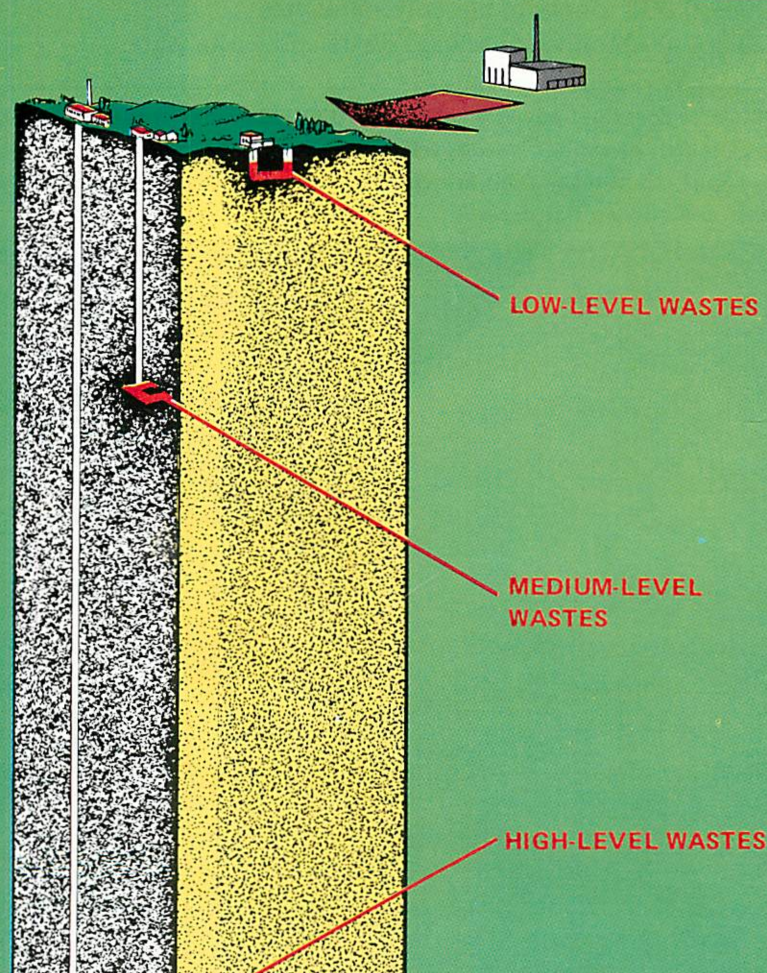
The Management of Radioactive Wastes



INTERNATIONAL ATOMIC ENERGY AGENCY

Wastes in the 20th Century

Modern society creates waste materials which have to be disposed of in nature without disturbing the ecological equilibrium. For some of them, effective disposal techniques have not been found as yet: most plastic products do not degrade, poisonous mercury does not decay, piles of scrap cars, airplanes and metal containers rust away in junk-yards. We live and breathe amidst discharges of noxious gases, aerosols and the exhaust emissions of motor vehicles.

The nine countries of the European Community are producing nearly 1 800 000 000 tonnes of waste per year. This includes:

- 1 000 000 000 tonnes of agricultural wastes.
- 300 000 000 tonnes of sewage waste and waste water.

One 1000 MWe coal-fired power plant uses 60 000 000 tonnes of fuel in 30 years, producing millions of tonnes of various gaseous wastes and 15 000 000 tonnes of ash, which means a heap of 1 km², 15 m high. This ash contains cadmium, mercury, etc. which are non-degradable and also do not decay.

- 200 000 000 tonnes of consumer wastes, 50% of which is household waste and the rest metals, old tyres, waste oils, etc.
- 200 000 000 tonnes of wastes from the mining industry, ash and clinker from coal combustion.
- 150 000 000 tonnes of industrial waste, of which 40 000 000 tonnes are chemical wastes — often toxic.

This mass of waste, growing in output at the rate of 2–3% per year, poses serious problems of pollution, particularly where the toxic contaminants do not decay.

A 1000 MWe nuclear power plant and its associated fuel cycle facilities generate about 2 m^3 of solidified high-level radioactive waste per year and 23 000 m^3 of lower level solid waste per year, which remain under control and are safely disposed of in special waste repositories. Small amounts of low-level radioactive wastes are released under controlled conditions from nuclear power plants. For example, the radiation exposure to people in the vicinity of a nuclear power plant due to its radioactive releases is normally *less than 5%* of their exposure arising from natural background radiation.

Radioactive Wastes

Wastes are nominally labelled as low-level, medium-level and high-level in relation to their radionuclide content, heat generation rates and methods of treatment.

Three principles govern the management of radioactive waste:
1. Dilute and disperse wastes to environment in effluents containing radionuclides in amounts below authorized radiological protection limits.*
2. Delay and decay those wastes which contain only short-lived radionuclides.
3. Concentrate and confine those wastes which contain significant amounts of long-lived radionuclides.

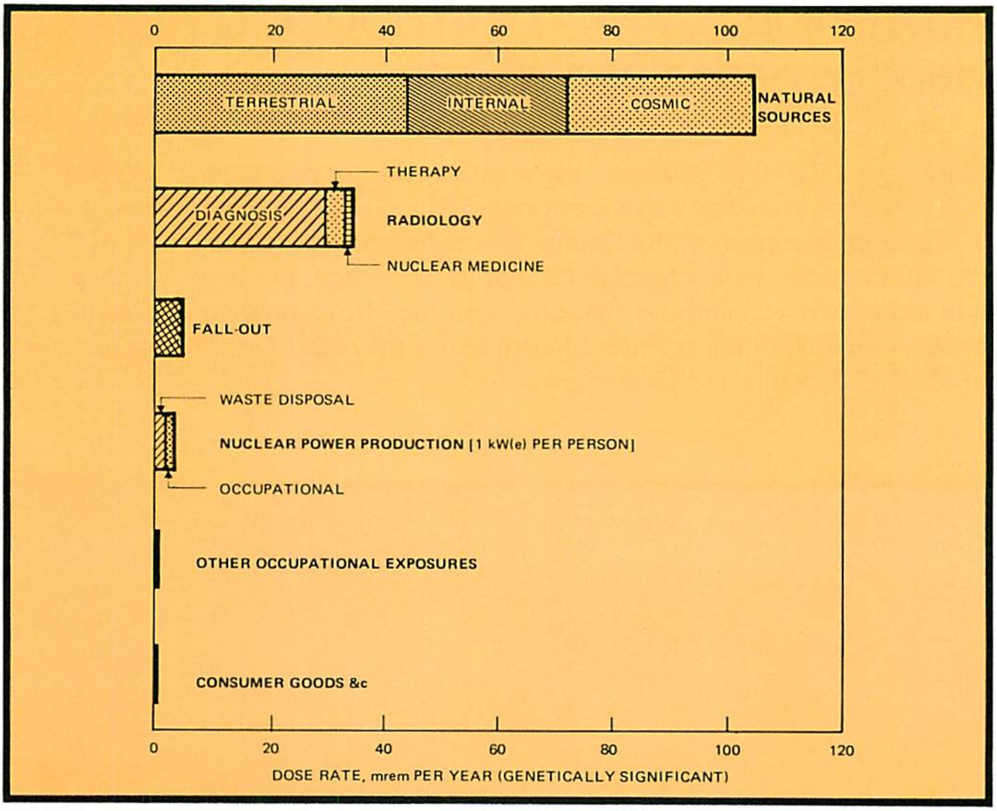
The management of low- and medium-level wastes has become a routine industrial operation. They are disposed of in shallow ground and rock cavity repositories.

The high-level wastes:
1. There are already more than 30 years of experience in storing high-level nuclear waste. The first high-activity wastes were produced in the United States during the Second World War as part of the nuclear weapons and defence programme. Thus far the US weapons programme has generated – in equivalent solidified volumes – 0.2 million m^3 of high-level waste or 700 times more than the 300 m^3 from commercial nuclear power plants. Civilian reactor waste in the United States is not expected to reach even 10% of volume of military waste until the end of the century.
2. A 1000 MWe reactor of the most common type produces about 30 tonnes of spent fuel per year.
3. By reprocessing this spent fuel, high-level waste is separated and concentrated. In France the vitrification of high-level waste from a 1000 MWe nuclear power reactor produces 2 m^3 of high-level waste per year.
4. One large reprocessing plant, depending on its capacity, could service 30–50 commercial nuclear power plants of 1000 MWe each. It is likely that very few countries will have reprocessing plants until the end of the present century. There are at present only two commercial reprocessing plants, one at Sellafield (in the UK) and one at La Hague (in France).
5. In France it has been calculated that all high-level wastes produced between 1974 and the year 2000 (20 nuclear power reactors were operating in 1980) will, in solid form, make up no more than the volume of one Olympic-size swimming pool.

In fact, the technology for storage of high-level waste, both liquid and solid, is available and demonstrated.**

* Based on recommendations of the International Commission for Radiological Protection (ICRP).

** World Health Organization Report on "Nuclear Power: Health Implications of High-Level Waste Management", WHO Regional Office for Europe, Copenhagen, Denmark, 1981.



Protection of the public against potential radiation exposure has been and continues to be the overriding health concern in radioactive waste disposal, but it must be seen in perspective.

According to the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR)* "Surface and deep burial of solid wastes carried out under control at suitable sites is expected to give rise to *no public exposure.*" (See UNSCEAR Report 1977, Volume I, "Sources and Effects of Ionizing Radiation").

The International Nuclear Fuel Cycle Evaluation (INFCE)** concluded that, "employing technology as assumed, the radioactive wastes from any of the fuel cycles studied can be managed and disposed of with a high degree of safety and *without undue risk to man or the environment.*" (See INFCE Report 1980, Working Group 7).

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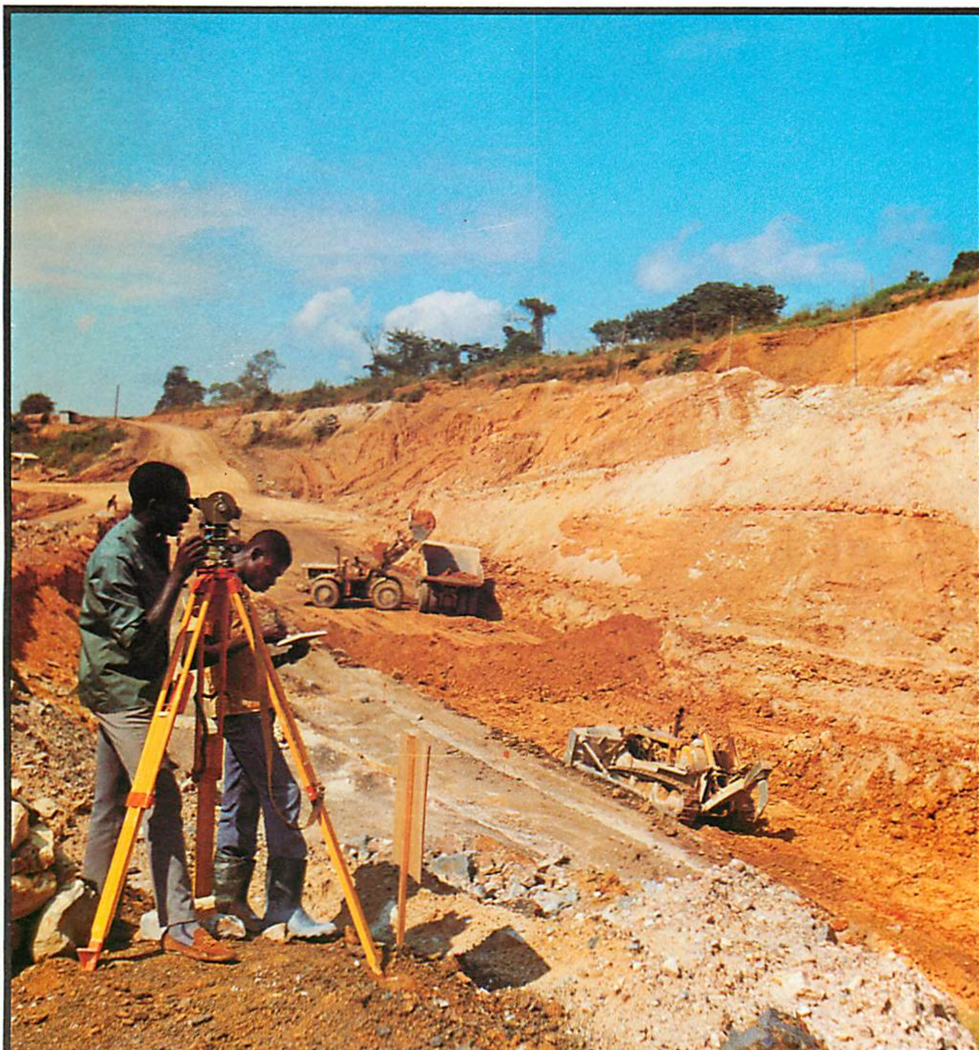
* UNSCEAR was established in 1955 as a result of international concern about the effects of fallout from atmospheric testing of nuclear explosives. It studies and disseminates information on observed levels of ionizing radiation and radioactivity (both natural and man-made) in the environment and on the effects of such radiation on man and his surroundings.

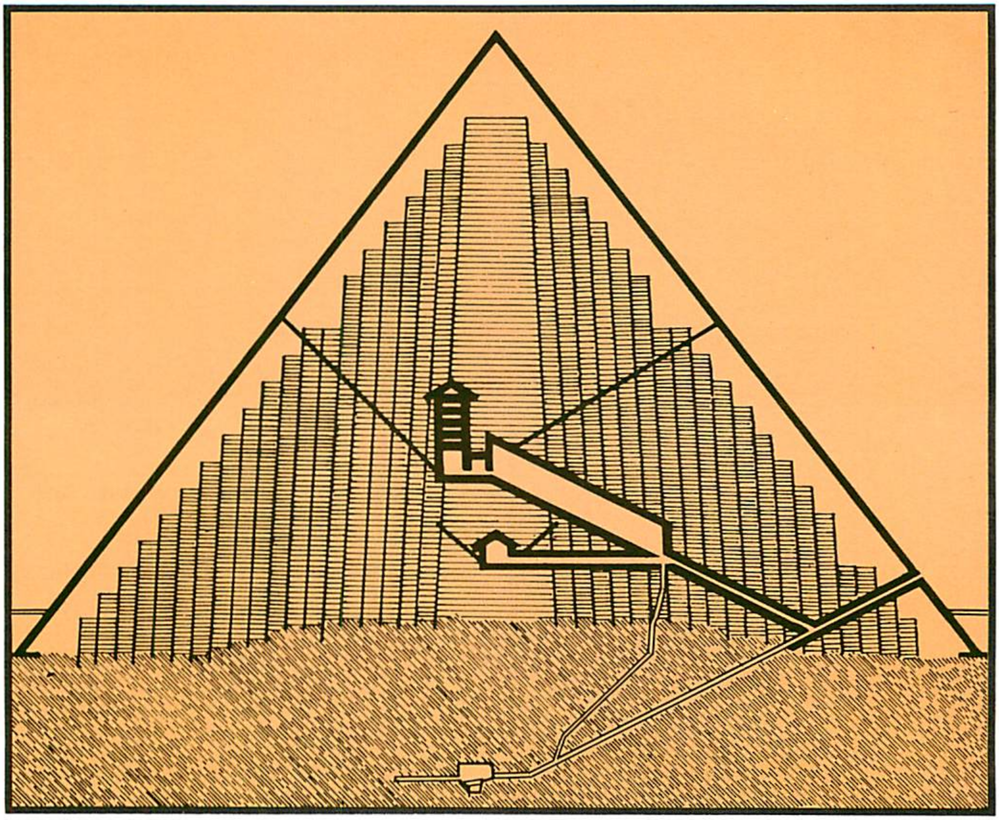
** At the request of President Carter in 1977, 66 countries and 5 international organisations participated in an international evaluation of the technical and analytical aspects of the nuclear fuel cycle. One of the eight working groups concerned itself only with waste management and disposal problems. The study lasted over two years.

How Nature Handles Radioactive Waste 1700 000 000 Years Ago

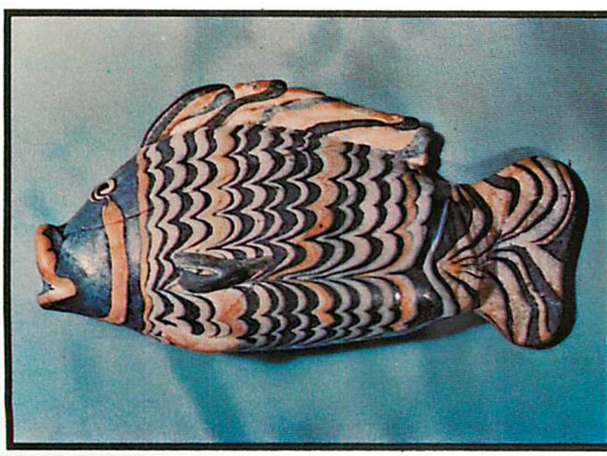
More than 1 700 000 000 years ago a natural reactor operated for at least 100 000 years in an uranium deposit near Oklo, Gabon, in West Africa. Like all reactors, it produced plutonium. Scientific investigations showed that this plutonium never moved from the site of its formation, but decayed slowly into non-radioactive elements on the spot. This fact, from a page of the earth's history, should eliminate some concern about the risks of storing nuclear wastes in suitable underground formations.



The Result of Technology ___ 3500 Years Ago

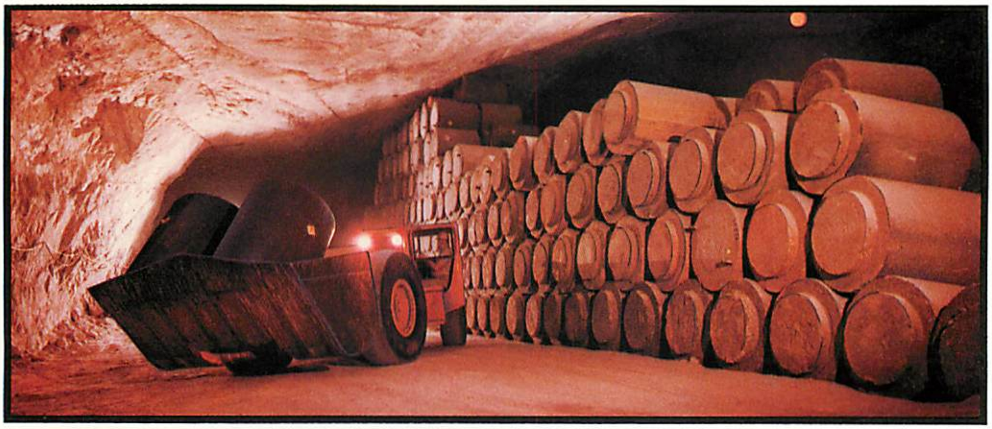


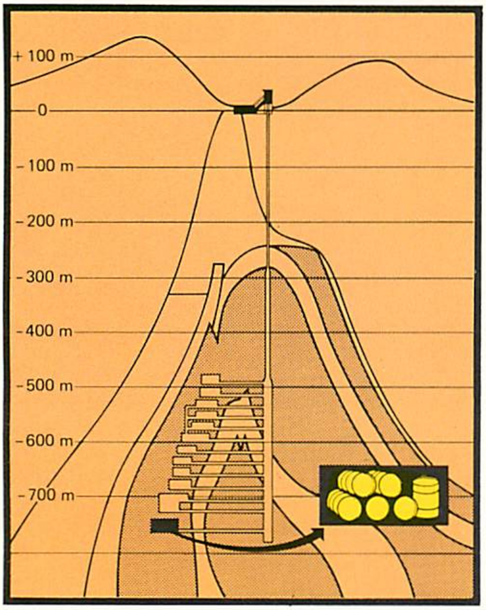
"The virtue of solids for the safe holding of things over long times are obvious – fossil insects, many millions of years old, have been found perfectly preserved in amber – mammoths have emerged from glaciers after 30 000 years with their meat still fresh – Egyptian pyramids have stood the test of time,



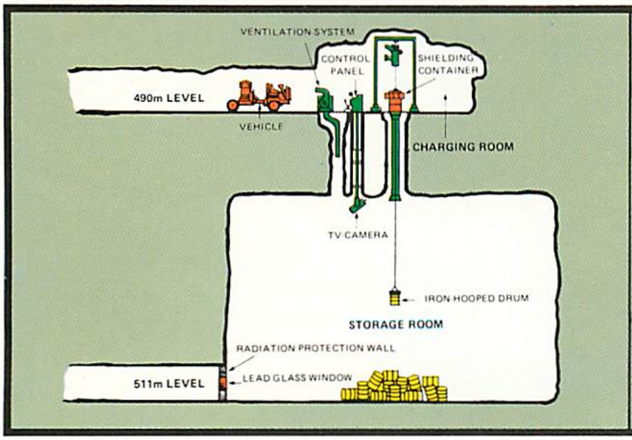
– and ancient decorated glass-ware, 3500 years old, remains in perfect condition today with no significant deterioration or erosion of the glass or running of the colours ..."

Over 100 000 000 Years of Stability





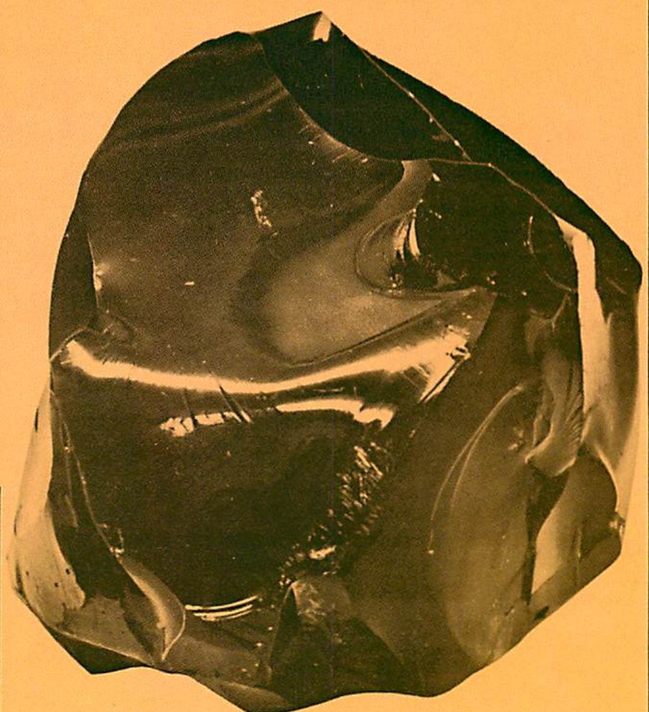
Formations as that of the Asse salt mine in the Federal Republic of Germany, which is 750 meters deep, can be used for disposal of radioactive wastes. Salt formations are extremely stable. The Asse salt formations have remained undisturbed for more than 100 000 000 years and are likely to continue to exist for the time required for the radioactive wastes to decay.

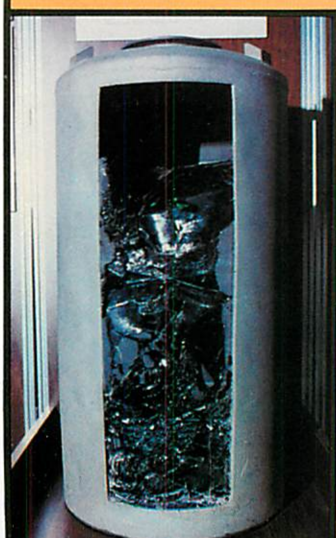


Since 1967, the Asse salt mine has been used as an experimental facility for the development of methods and techniques for the safe disposal of low- and medium-level wastes with long-lived radionuclides.

How Technology Handles High-level Wastes To-Day

Glass is a proposed material for the solidification of high-level nuclear wastes which combine well with the standard ingredients used in glass-making. Vitrified waste glasses can be very stable, like Pyrex, with good resistance to heat, chemical action, radiation and mechanical stress. Even in flowing warm water (40°C) it would take *100 years* to dissolve away about *1mm* of the surface of such a glass. The vitrified waste would then be sealed in stainless steel containers chosen to resist corrosion.





▲ Example of the vitrified high-level waste produced at the Marcoule plant.

◄ Cut-away view of a container with high-level vitrified wastes.

For the first 30 to 50 years the containers would be stored in water ponds or air-cooling chambers at the reprocessing plant. After this time, the heat output will have declined sufficiently to allow the containers to be transferred to boreholes in rocks where natural cooling is adequate.

Present proposals suggest that the stainless steel containers should receive extra protection against corrosion in case of ingress of ground water, which is likely to be saline. A Swedish proposal calls for a further cladding of 10 cm of lead and an outer case of 6 mm of titanium. The solution rate of the titanium in flowing saline water at ambient temperatures is 0.0013 mm per year, so although the temperature is likely to start at 60°C or more, dropping to a few

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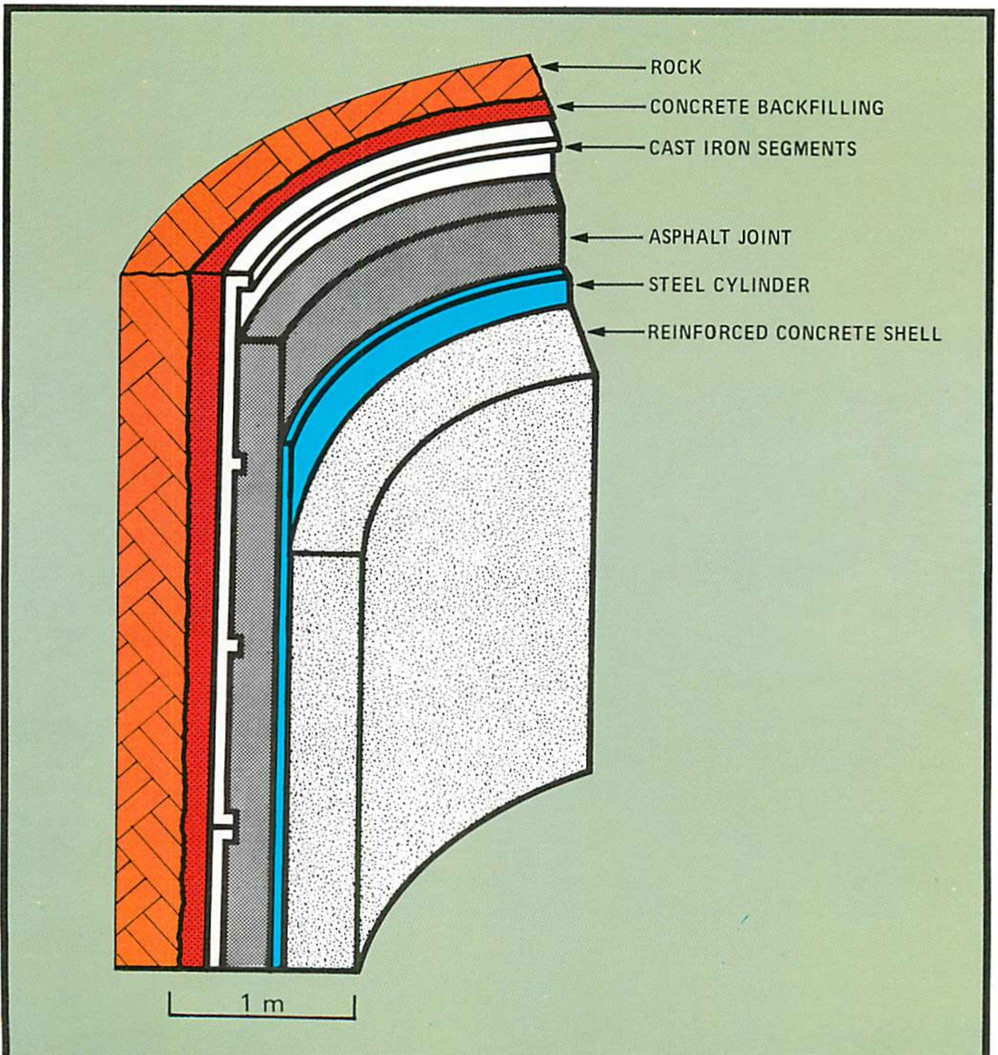
Storage of vitrified wastes. This mobile installation transport and deposits the container with the wastes in the storage wells.

degrees above ambient in 100 years, the titanium layer itself is likely to last for at least 4000 years. Roman lead articles have survived in the Mediterranean for 2000 years with little loss so that the 10 cm of lead should last for longer still.

The high-level waste containers will be finally disposed of in excavated repositories in deep geological formations hundreds of meters below ground. Other engineered barriers (in addition to the waste glass and its container) can be added to assure waste containment for more than *1000 years* even in the presence of corrosive ground water. The access tunnels to these repositories will be filled in with rocks and sealed. Significant movement of radionuclides from the waste to the human environment will therefore be prevented by these engineered barriers and the natural geological barriers surrounding the repositories at suitable sites.

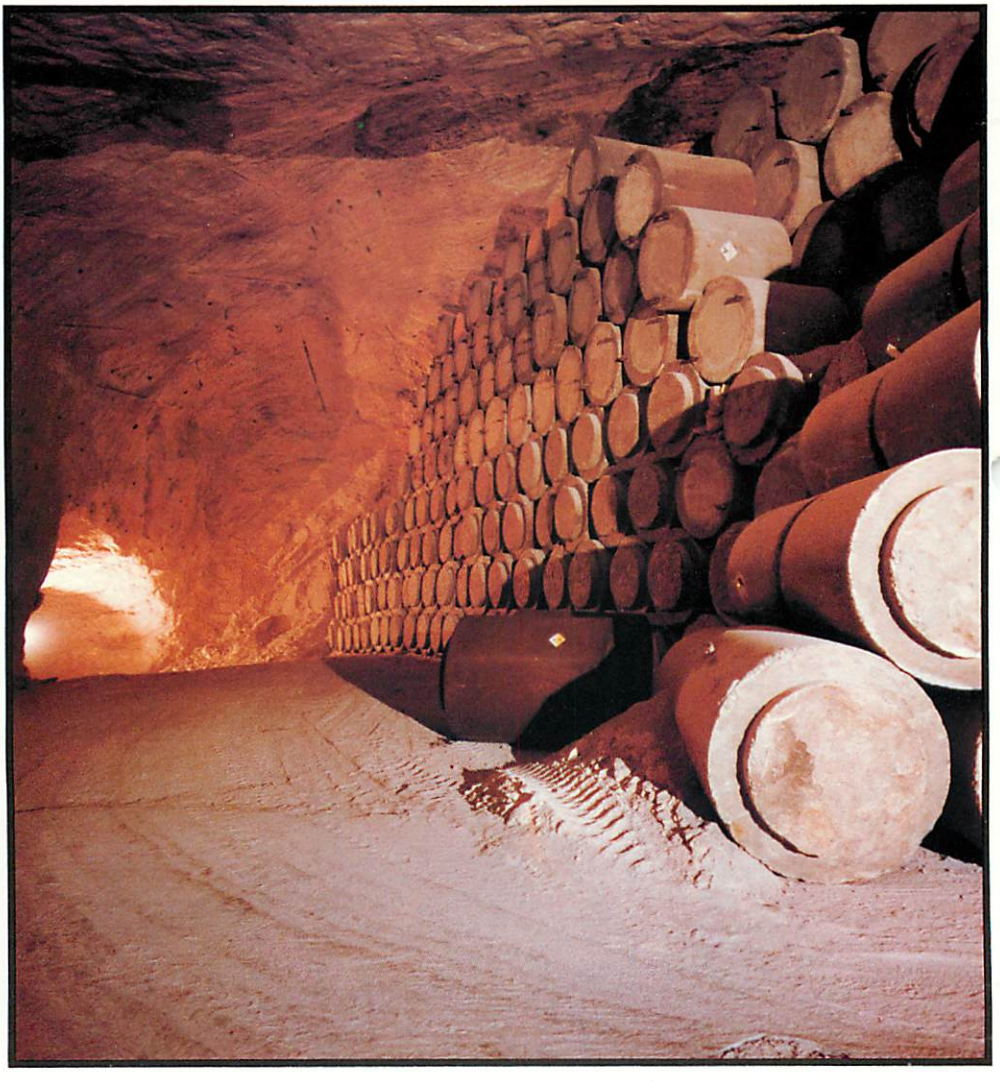


"The advantage of going to depths of hundreds of meters is that in inactive parts of the earth's crust the geological structures and materials remain stable for *millions of years.*

It is therefore already possible to guarantee that we are not bequeathing to future generations a higher radioactivity than that which our earth contains naturally."

(A. Gauvenet, CEA, France)

Photographs:
Commissariat à l'énergie atomique, Gesellschaft für Strahlen- und Umweltforschung, Oskarshamnsverkets Kraftgrupp AB, Trustees of the British Museum, United Nations Environment Programme.



Who is Doing What with High-level Waste and Where?

Country	Current Practice	Future Plans
Belgium	Liquid wastes from Eurochemic reprocessing plant are stored in stainless steel tanks.	Vitrification processes are being considered for waste solidification, including the incorporation of a granular product into a metallic matrix. Solidified waste will be placed in engineered surface storage. Investigating clay formations for waste repository.
Canada	Engineered storage of irradiated fuel assemblies, both surface and underground.	Storage of fuel without reprocessing is considered satisfactory for at least 75 years. Methods for disposal of irradiated fuel and/or separated wastes in deep underground rock formations are being developed.
CSSR	Fuel reprocessing in another country.	Two-step solidification process on a pilot scale basis (10–20 litres/h) should be completed in 1982. An experimental storage facility for vitrified wastes is designed and will be constructed in the late 1980s.
Finland	Fuel reprocessing in another country.	Investigating crystalline rocks for repository of any returned solidified waste.
France	Liquid wastes are stored as acidic solutions at the Marcoule and La Hague reprocessing plants in stainless steel tanks. The PIVER pilot plant to solidify wastes into borosilicate glass was in operation from 1969 to 1973. It has been superseded by the AVM plant which commenced operation at Marcoule in 1978, capable of vitrifying wastes from essentially an 800 ton/y fuel reprocessing facility.	Solidified waste will be stored in air-cooled vaults. A similar vitrification plant (AVH) will be installed at La Hague after confirmation of routine operation of the AVM plant. Investigating salt and crystalline rocks for waste repository.
Germany, Federal Republic of	Liquid wastes from WAK reprocessing pilot plant are stored in stainless steel tanks. Studies of solidifying wastes into borosilicate and phosphate glass are in progress.	Vitrification processes are being developed for conversion of the high-level wastes to glass after a three to five year cooling period. Salt formations similar to Asse are being studied for disposal of vitrified product and other solid radioactive wastes.
India	Liquid wastes stored as acidic solutions in stainless steel tanks.	A waste immobilization plant using a batch glass-making vitrification process is expected to be operating in 1981. Vitrified wastes will be stored in air-cooled vaults. Investigating igneous rock and sedimentary formations for waste repository.
Italy	EUREX pilot reprocessing plant began operation in 1970. Small quantities of liquid wastes are stored in stainless steel tanks.	Batch solidification to form borosilicate or phosphate glasses under consideration. Disposal of solid wastes in clay formations of low permeability is being investigated.
Japan	Reprocessing plant commenced operation in 1977 and liquid wastes are stored in stainless steel tanks.	Solidification processes being developed and a pilot plant will be constructed in early 1980s. Investigating granite and zeolite rock formations for waste repository.

Country	Current Practice	Future Plans
Netherlands	Fuel reprocessing in another country.	Investigating rock salt formations for repository of any returned solidified waste.
Sweden	Fuel reprocessing in another country.	Any returned solidified high-level waste will be stored in underground air-cooled vaults and eventually disposed of in a repository deep in Swedish bedrock.
Switzerland	Fuel reprocessing in another country.	Investigating evaporite formations for repository of any returned solidified waste.
UK	Liquid wastes are stored as acidic solutions at Sellafield and Dounreay reprocessing plants in stainless steel tanks.	Highly active waste is currently stored as a liquid. It is planned from the late 1980s to vitrify the waste using the French AVM system. Because of the temperature, the vitrified blocks will be placed in a specially designed store, cooled by air or water, on or near the surface for at least 50 years. The possibilities for disposal being considered are placing the blocks on or under the bed of the ocean or in deep geological formations on land. Research into the feasibility of ocean disposal and drilling programme to investigate the properties of certain rock formations and the feasibility of geological disposal.
USA	Liquid wastes from government operations at Hanford and Savannah River plants are alkaline and stored as concentrated salt solutions or salt cakes in mild steel tanks; heat-generating caesium-137 and strontium-90 are chemically separated from Hanford wastes, encapsulated and stored in water-cooled basins. At the National Reactor Testing Station in Idaho, acidic wastes are stored in stainless-steel tanks prior to calcination; calcined wastes are stored in stainless steel bins. No commercial plants are operating. The Nuclear Fuel Services Plant in New York State operated 1966–1972 but is now shut down. Most high-activity wastes from this plant were made alkaline and are stored in a mild steel tank but small quantities of special wastes are stored in a stainless steel tank. The Barnwell Nuclear Services Plant in South Carolina is awaiting authorization to commence operation.	All high-activity wastes are to be solidified as soon as practicable. Long-term options being evaluated including storage in existing tanks or vaults, storage on-site in underground caverns, or shipment to off-site federal repository. Commercial fuel reprocessing was delayed for the International Nuclear Fuel Cycle Evaluation (INFCE) study and may be delayed indefinitely with the spent fuel being stored or disposed of. Any high-activity waste from fuel reprocessing is to be converted into an immobile form within five years after generation and transferred to a national repository within ten years. Pilot plant demonstrations during 1966–72 and 1978–79 at Hanford established necessary technology for waste solidification processes with development still proceeding. Both surface storage and deep geological disposal concepts for solidified waste and/or spent fuels are being considered within a National Waste Terminal Storage Programme.
USSR	Liquid wastes stored in stainless steel tanks. Solidification processes to produce phosphate and borosilicate glasses have been investigated on a laboratory scale with radioactive wastes and on a pilot plant scale with inactive simulated wastes.	Industrial scale plant to vitrify wastes is expected to begin operation in the 1980s. Storage of solidified waste in near-surface facilities and deep geological disposal concepts are being studied.

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About IAEA

The International Atomic Energy Agency (IAEA) came into being in Vienna, Austria, on 29 July 1957. Its main objectives are to "seek to accelerate and enlarge the contribution of atomic energy to peace, health and prosperity throughout the world" and to "ensure, so far as it is able, that assistance provided by it or at its request or under its supervision or control is not used in such a way as to further any military purpose".

In particular, in the area of health and safety, the IAEA's Statute directs it to establish or adopt standards of safety for the protection of health and the minimization of danger to life and property, including standards relating to the workplace. These standards are to be applied to the IAEA's own operations as well as to those making use of materials, services, equipment, facilities and information supplied by or through the Agency. Where appropriate, the IAEA is required to consult or collaborate with other United Nations bodies and specialized agencies, in developing or adopting these safety standards.

The IAEA is an intergovernmental organization like the United Nations, the World Health Organization and other specialized agencies of the United Nations. It is directed by a Board of Governors, which is composed of representatives from 34 Member States, and a General Conference of the entire membership of 110 States. The IAEA has its own programme, approved by the Board of Governors and the General Conference, and its own budget, currently about 80 million dollars a year, financed by contributions from its Member States.

Although autonomous, the IAEA is a member of the United Nations system and sends reports on its work to the General Assembly and to other United Nations organs.

INTERNATIONAL ATOMIC ENERGY AGENCY, Wagramerstrasse 5, A-1400 Vienna, Austria, P.O. Box 100

About WHO

The World Health Organization is a specialized agency of the United Nations with primary responsibility for international health matters and public health. Through this organization, which was created in 1948, the health professions of some 150 countries exchange their knowledge and experience with the aim of achieving the highest possible level of health throughout the world.

By means of direct technical cooperation with its Member States, and by stimulating such cooperation among them, WHO promotes the development of comprehensive health services, the prevention and control of diseases, the improvement of environmental conditions, the development of health manpower, the coordination and development of biomedical and health services research, and the planning and implementation of health programmes.

These broad fields of endeavour encompass a wide variety of activities, such as developing systems of primary health care that reach the whole population of Member countries; promoting the health of mothers and children; combating malnutrition; eradicating smallpox throughout the world; controlling malaria and other communicable diseases including tuberculosis and leprosy; promoting mass immunization campaigns against a number of preventable diseases; improving mental health; providing safe water supplies; and training health personnel of all categories.

Progress towards better health throughout the world also demands international cooperation in such matters as establishing international standards for biological substances, pesticides and pharmaceuticals; recommending international nonproprietary names for drugs; administering the International Health Regulations; revising the international classification of diseases and causes of death; and collecting and disseminating health statistical information.

WORLD HEALTH ORGANIZATION, 20 Avenue Appia, CH-1211 Geneva 27, Switzerland

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About ICRP

The ICRP is an independent non-governmental expert body which was established in 1928 to formulate radiation protection recommendations to be used for protection of individuals. Its members are chosen on the basis of their individual merit in the fields of medical radiology, radiation protection physics, health physics, biology, genetics, biochemistry and biophysics. The Recommendations of the ICRP have been universally accepted for the last 50 years both by national and international bodies for radiation protection.

INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION, Clifton Avenue, Sutton, Surrey, England

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