>private</u> set up in Dec. 1982	X (2)	X	X	Site and environmental impact studies		X (2)	X (2)
PORTUGAL	The collection, packaging and storage of radioactive waste from research laboratories, hospitals and industry are the responsibility of the Department of Radiological Protection and Safety of the Laboratorio Nacional de Enghenaria e Tecnologia Industrial (LNETI) in Sacavem. The requisite licences are issued by an inter-ministerial Commission for protection against ionizing radiation (Law 44060 of 1961).							
UNITED KINGDOM	NIREX <u>private</u> set up in July 1982 and made <u>semi-public</u> in 1985	Waste producer	X (3)	X (3)	X (3)	- (responsibility of the Department of Environment)	X (3)	

(1) Solely in the case of low- and medium-level waste.
(2) In the case of interim storage of low- and medium-level waste at present; preparations for the storage of high-level waste are in progress.
(3) Solely in the case of low- and medium-level waste and alpha waste.

- In every case, the State assures permanent responsibility in the field of radioactive waste disposal, either directly, or by participating, even symbolically*, in the abovementioned bodies.

In view of their common objectives and characteristics, these bodies or agencies have been holding joint meetings regularly twice a year since 1985 in order to exchange information and, where necessary, confer on matters of common interest within the framework of the Community plan of action in the field of radioactive waste.

IV.3. Arrangements to ensure safe disposal of radioactive waste

These arrangements are to large extent still at the development stage, since the disposal of high-level waste (or, in certain cases, spent fuel) will not be practised in the Community until the next century, and surface storage, which has been practised in certain Member States for decades, is being studied in several other countries with a view to its adoption.

Most of these arrangements concern the components of the waste-containment system described earlier on, that is to say, the radioactive packages, the disposal installation and the host geological formation.

A. Arrangements relating to radioactive packages.
The situation in the Community is described below (it will be seen that the development and application of technological treatment and conditioning processes is generally left to industry).

In Belgium, ONDRAF/NIRAS, a public body set up in 1982, has been assigned the task of managing radioactive waste from the moment it leaves the production site. The responsibilities of ONDRAF/-NIRAS relate mainly to two areas:

- Seeking and proposing to the competent authorities the most suitable systems for the management and disposal of the waste produced in Belgium.

- Ensuring that the resources required to carry out the various stages of waste management properly (transport, treatment/conditioning, temporary storage pending disposal) are used in compliance with the procedures and specifications drawn up in agreement with the authorities.

As regards the latter area, ONDRAF/NIRAS has hitherto concentrated on readapting the management of low-level waste following the cessation in 1983 of sea dumping of such waste (volume reduction, packaging standardization, construction of temporary storage facilities, etc.).

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* This is the case with NIREX, a body set up in 1982 by the British nuclear industry; it was transformed into a company (United Kingdom Nirex, Ltd) in 1985, with symbolic government participation, in order to acknowledge the long-term nature and national importance of its task.

A programme for the qualification of treatment/conditioning processes and for the characterization of conditioned packages for the various categories of waste produced is also being implemented.

In Denmark, the Nuclear Inspectorate* issues rules concerning the types of container, the permissible quantities of fissile materials, the external radiation levels, etc., which are applicable to the products to be stored. The Risø Centre defines the waste acceptance conditions with a view to waste storage at Risø. Such a simple scheme is suitable, since Denmark has no nuclear power programme.

In France, within the framework of the basic safety rules issued by the Central Service for the Safety of Nuclear Installations (SCSIN) on behalf of the Ministry of Industry, ANDRA lays down the regulations governing the operation of disposal centres and those applicable to specific waste categories. These basic rules** set out the general principles applicable to the production, treatment, control of conditioning and temporary storage of the various types of solid waste produced by the reprocessing plants, the special conditions which apply to vitrified waste and waste encapsulated in bitumen or in cement and the conditions that must be fulfilled before such packages are accepted for disposal. On the basis of these rules, ANDRA defines the conditions for the acceptance of waste in the disposal centres which it manages and, in particular, the associated quality control tests.

In Greece, radioactive waste is produced mainly by the Demokritos Research Centre, and by hospitals and educational and research institutes where radioactive materials are used. Where radiation protection is concerned, the law which sets up the Greek Atomic Energy Commission and the legislation concerning the granting of permits to construct nuclear installations also govern the safe management and disposal of radioactive waste. Supervision is exercised by the ministries concerned in cooperation with the Greek Atomic Energy Commission and the Demokritos Centre. Waste which is considered under the regulations to be too radioactive for disposal with non-radioactive waste, is stored at the production site. Certain types of waste are transported to the Demokritos Centre for appropriate conditioning and storage. Since Greece produces only small quantities of waste, a disposal site has not yet been opened up in that country.

In Ireland, the Nuclear Energy Board is responsible under Statutory Instrument 166/1977 for regulating the storage and disposal of radioactive waste arising from industry, research laboratories and hospitals.

In Italy, the waste producer must submit a "qualification and control programme" to the Directorate for Nuclear Safety and Radiation Protection (DISP) of the ENEA (which prepares the technical guides to be used by the legal authority, the Ministry of Industry and Commerce) in order to obtain a licence to

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* Tilsynet med Nucleare anlaeg.

** R.F.S. of 24.9.82, 12.11.82 and 1.2.85.

operate an installation for the treatment and/or conditioning of waste. The programme must show that the products obtained will satisfy the quality requirements and criteria set out in DISP Technical Guide No 26 before they can be stored or disposed of. Such provisions have so far been adopted only for low-level waste.

In the Federal Republic of Germany, the PTB (Physikalisch Technische Bundesanstalt), which is a Federal body, was assigned responsibility under the Atomic Energy Law of 1959, for the safekeeping of nuclear fuel and for issuing permits for the storage and transport of such fuel. A further important task was assigned to the PTB under the Law of 1976, which amends and supplements the Atomic Energy Law of 1959: responsibility for the construction and management of Federal installations for the long-term storage and disposal of radioactive waste.

The PTB acts under the technical supervision ("Fachaufsicht") of the Federal Minister for the Environment, Nature Conservation and Nuclear Safety and by agreement with the Minister responsible for nuclear technology (Federal Ministery for Research and Technology), when conducting R&D activities relating to the disposal of radioactive waste. The PTB may delegate to third parties the tasks of constructing and operating Federal facilities for the interim storage and disposal of nuclear waste. Responsibility in this area has accordly been assumed by the DBE (Deutsche Gesellschaft zum Bau und Betrieb von Endlagern für Abfallstoffe mbH), which was set up in 1979 for this purpose as a company under the direct supervision of the Federal authorities.

In the United Kingdom, waste producers must demonstrate that the treated waste can be disposed of in compliance with the conditions laid down by the Department of the Environment (DOE) in 1984*; they must also demonstrate that the treatment installation and the associated temporary-storage structures meet the requirements of the Nuclear Installations Inspectorate. The waste producers are responsible for quality assurance in all waste treatment and conditioning installations; however, the regulatory authorities can request that independent inspections be carried out; the DOE is at present developing the capacity to carry out such inspections on radioactive packages before their disposal.

In Spain, the Ministry for Industry and Energy is the authority which prepares legislation and regulations and issues permits and licences for nuclear installations, in particular those for the storage and disposal of waste. The sole competent authority in the field of nuclear safety and radiation protection is the Consejo de Seguridad Nuclear (CSN) from which the Ministry must request a safety report for the licensing of a nuclear installation; any decision based on that report, if unfavourable, is binding. The CSN is also entitled to propose to the Ministry of Industry and Energy legislation and regulations falling within its sphere of competence. ENRESA lays down waste acceptance criteria and specifications in conformity with the operating licenses of these installations.

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* Outline requirements for the quality assurance of encapsulated waste; information note No. 2, DOE, 1984.

It can be seen that the purposes of all these measures is to ensure that the radioactive packages to be disposed of at a given site fully meet the safety requirements.

Where the European Community is concerned, efforts are being made to harmonize inspection procedures for packages, test conditions, quality criteria and procedures for the quality control of products and their packagings under point 3 of the Community plan of action in the field of radioactive waste. These harmonization activities are backed up by coordinated experiments in all the national laboratories concerned which are financed under the Commission's R&D programme.

B. Arrangements relating to disposal installations and the geological formations accommodating them.
The situation today is as follows:

Geological formations and site selection

The R&D programmes undertaken over the last 10 to 20 years, at both national and Community levels, now clearly indicate that:

- several types of geological formation are capable of accommodating deep repositories of radioactive waste;

- the choice of the precise locality of the repository, that is to say, the choice of site, is just as important as the choice of formation.

The procedures for selecting a disposal site for radioactive waste which have been adopted by the Community Member States are based on the scheme proposed by the International Atomic Energy Agency (IAEA):

- general survey,
- preliminary identification of sites of interest,
- site confirmation.

The executive bodies described in Section IV.2. are generally responsible for implementing that scheme and for submitting the final file to the competent governmental authorities for their decision. Furthermore, each phase is developed with the agreement of the authorities and in accordance with each State's own provisions governing information for, and consultation with, the public.

The decision concerning the site is taken on the basis of a number of fundamental scientific and technical principles such as those proposed by the Commission of the European Communities,* to which are added economic and socio-political considerations that apply to each State individually; in view of the extremely wide variety of specfic conditions that can arise, it seems difficult, if not unreasonable, to define detailed scientific and technical criteria with respect to the site geology, most particularly at international and Community level. As

* "Geological confinement of radioactive wastes within the European Community", EUR Report 6891, 1980.

regards the basic quality principles referred to above, harmonization at Community level would be desirable, more especially since it already exists to some extent in practice.

Design, operation and shutdown of storage and disposal installations

As has already been pointed out (Section IV.1.), the general regulatory provisions concerning nuclear installations apply to installations for the storage and disposal of radioactive waste. However, additional provisions are necessary, since such installations have to confine the radioactivity in the waste for hundreds of years (in the case of low- and medium-level waste) or thousands of years and more (in the case of alpha waste, high-level waste and, possibly, spent fuel).

Such provisions already exist for surface disposal (in France, for example) and are being prepared for deep geological disposal, which is not likely to be practised before 1990 in the case of the KONRAD installation (FRG) and before the end of the century where the other facilities are concerned. The basic principle adopted by the States which are most advanced in this field (France, Federal Republic of Germany) is that the repository must be intrinsically safe in the long-term, that is to say that, at the end of the period of repository operation (which covers the shutdown operations, the plugging of the access shafts*, etc.), the disposal conditions adopted must ensure that the environment and the public are protected without any need for human intervention. However, certain countries make provision for a "period of supervision" after shutdown, during which the measuring and monitoring systems are kept in service.

The present situation in the Member States concerned can be summarized as follows:

In the Federal Republic of Germany, where the only concept adopted is that of deep geological disposal, the "safety criteria for disposal of radioactive waste in a mine"** define quite fully all the conditions to be met and the safety study which must be submitted to the competent authorities.

In France, consideration is being given to two concepts: surface disposal (low- and medium-level waste) and deep geological disposal (high-level waste or waste containing transuranics); in the case of surface disposal (see section IV.3), a "règle fondamentale de sûreté"*** (basic safety rule) stipulates the safety requirements associated with the various stages in the lifetime of the surface storage site:

- period of operation,
- period of supervision,
- period when the sites are reopened for public use.

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* In the case of deep geological disposal.

** "Sicherheitskriterien für die Endlagerung radioaktiver Abfälle in einem Bergwerg", Federal Ministry for the Interior, Bundesanzeiger, Jahrgang 35, No. 2, 5 January 1983.

*** R.F.S. of 21.6.1984.

Provision is made for a maximum period of supervision of 300 years, during which the measuring and monitoring systems will be kept in service. After that period has elapsed, and with due regard to the radioactive decay of the radionuclides, it should be possible to return the sites concerned to the public domain. As regards deep geological disposal, the Ministry of Industry set up a working group in 1985 to be responsible for proposing technical criteria for the selection of deep sites.

The agreement to open a waste disposal installation is based on a safety analysis indicating, in particular, that any possible radioactivity transfer to the biosphere is likely to have only acceptable radiological consequences, and a study on the environmental impact of the planned installation, associated with a public inquiry in the area concerned.

In Belgium, provisions similar to those which exist or are in preparation in France and the Federal Republic of Germany are under study. A preliminary report on the safety and feasibility of a system for the disposal of high-level waste and alpha waste in a deep-lying clay formation is being prepared. That report, which is based mainly on the result of R&D work carried out by CEN/SCK (Mol) as part of the HADES project, will be submitted to the authorities for examination with a view to obtaining an agreement in principle on the system under consideration.

A study prior to the selection of sites for the surface disposal or shallow burial of conditioned slightly active waste has been set in train. Here again, the choice of one or more sites will have to be followed up by the preparation of a preliminary report on the safety and feasibility of a burial concept, which will be submitted to the authorities for examination and their opinion.

In the Netherlands, a document on radioactive waste management policy drawn up in 1984 by the Government makes provision for the surface interim storage of all categories of waste on a single site over a period of 50 to 100 years. In consequence, the regulatory provisions do not concern the geological barrier (which would be pointless in this case), but deal mainly with site selection. A site selection committee (the LOFRA Committee) had prepared proposals to the Government in October 1985, which left COVRA free to choose between three sites: COVRA selected the Borssele site. The final procedure requires that an environmental-impact study be submitted. The public participates in the process through hearings. Studies are under way on definitive disposal in deep-lying geological formations in the Netherlands (salt) or in cooperation with other countries.

In Italy, research was recently conducted by ENEA on the selection of sites for surface disposal.

In the United Kingdom, studies on optimum strategies for the management of radioactive waste in that country indicated the need for land facilities close to the surface for the disposal of large volumes of low-level waste and a deep underground installation for the disposal of alpha and medium-level waste. The principles for protection of the human environment were published in 1985 by the Government, and every new disposal installation must comply with them. These principles, of course, require that a multi-barrier approach be used and specify the level of radiological risk that must not be exceeded by the disposal system as a whole. NIREX has to carry out a detailed geological study of each new potential site and submit a safety analysis to the competent governmental bodies, before a public enquiry is conducted. The Department of the Environment then ensures that an independent safety assessment is made before authorization to operate the disposal facility is granted.

In Spain, ENRESA is responsible for the management and disposal of radioactive waste. Under its statute, it must submit by mid-year an annual "Plan General de Residuos Radioactivos" for Government approval. Shallow burial is being considered for low- and medium-level waste and deep geological burial for high-level and long-lived waste. Radioactive-waste storage facilities are subject to the laws and regulations applicable to nuclear or radiological installations.

Finally, in the context of the European Community as a whole, the PAGIS project (Performance Assessment of Geological Isolation Systems), which has been under way since 1982 as part of the Commission's R&D programmes on radioactive waste management with the participation of all the Member States concerned, has already contributed in large measure in phase I (1982-84) to the harmonization of methods for the analysis of risks associated with deep geological disposal; during its final phase (1987-88), the project will also provide for consultations to be held at Community level in relation to the criteria to adopt for assessment purposes.

IV.4. Financing

The general principle that the polluter (producer of waste) has to pay for the pollution he creates (the waste), which is known as the "polluter pays principle", forms the basis for action by the Member States of the European Community in financing the management and disposal of radioactive waste. This principle has been incorporated into the laws of several countries (Belgium, Spain, France, Federal Republic of Germany), and the executive bodies or national agencies referred to in Section IV.2. are financed, at least in part, through payments made by the waste producers.

Such financing can be achieved in a number of ways, for example, by subjecting the operators of nuclear power stations to a legal obligation to pay fixed sum to the abovementioned bodies, or by setting up a fund to be financed by the operators as a means of covering current and future expenditure.

The objective of all these measures is to achieve a compromise between the most realistic possible financial assessments and the need to finance the management, and particularly the disposal, of waste over periods ranging from decades to a century or more.

According to studies performed at both national and international level, particularly those conducted by the Commission, the financial impact of radioactive waste management on the cost of a kWh is of the order of a few percent. The greater part of this cost is attributable to the disposal of long-lived and high-activity waste (or spent fuel) in deep-lying geological formations, which was described in Chapter III*.

IV.5. Conclusions

- In the Member States of the European Community, safe radioactive waste disposal is based on the concept of "multiple barriers", on which consensus has been reached at international level and which is backed up by the Community's R&D programme. This concept requires that the radioactive packages to be disposed of, the repository itself (mine, cave, trench, etc.) and, to an extent appropriate to the radioactive lifetime of the waste, the geological formation accommodating the repository must all participate in confining the radioactivity in the packages. That confinement system must remain effective over very long periods.

- The Governmental bodies in the Community countries concerned have laid down basic principles, regulations and criteria governing the effectiveness of the confinement system components in the case of surface disposal and are in the process of preparing such provisions for application to deep geological disposal, which is not likely to be practised before the end of the decade (in the case of the KONRAD installation) or at the end of the century. The R&D programmes which are being implemented at both national and Community level provide the support necessary for such development work.

- Harmonization of these provisions at Community level is desirable, but, in view of the importance of the disposal site and of its specific characteristics to the safety of the confinement system, is not always possible to achieve. The Community R&D programme and the Plan of action in the field of radioactive waste are contributing to such harmonization.

- Participation by the public in the decision-making process in respect of the setting-up of installations for the storage and disposal of radioactive waste is guaranteed by law in all countries.

- In all Community Member States which possess nuclear power programmes, the development and application of disposal methods and the design and operation of the associated confinement systems are nowadays entrusted, either wholly or in part, to executive bodies (Agencies or the like) in which the States are shareholders - even in a symbolic capacity - so that the requisite permanence of the undertaking can be guaranteed.

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* A recent study financed by the Commission predicts that the cost of such a programme, intended to cover the disposal of waste generated by several dozens nuclear power stations with a capacity of 1000 MWe each throughout their operating lifetimes, would amount to 3 to 4 milliard ECU over 40 to 60 years.

It is hence evident that appropriate structures and arrangements for the safe storage and disposal of radioactive waste exist in the Community Member States concerned and have been undergoing further development over the last few years. This development work must be continued with all the requisite vigour, at national, Community and international level, so that it will be possible to set up the administrative, legal and financial framework which is indispensable if future disposal operations are to be carried out as safely as mankind has the right to expect.

ANNEX

List of abbreviations

AFR Away from reactor
AGR Advanced gas-cooled reactor
ALARA As low as reasonably achievable
ANDRA Agence Nationale pour la Gestion des Déchets Radioactifs
AR At reactor site
AVM Atelier de Vitrification de Marcoule
B Belgium
BWR Boiling-water reactor
CEGB Central Electricity Generation Board
CEN/SCK Centre d'étude de l'énergie nucléaire/Studiecentrum voor Kernenergie
COVRA Centrale Organisatie voor Radioactief Afval
CSN Consejo de Securidad Nuclear
D Deutschland
DBE Deutsche Gesellschaft für den Bau und den Betrieb von Endlagern für Abfälle
DISP Direzione Sicurezza e Protezione
DOE Department of the Environment
DWK Deutsche Gesellschaft für die Wiederaufarbeitung von Kernbrennstoffen
ENEA Comitato Nazionale per la ricerca e per lo sviluppo dell'energia nucleare e delle energie alternative
ENEL Ente Nazionale per l'Energia Elettrica
ENRESA Empresa Nacional de Residuos Radioactivos, S.A.
E Espana
F France
FBR Fast Breeder Reactor
FRG Federal Republic of Germany
GBq Giga-Becquerel
GCR Gas-cooled reactor
GGR Gas-graphite reactor
GWe Electrical Gigawatt
HADES High Activity Disposal Experimental Site
HMI Hahn Meitner Institut
IAEA International Organisation for Atomic Energy
KfK Kernforschungszentrum Karlsruhe
KWh Kilowatt-hour
LNETI Laboratorio Nacional de Enghenaria e Tecnologia Industrial
LOFRA Cie Locatiekeuse Opslagfaciliteit Radioactief Afval
LWR Light-water reactor
MTHM Metric tonnes of heavy metal
MTR Material Test Reactor
MWe Electrical Megawatt
NIRAS Nationale Instelling voor Radioactief Afval en Splijtstofcyclus
NIREX Nuclear Industry Radioactive Waste Executive
NL Nederland
NPH Nouvelles piscines de la Hague
NUCLECO Nucleare-Ecologia
OECD Organisation for Economic Co-operation and Development
ONDRAF Organisme National des Déchets Radioactifs et des Matières Fissiles

PAGIS	Performance Assessment of Geological Isolation Systems
PAMELA	Pilotanlage Mol zur Erzeugung lagerfähiger Abfälle
PTB	Physikalisch-Technische Bundesanstalt
PWR	Pressurised-water reactor
R&D	Research and Development
R.F.S.	Règles Fondamentales de Sûreté
SCSIN	Service Central de Sûreté des Installations Nucléaires
SIXEP	Site Ion Exchange Effluent Plant
THORP	Thermal Oxide Reprocessing Plant
THTR	Thorium-Hochtemperaturreaktor
UK	United Kingdom
UNGG	Uranium Natural Gas Graphite
WAW	Wiederaufarbeitungsanlage Wackersdorf
WVP	Windscale Vitrification Plant