European Community Research Programme on Radioactive Waste Management

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INTRODUCTION

All Member States of the European Communities make use of radionuclides, and consequently produce radioactive waste, but the main quantities from peaceful applications arise in activities linked with the nuclear power production. The Commission of the European Communities carries out research programmes aimed at ensuring health and safety of public and workers in all steps of management and disposal of radioactive waste.

After a summary of the situation of radioactive waste management in the Community, a short description is given of the research programmes, direct research at the Joint Research Center and the shared-cost action programmes financially supporting research by institutes in the Member States, and of the main areas of research and development.

A more detailed review deals with research in two areas of particular interest to structural engineering: the disposal of high-level waste in sediments of the deep sea, and disposal of radioactive waste in deep geological formations.

SITUATION AND PROSPECTS OF RADIOACTIVE WASTE MANAGEMENT IN THE EUROPEAN COMMUNITY

The main quantities of radioactive waste produced are linked with the nuclear power production programmes and the various associated fuel cycle installations. Seven Community countries operate or have operated nuclear power plants (Belgium, France, Italy, the Federal Republic of Germany, the Netherlands, Spain, the United Kingdom) with a net capacity of 92.6 MW in 1988, which is expected to grow to nearly 140 MW in 2000. The Community Plan of Action in the field of radioactive waste management 1980-1992 asks for the continuous analysis of the situation and the Commission has drawn up a report which describes this situation in 1986 and gives a forecast to 2000 (Commission, 1987).

Before summing up the main findings of this report, it is useful to recall that treatment, storage and disposal of radioactive waste is common practice, and in particular it is noticeable that more than 1 million m^3 of mostly low-level activity waste have been disposed of since the beginning of the nuclear era. The disposal route for most of the waste has been and is actually near-surface burial; some Community countries have practised sea-dumping under an international agreement before 1983 and one country has performed trial disposal by deep burial in a former salt mine.

Estimates of the total production of conditioned waste (i.e. ready for disposal) for the period 1986 to 2000 have been made; the annual production is at present near 70,000 m^3 and is expected to exceed 100,000 m^3 in 2000. Figure 1 shows expected volumes for five-year periods separately for the seven Member States having a nuclear power production; these 1986 figures certainly overestimate the amounts to be expected, as they are based on a slightly optimistic forecast for new nuclear power plant capacities (Italy has stopped the nuclear production; other countries have reduced their plans). Furthermore, improved treatment and conditioning techniques allow lower waste volumes per unit of electric power produced.

Typically, low- and medium-level waste with mainly short-lived radio isotopes which decays after some centuries to levels near the natural radioactivity makes up more than 85% of the volume.

Almost all of the radioactivity generated is concentrated in spent fuel which is unloaded at a rate of 3,500 tons of heavy metal per year at present, increasing to slightly more than 4,000 tons in 2000. A large proportion of spent fuel is to be reprocessed and the vitrified high-level waste from reprocessing will cumulate at a rate of some hundreds of cubic meters per year. Waste from decommissioning of nuclear installations will arise in large quantities only after 2000; effectively, already more than ten medium-sized nuclear power plants have been closed down definitively in the Community and more than 50 large nuclear installations, with expected amounts of waste between 20,000 and 40,000 m^3 per installation will be taken out of service by the year 2000. Delayed dismantling (in order to benefit from natural decay) will be widely applied, which will postpone the arising of waste well beyond the year 2000.

Treatment and conditioning processes for short-lived low- and medium-level waste are available at industrial scale in the Community; nevertheless work on volume minimisation and on the improvement of the long-term resistance of conditioned solid products is going on. Conditioning of long-lived non-heat generating waste (alpha waste) has not been performed to any great extent since these processes must be suited to the disposal site. Vitrification of the liquor from reprocessing containing the fission products has reached the stage of industrial scale application and research on conditioning of spent fuel for direct disposal is going on in some Member States.

Disposal of waste is currently limited to near-surface disposal in engineered structures, practised in France and the United Kingdom. Some countries also prepare near-surface disposal of short-lived waste, whilst some others have decided to bury all types of waste in deep-lying geological formations. Site selection procedures have been started in most countries and two pilot installations for simulation of disposal in deep geological formations are operating.

As far as regulatory and operational aspects are concerned, it is to be noted that all countries with a nuclear power programme have entrusted the development and application of disposal methods, and the design and operation of the waste confinement systems to executive bodies (Agencies or the like) in which the State is shareholder. This means that the State insures the needed guaranty of continuity and stability for the future to these Agencies. Licensing and control authorities remain of course independent.

THE ROLE AND THE IMPLEMENTATION OF THE COMMUNITY RESEARCH PROGRAMME

The Commission's research in the nuclear field is based on the provisions of the EURATOM treaty. The paramount objective of the research programme is to ensure health and safety of public and workers in the nuclear field in an economically acceptable manner; consequently, studies on the three main components of the waste management system, the waste packages, the repository and the geological environment are performed, either through experiments or by theoretical evaluation.

Research and development devoted to radioactive waste management have been carried out in specific programmes for more than 17 years. The early programmes supported technological development for improved treatment and conditioning processes, and identified geological formations suitable for deep disposal of waste in the territory of the European Community. At this early stage, the concept of actinide separation, followed by transmutation to short-lived isotopes has been studied as a management alternative: this concept, although being feasible, has heavy drawbacks concerning cost and radiation exposure as compared to deep burial.

Progressively, activities in more recent programmes have been aimed at development and implementation of geological disposal concepts which provide for safe and economically optimal solutions for disposal of the different categories of radioactive waste.

The Commission's Joint Research Center contributes with activities in its own laboratories (so-called direct action), and the Shared Cost Action Programmes support selected national research by contributing to the cost of work, typically taking over half of the expenses.

Direct research and shared cost research carried out in laboratories, universities and by industrial organisations of the Member States are closely coordinated and interact strongly. Management and coordination is in the hands of the Commission's civil servants, assisted by managing and coordinating committees and expert groups including delegates of the Member States.

Presently about 400 European scientists are involved in the Commission's programmes, with annual expenditures of roughly 40 million ECU. The Commission's involvements cover about 20% of the total sum of national expenditures in the field of all Community Member States.

PROGRAMME OF THE JOINT RESEARCH CENTRE

The previous Joint Research Centre (JRC) programme 1984-1987, with involvement of the Ispra and Karlsruhe Establishments and a budget of 42 million ECU covered two broad areas: "Waste management and the nuclear fuel cycle" and "Safety of waste disposal in geological formations".

In the first area, optimisation of waste arisings with respect to quantity as well as to waste type has been studied. The main tool is the PETRA installation, a hot cell facility designed and built at Ispra which is aimed at investigating processes of production, treatment and conditioning of high-level and medium-level activity waste in order to identify ways to minimise arising and to improve waste quality. PETRA is designed to process 6 kg batches of light-water reactor spent fuel following the PUREX process producing typical reprocessing waste streams. Liquid waste is concentrated and solidified. Studies of non-destructive analytical methods to determine the actinide content in solidified waste are included in the project.

The "safety of waste disposal" area is including theoretical evaluations and related experimental activities in order to contribute to long-term risk assessments. These actions are closely integrated in projects progressing in cooperation with the shared cost programme, and in particular the MIRAGE (Migration of Radionuclides in the Geosphere) and the PAGIS (Performance Assessment of Geological Isolation Systems) projects. The JRC has strongly contributed to the development of probabilistic site assessment methodologies and to experimental investigation of the interactions between radionuclides and the surrounding geological formations.

The contributions to the studies on the feasibility of disposal of high-level waste in sediments of the deep ocean will be mentioned later.

Within the actual JRC programme 1988-1991 (Commission, 1987) with a total budget of 448 million ECU (with 48.5 million ECU earmarked for radioactive waste management research), radioactive waste research is structured around four projects: operation of the PETRA facility, actinide monitoring, waste characterisation and safety of waste disposal in geological formations; again, the work is carried out at the Ispra and Karlsruhe Establishments and is performed in close cooperation with the shared cost action programme.

The hot operation of the PETRA facility is oriented by its users and customers. A users' group with experts from nuclear fuel cycle operators and research organisations of the Member States has defined a set of actions to be undertaken and priorities to be given.

Actinide monitoring consists in the development of an instrumentation for the non-destructive detection and quantification of Plutonium or the alpha emitting radionuclides present as contaminant in waste packages. Field tests will be made in various fuel cycle facilities.

The waste characterisation deals with the characterisation of vitrified high-level waste and spent fuel declared as being waste; work is performed in the hot cells of the Karlsruhe Establishment.

The actions of safety of geological waste disposal will continue as in the preceeding programme within the frame of the MIRAGE and PAGIS projects implemented also by national laboratories. Later in the programme, this activity will be re-orientated to application to real waste disposal sites.

SHARED COST ACTION PROGRAMME

The presently running shared cost action programme 1985-1989 is already the third of its kind; with a budget of 62 million ECU, it is managed by the Commission's nuclear fuel cycle division. Research in Member State organisations is supported within six tasks; furthermore an important part of the budget is devoted to assist the operation of experimental underground facilities; a breakdown of distribution of funds is shown in figure 2.

In "System Studies" various options for managing particular waste streams are assessed in terms of industrial feasibility, cost and radiological impact to workers and public. The waste streams analysed are waste from nuclear power plant operation (reactor waste) and hulls and caps from reprocessing of light-water reactor spent fuel. A comparative evaluation of waste management aspects of the reprocessing option as opposed to direct disposal of spent fuel is also in progress.

"Improvement of waste treatment and conditioning technologies" is aimed at optimising management of low- and intermediate level activity waste. In liquid waste treatment, this work includes processes to separate actinides by new extractive methods, application of selective inorganic ion exchangers as well as electrochemically controlled ion exchange processes and a series of purification methods involving membrane techniques. The most important issue of solid waste management in the programme is the treatment and conditioning of Plutonium containing waste, where a strategy study had been commissioned to optimize the choice between different treatment and conditioning options. Processes currently being studied include two advanced decontamination techniques and a variety of conditioning methods for incinerator ashes and fuel element hulls.

"Testing and evaluating conditioned waste and engineered barriers" is devoted to the characterisation of waste forms and barrier materials, a better qualification of the source term needed for performance analysis calculations, and the improvement of quality assurance and quality control of waste packages. The characterisation activities include the currently produced waste forms: cement, bitumen and polymer encapsulated low-level waste, cemented and bituminised waste containing alpha emitters, and ceramics and borosilicate glass products for alpha and high-level waste. Tests provide data in respect to leaching, waste form stability, radiation resistance and compatibility with the respective disposal environments. In the course of the programme, the development of methods for quality assurance and in particular quality control became an important issue: the control of the nuclide inventory, of the chemical composition of the waste as well as of the correct operation of treatment and conditioning processes are being investigated in specialised laboratories.

"Research in support of development of disposal facilities, with studies on disposal in continental geological formations and in shallow land burial" deals with design and engineering problems of repositories; this task includes the characterisation and the modelling of geological formations surrounding the repository (the so-called far-field) and the quantitative description of the migration of radionuclides through the geological barrier to the biosphere (the already mentioned MIRAGE project). The projects are orientated towards research and testing under field conditions.

The task "Safety of geological disposal" has just completed an important phase of the PAGIS project, assessing the isolation performance of deep repositories in clay, granite and salt formations, and the sediments of the deep ocean (Cadelli, 1988). It is worthwhile to summarise the main conclusions:

- during many thousands of years after disposal, no radioactivity at all will reach the biosphere;
- the most efficient barrier is the natural geological barrier; if well chosen, its chemico-physical properties and hydrology impose radionuclide travel times which allow a substantial decay and dilution before the biosphere is reached;
- the engineered barriers may play a role essentially in accidental situations; their contribution in the normal evolution of the repository is very low;
- the analysis of a selection of natural events which may alter the normal evolution of the disposal system (e.g. climatic changes, tectonic displacements etc.) has shown no significant increases of the potential dose rate;
- human intrusion scenarios into or near the underground repository need consideration since exposure may occur at earlier times and at significantly higher dose rates than in the normal evolution scenarios.

Applying the methodologies used for the PAGIS project, work is now extended to cover alpha bearing waste.

A working group related to "Joint elaboration of radioactive waste management policies" has finished drafting a report on "Objectives, standards and criteria for radioactive waste disposal in the European Community". The group is working now on a common position concerning exemption from regulatory control of very low-level radioactive waste not linked with the nuclear fuel cycle. It may be added here that in the frame of the Plan of Action, two working groups attempt to harmonise the practises in quality assurance and quality control of waste products and on radioactive waste equivalence.

The programme's contribution to "experimental underground facilities" is concerned with two facilities: the Boom-clay facility beneath the nuclear research center in Mol (Belgium) and the Asse salt mine facility in the Federal Republic of Germany. These facilities which are of high interest for structural engineering will be described further in more detail.

RESEARCH ON THE FEASIBILITY OF DISPOSAL OF HIGH-LEVEL WASTE INTO THE SEDIMENTS OF THE DEEP OCEAN

It is worthwile to mention particularly a field of research, where a lot of structural engineering is involved: the Community participation in the study of the feasibility of disposal of high-level radioactive waste into the seabed. Besides, the coordinated action of direct JRC research and shared cost contractual work had been integrated in the international "Seabed Working Group", which was formed under the auspices of the Organisation for Economic Cooperation and Development's Nuclear Energy Agency.

Two emplacement options, penetrator and drilled emplacement as shown in figure 3, have been investigated; the results of this work are now available (OECD/NEA, 1988) showing that:

- sites suitable for disposal in fine-graded sediments of the North Atlantic and the North Pacific oceans exist;
- conditioned high-level waste could be emplaced using currently available technology at economically reasonable costs;
- radiological consequences to individuals and the population as a whole would be many orders of magnitude below present standards for human health protection;
- further research would be needed in particular areas before implementing disposal schemes.

Community experts assisted in all working groups, but the main efforts had been concentrated on engineering and feasibility, with participation in penetrator experiments and studies of the overall schemes for the options, including reliability of operations, safety and technological consequences, and processes at and around an emplaced canister. Figure 4 gives an example of an estimate of the individual dose rate evolution, demonstrating that doses are very low, reaching less than 10^{-9} Sv/y at the 10,000 year peak.

EXPERIMENTAL UNDERGROUND FACILITIES

Disposal of radioactive waste in deep geological formations is actually not practised, and has never been practised for high-level waste in the Community Member States. A large body of research is performed on safety and radiological aspects, migration and chemical interactions, material behaviour, thermal evolution around heat emitting waste, groundwater flow and structural behaviour of the underground installations.

A particularly valid test-bed for all investigations is clearly an underground laboratory and as already mentioned, the Community cost-shared action programme supports in-situ research in two geological formations, clay and salt. It has to be underlined that research at these pilot facilities presents a fine example of Community cooperation: in the HADES facility in Mol a test drift has been realised in close cooperation between the Belgian research center CRN/SCK and the French agency ANDRA; a British group is involved in testing instrumentation at the facility; the HAW project in Asse is performed by the German GSF in cooperation with the Dutch ECN and with the participation of the French ANDRA and the Spanish agency ENRESA.

The HADES facility (see fig. 5) provides test-drifts and building the drifts has been a demonstration of mining capabilities in plastic clay with properties and under conditions valid for real radioactive waste disposal.

Effectively, adequate tunnelling methods exist, which are used in civil engineering for soft grounds, or difficult conditions, but they bring about strong disturbances to the geological environment eg. fracturing, drawdown of water table, significant swelling. As regards geological disposal, the host medium should undergo minimum disturbance in order to maintain its isolation capacities. Therefore, techniques such as large-scale grouting, or ground freezing, cannot be applied.

In case of the pilot facility at Mol, an extensive programme of sample testing and calculations led to the selection of the most adequate techniques for excavation and support. These techniques (heavy concrete segments, and "sliding" steel ribs) were successfully applied.

Tests performed within the test-drift are related to heat-transfer, radiolysis and active source handling, gallery heating-tests and model emplacement and backfill procedures.

The HAW facility in a salt dome in Asse is being prepared for test storage of simulated high-level waste canisters (see fig. 6) over a five year period with measurement of all relevant parameters. Additional experiments are made by in-situ measurements of gamma radiation doses and the radiolytic gas production in salt.

CONCLUSIONS

The Commission's radioactive waste management programmes complemented by the Action Plan are representing a coherent set of activities and support and coordinate work of most of the Community research organisations involved in radioactive waste management. The promotion of a multinational consensus on the most reliable options for waste management in Europe is attempted. Additionally, through agreements of cooperation the Community research programme is exchanging information with a number of non-Community countries.

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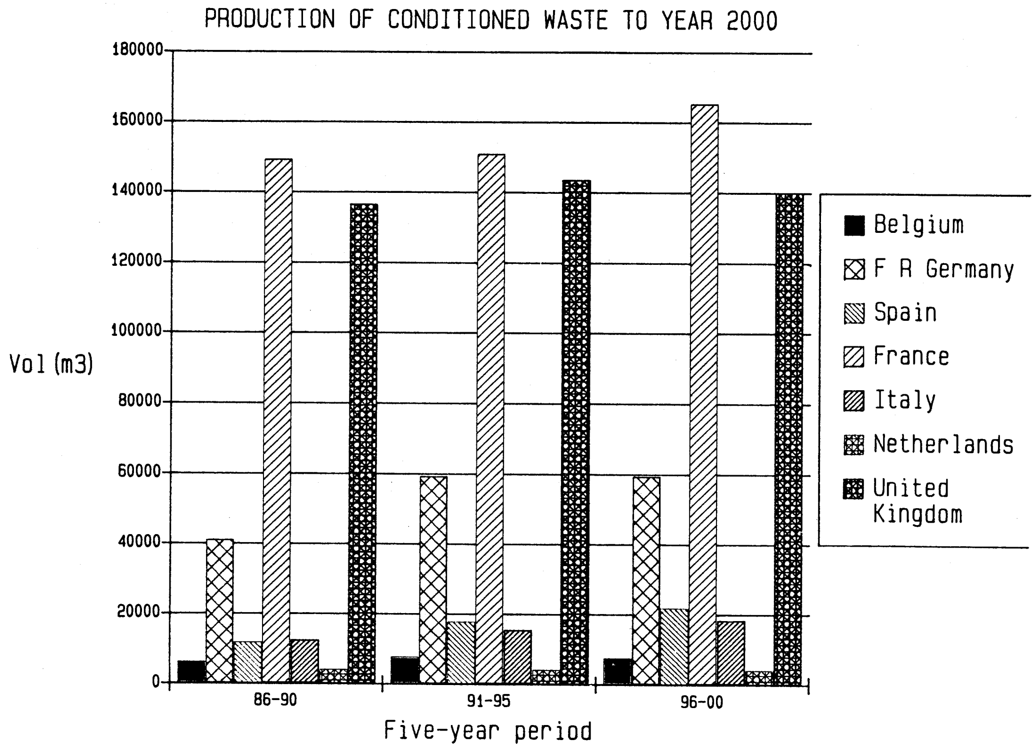

Fig. 1 : Expected quantities of waste produced by EC-Member States with a nuclear power programme till 2000

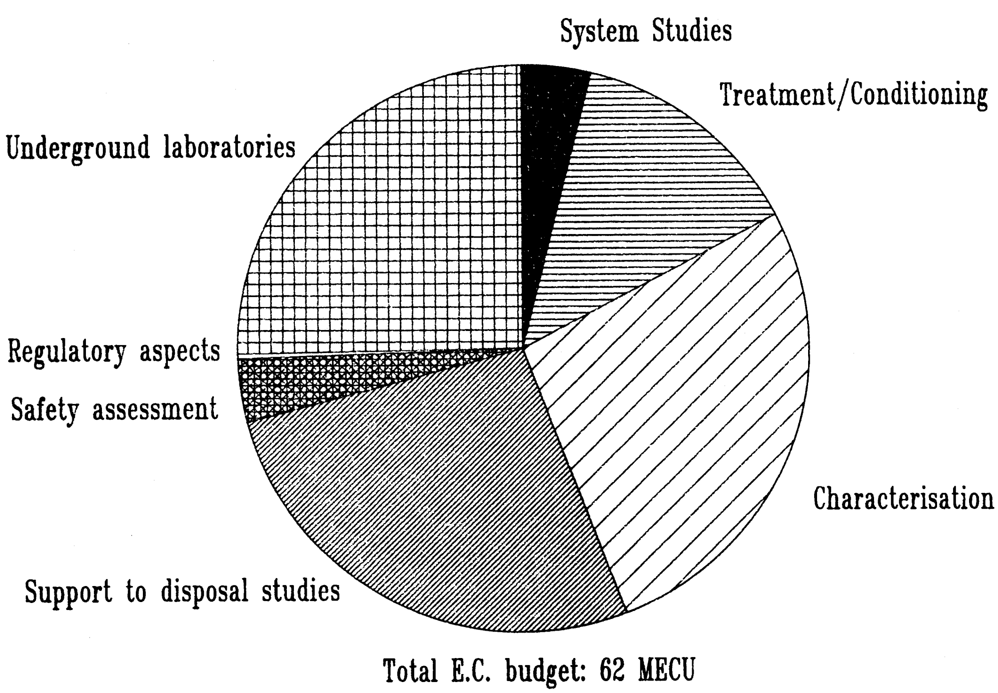

Fig. 2: Breakdown of funds for the 3rd shared-cost research programme (1985-1986) on radioactive waste management

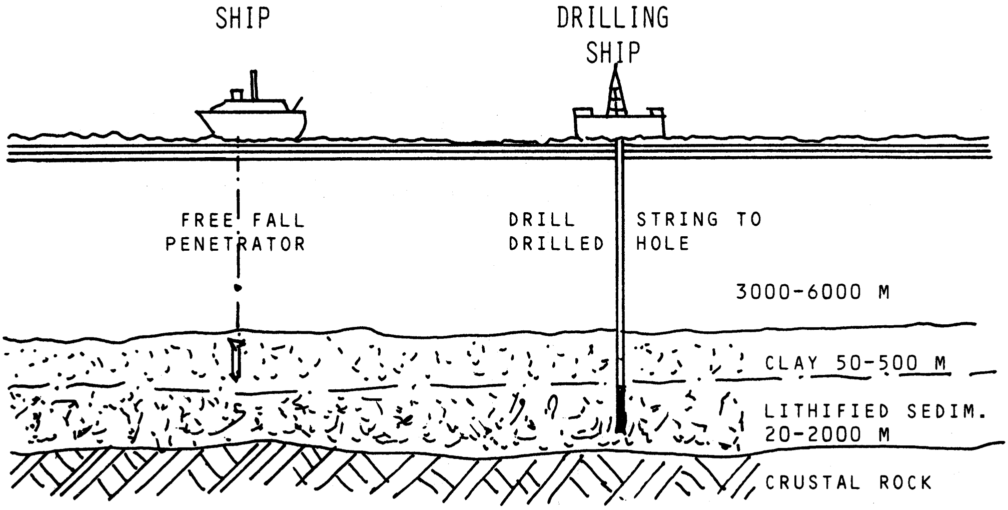

Fig. 3: Seabed disposal: penetrator and drilled hole emplacement concepts

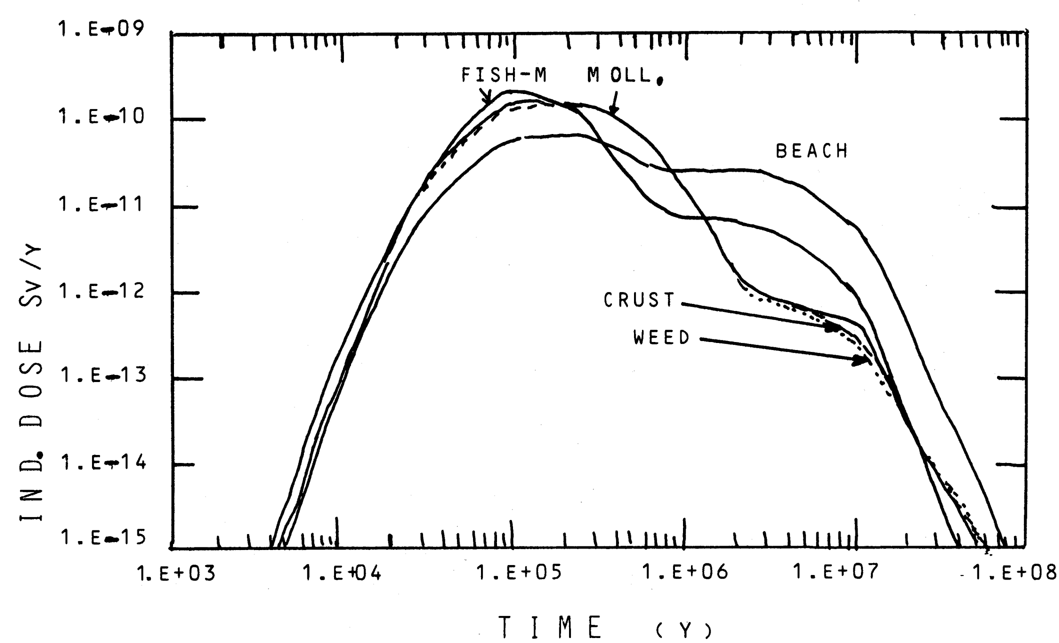

Fig. 4: Seabed disposal: best estimate of individual dose-rate evolution at the Great-Meteor-East site (North Atlantic) for fish ingestion pathway

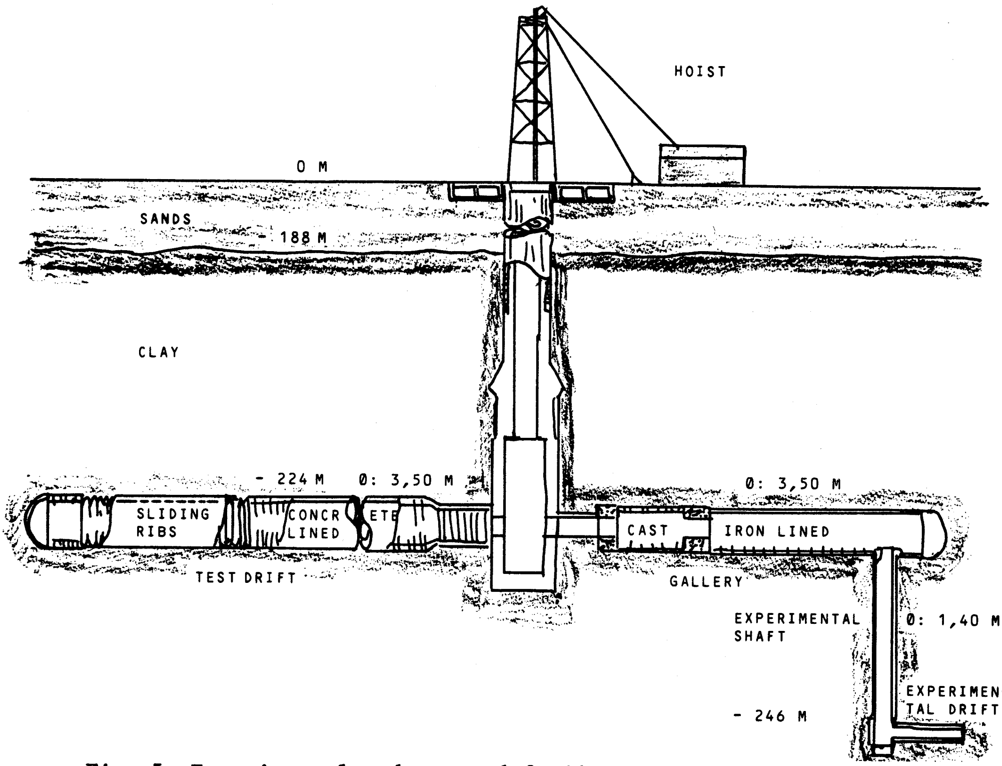

Fig. 5: Experimental underground facility in clay at Mol (Belgium)
(Courtesy CEN/SCK Mol)

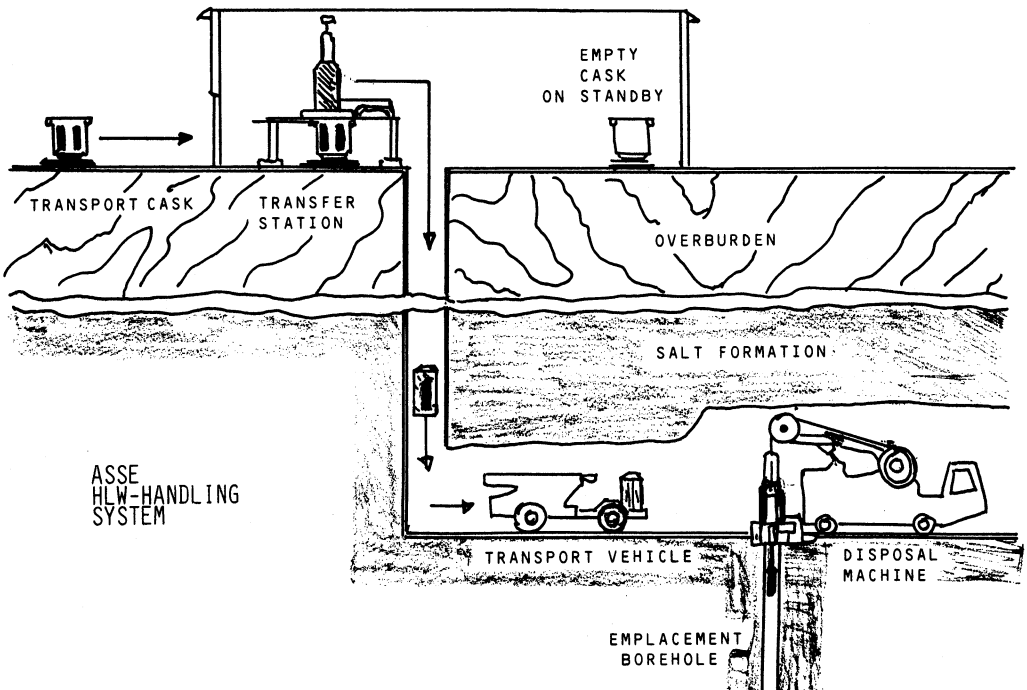

Fig. 6: Experimental underground facility in salt at Asse (F.R.G.)
(Courtesy GSF Braunschweig)