Nuclear waste management in Switzerland

by R. Rometsch*

Revised atomic energy legislation has been in force in Switzerland since July 1979. It deals mainly with licensing of nuclear installations, introducing new procedures and clarifying conditions under which licenses may be granted. One condition is that projects should exist guaranteeing the long-term safety of nuclear waste, including final disposal in a repository. Thus the way in which one must fulfil the requirement to protect human health, rights, and property is now prescribed for radioactive waste, although this was obviously already stipulated in the old atomic energy law. Similar requirements are valid through general legislation for all other types of wastes.

The reason for special strengthening of legal requirements for radioactive waste management lies in the drastic change in public perception of nuclear energy. During the early years of pioneering peaceful uses of atomic energy, it was generally accepted as adequate to apply the usual strict radioprotection rules to the new type of industrial applications as well as to nuclear waste handling. Only in the mid-1960s, when atomic energy became competitive and a rapid (maybe sometimes too rapid) development of production of nuclear electricity took place, did an intense public debate start up. Concerns about possible ill-effects of nuclear energy were voiced and radioactive waste became a very special subject. Knowledge of radioactive decay properties made it possible to calculate the remaining radiotoxicity far into the future, and thus caused people to think of the future and to require explicit protection of future generations – a claim seldom made for wastes of permanent toxicity.

This kind of public reaction developed in many countries. The fact that many people first became aware of atomic energy through the bombing of Hiroshima and Nagasaki did not help either. Atomic energy became a symbol of power and evil – and its waste byproducts clearly needed special treatment in every sense. What had been a matter of course, namely that countries performing the service of reprocessing nuclear fuel for others would also assume responsibility for the separated radioactive wastes was no longer possible. Switzerland, because of its small nuclear programme, is restricted to the role of customer with regard to reprocessing, and had to accept new contracts. These foresee the return of all wastes from reprocessing for final disposal by the country in which the nuclear energy was produced.

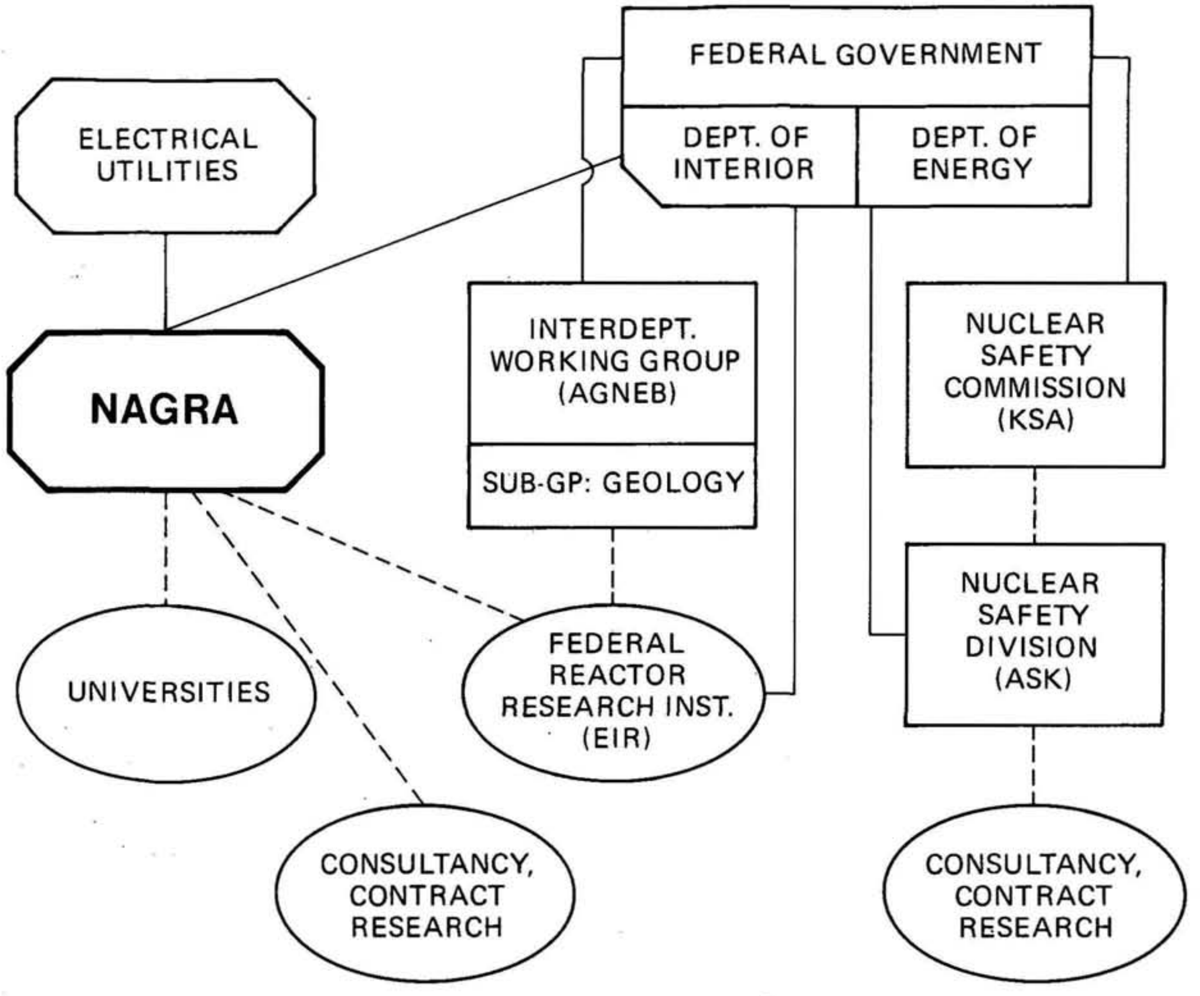
All these elements led quite naturally through the traditionally democratic procedures in Switzerland to the new and stringent legislation. As this cannot be implemented retroactively for nuclear power plants already in operation, the Federal Government had to deal with those separately. Parallel to the law, which was ratified by a great majority in a popular vote, requirements were placed upon the four utility companies operating or constructing nuclear plants to establish a project guaranteeing the long-term safety of waste management and disposal. December 31, 1985 was specified as the date beyond which operating permits for nuclear plants would not be renewed if appropriate projects were not available.

The requirement placed upon existing nuclear plants, as well as the legal condition for new licenses, should be seen also in connection with another newly formulated article. The revised law leaves no doubt that in Switzerland responsibility for final disposal lies directly with the producers of nuclear wastes, although the Government reserves the right to dispose at the cost of the producers. This right would be exercised only if the producers were to be hindered in fulfilling their obligations.

Who does what?

Confronted with the parallel tasks of establishing the demonstration project guaranteeing feasibility and safety of disposal, and of preparing concrete projects for actual disposal of all kinds of radioactive wastes, the producers decided to charge one common organization with both tasks. The co-operative *Nagra* was founded in 1972, with the objective at that time of setting up a disposal facility for low-level wastes. Its members are six utilities with nuclear power interests and the Federal Government, represented by the Office of Public Health which is responsible for industrial, medicinal, and research wastes. New resources were allocated to the co-operative in 1979 when responsibilities were extended to high-level wastes and the project deadlines described above were established. For the period 1980–1985 they are broadly assessed at approximately 200 million

* Mr Rometsch is President of the Nationale Genossenschaft für die Lagerung radioaktiver Abfälle, *Nagra*, (National Co-operative for the Storage of Radioactive Wastes), Parkstrasse 23, CH-5401 Baden, Switzerland and former Deputy Director General, Department of Safeguards, IAEA.



The organizations involved in nuclear waste management and disposal in Switzerland.

Swiss Francs*. The 1982 budget allocation is 40 million Swiss Francs. The permanent staff positions at Nagra number only around 30, the objective being to provide a project-management structure for allocation and control of contract work to universities and to the Federal Reactor Research Institute (EIR) as well as private engineering or geological consultant organizations.

As the licensing authorities of the Government use similar working methods it is important to avoid conflicts of interest. This is achieved by separating Government implementation and regulatory interests into different political departments and by use of different consulting offices by Nagra and by the regulatory authorities. Complete duplication of technical methodology is, on the other hand, not sought; for example common safety analysis models may be employed. The Federal Reactor Research Institute (EIR) has a special role in that it acts as contractor to Nagra, has an independent waste programme and may also be asked by the regulatory bodies to perform specific technical tasks. An overview of the total organization is given in the Figure.

* In April 1982, 1 SwFr was worth approximately US $0.51.

Volumes and classes of waste

In Switzerland, national disposal projects are being planned for all types of nuclear wastes produced. For planning purposes, even the option of sea-disposal of low- and intermediate-level wastes (LLW/ILW), an option currently in operation, is assumed to be discontinued. On this basis, the utilities with nuclear power interests together with Nagra published in 1978 a management and disposal concept for the totality of radioactive wastes which would result from a maximal nuclear power programme. Installed capacity was assumed to reach eventually 6000 MWe, although to date only about 2000 MWe are in operation and 1000 MWe under construction. The overlapping probable lifetimes of 40 years per plant make it necessary to cover a period of 60 years. The wastes from isotope applications and

Geophysical field work in the north of Switzerland being carried out in co-operation between the Swiss Geophysical Commission (SGPK) and the National Co-operative for the Storage of Radioactive Wastes (Nagra).

nuclear research were also estimated and added to the total.

A waste categorization similar to that proposed and in use by the IAEA was adopted. It is based on activity per volume, i.e.

10^{-9} to 10^{-1} Ci/m^3 for LLW
10^{-1} to 10^{4} Ci/m^3 for ILW
and above 10^{4} Ci/m^3 for HLW.

Accordingly, for all types of wastes the option of geologic disposal was chosen and three types of final repositories were defined. However, more detailed safety considerations led to the decision that LLW containing long-lived radionuclides above a certain concentration would be disposed together with ILW. Thus, LLW will be disposed of in a repository providing 100 years of absolute containment (Type A); the combination of LLW with long-lived components together with ILW in a repository providing about 600 years of absolute containment and showing a very low probability of geological disturbances during a few thousand years (Type B); and HLW in a repository (Type C) where absolute containment would last at least 1000 years and for which geological disturbances are forecast to be extremely improbable for some 10 000 years. Assuming that all Swiss spent fuel will be reprocessed in other countries with all wastes from this operation being returned to Switzerland, and assuming that all power plants at the end of their lifetime will be dismantled with the radioactive parts being allocated to a final repository, the total volumes of conditioned wastes for the coming sixty years amount to approximately:

- 100 000 m^3 LLW for Type A repository in a near-surface cavern
- 60 000 m^3 LLW + ILW for Type B repository in a rock cavern at 100 to 600 m depth
- 1 000 m^3 HLW for Type C repository in a deep rock cavern in the crystalline basement underlying the lowlands.

Table 1. Waste management steps

Location of production and category of waste	Conditioning at location of production	Capacity of intermediate storage at location of production in years of output	Capacity of intermediate storage in years of output Responsible organization	Final conditioning Responsible organization	Type of final repository Responsible organization Year of start-up
Nuclear research and application in medicine and industry LLW	none	1 y, early collection	3 to 5 y EIR	Compacting, incineration, and concreting EIR	Sea dumping EIR since 1969
					Type A repository Nagra 2000 or later
Operation of nuclear power plants LLW + ILW about 1/5	Concreting, bituminization, or incorporation in plastics	10 to 20 y	3 to 5 y EIR	Some additional concreting EIR	Sea dumping EIR since 1969
			10 to 20 y CEL	Some additional concreting Nagra	Type B repository Nagra 1995
Dismantling of nuclear power stations LLW some ILW	Disintegration and partially concreting	During dismantling operation	Not applicable Utilities	Some additional concreting Nagra	Type A repository Nagra after 2000
Spent fuel without reprocessing HLW	none (underwater storage)	7 to 12 y	50 to 60 y CEL	Metallic or ceramic overpack Nagra	Type C repository Nagra after 2020
Spent fuel with reprocessing HLW	Vitrification at reprocessors	At reprocessors 3 y In Switzerland 10–20 y CEL	10 to 30 y Nagra	Metallic or ceramic overpack Nagra	Type C repository Nagra 2020
Returned from reprocessing ILW small share	Vitrification; concreting or bituminization	Some years at reprocessors	10 to 20 y CEL	Possibly additional overpack Nagra	Type B repository Nagra 1995

Abbreviations for responsible organizations:
EIR Federal Institute for Reactor Research
CEL Study Consortium of Utilities
Nagra National Co-operative for the Storage of Radioactive Waste

Recently, in agreement with an interdepartmental working group of the Federal Government, the case of "no reprocessing" has also been evaluated. The result is a reduction of Type B waste volume by about two fifths but an increase of Type C waste volume by at least a factor of ten.

In addition to the waste volumes and repository criteria, the dates at which different repositories must be commissioned are important parameters in the Nagra work programme. These dates are determined by intermediate storage capacity (both central and at the nuclear power plant site) and by the cycle-time for reprocessing and return of the solidified wastes. Analysis of all these factors yielded the scheme indicated in Table 1. The table also gives the allocation of responsibilities to the different organizations involved in the various waste management steps.

Caring for future generations

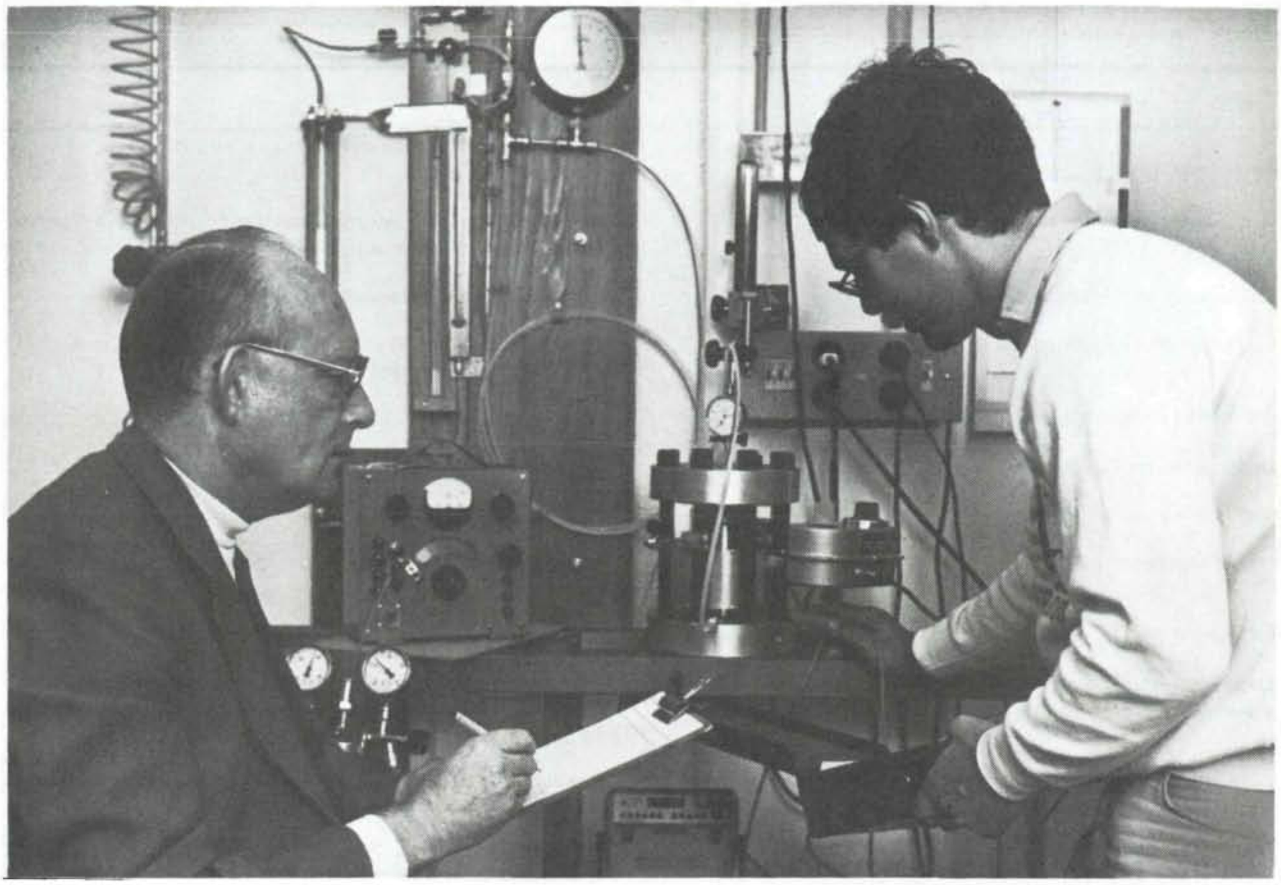
Thirty years' experience in handling radioactive wastes certainly provides an excellent basis for development of the additional step required by the new law, namely to assure long-term safe disposal in a repository requiring neither surveillance nor control of any kind. It is clear, however, that considerable amounts of further detailed knowledge must be gathered. This

Table 2. Nagra research and development programme

Project	Activities
Waste technology	
Nuclide-specific waste characterization of	Analysis of literature, lab-work, calculations; liaison with power plants; lab-work; large-scale experiments
Characteristics of HLW-glasses	International project lab-work
Evaluation of overpack concepts for HLW and spent fuel	Literature; engineering studies; complementary lab-work
Repository planning	
Design work for repositories Type A, B, C	Engineering design; calculation
Evaluation of buffer materials	Joint studies; international project; complementary lab-work
In-situ experiments	Stripa participation; Grimsel rock laboratory
Earth sciences	
Local and regional geological investigation of granitic basement in north of Switzerland	Literature study and analysis; Geophysics (reflection and refraction seismic, gravimetry, aeromagnetic survey, magnetotellurism); 12 deep drillings (1200-2500 m)
Local and regional hydrology in north of Switzerland	Characterization of mineral waters; Isotope age determinations; regional flow models
Tectonic studies	Study of neotectonics; possible geodesic field programme; earth quake statistics
Site selection for L/ILW repository	Literature evaluation, selection of 3–6 sites for field-work
Host-rock characterization (rock mechanics, geochemistry, sorption)	Literature analysis; lab-work on sorption; in-situ experiments in anhydrite and in granite
Methodology for water age determination	Development and application of ^{39}Ar, ^{14}C, ^{36}Cl, ^{81}Kr methods; investigation of sampling techniques
Safety analysis	
Determination of criteria for allocation of wastes to appropriate repository type	Improved characterization of waste; categorization of waste; simplified safety analyses
Mathematical modelling:	
hydrogeology	model development; calibration; calculation
leaching	model development; calibration; calculation
chemical speciation, solubility	model adaption; data extension
geosphere transport in porous and fissured media	model development; intercomparison
biosphere transport	model adaption; collection of local data

is particularly important for the deep geological formations envisaged for the Type C repository. Accordingly, Nagra has established an extensive research and development programme. Most time and money is devoted to geological, geophysical and hydrological field work. The major components of the programme are indicated in Table 2.

The preparatory work on safety analysis involves fundamental philosophical questions concerning predictability in the far future of possible disturbances at the repository site and calculation of the consequences to human beings. In October 1980 the Swiss Nuclear Safety Commission and the Nuclear Safety Division of the Department of Energy issued guidelines which provide an important basis for this work. Besides defining the concept of "final repositories" as used above, the guidelines set a limit, 10 mrem/y, for the radiation dose which an individual may receive at any time due to radionuclides released from a repository. This implies a deterministic approach to the safety analysis. However,



Two researchers from Zürich Polytechnic's Institute for Soil Mechanics carry out an experiment on sealant material for a final repository, part of a programme of research funded by Nagra.

Examining drill-core samples from Nagra's drilling in the Grimsel, Switzerland.

it is also recongized that certain disruptive events may be excluded from mechanistic radiation dose calculations on the basis of their extreme improbability.

Status, public debate and outlook

Good progress has been achieved on most aspects of the research and development programme. In particular, the work at university laboratories, institutes and consultant offices, i.e. all activities with no legal requirements for special permits, is being performed according to schedule.

However, the preparatory field work connected with geological investigations – the deep drilling programme – has been considerably delayed due to complications in licensing procedures. Originally the new legislation was intended to smooth the way for such investigations and to avoid prejudicing repository siting choice by allocating responsibility for granting of permits directly to the Federal Council of Government ministers. However, the democratic processes for protection of the citizen's rights imply also a complicated administrative procedure.

Consultation was required with cantonal and communal authorities as well as other federal departments. Moreover, hundreds of objections by citizens and groups of citizens had to be dealt with. A major public debate with media participation took place. This made necessary numerous information meetings where officials and Nagra representatives had to discuss the issues involved. The responsible minister from the Federal Council took it upon himself to visit the local authorities in all four cantons where deep drillings were planned. Finally, it appeared judicious to go through also the usual local permit procedures, even after the granting of the federal licence. It is, of course, understood that the federal permission should not be blocked by introduction of issues foreign to the matter at hand.

Commencement of the deep drillings, which are an essential part of the geological investigations for a HLW repository, will probably be possible now in late summer 1982. Only then will the first two or three drillings be fully authorized, although the federal permit was granted in February of this year. For a number of drillings the local permits will be further delayed. Under these circumstances there is no chance of completing the full programme within the deadline set for the guarantee project. Nevertheless, the aim remains to submit such a project at the required date, even if it does not contain all the conclusive results originally planned. The further advanced such a project is, the easier it is for the Federal Government to extend the deadline for a specified period.

The projects for actual repositories are not affected by the present licensing delays. The time-scales are dictated here by the practical necessities, with the most pressing need being for a repository for LLW and ILW in the mid-1990s. About one hundred siting possibilities have been examined for this type B repository. Twenty of these were selected as the most appropriate for further investigations, the results of which were published in a detailed geological report to stimulate public discussion.

It appears that only by the most exacting scientific and technical work and by fully open public debate of all results will it be possible eventually to reduce the gap between the perceptions of the nuclear waste problem by a major part of the population and by scientists and engineers who consider, on the basis of their experience, that technical solutions are certainly achievable. Such a development is necessary for traditionally democratic Switzerland in order to render technical solutions politically acceptable.