Waste Management Practices in Selected European Countries

by V.A. Morozov

INTRODUCTION

In autumn 1978 the IAEA arranged a Study Tour on Radiation Protection and Waste Management, as a form of technical assistance to developing countries. This tour was organized in collaboration with the Governments of Czechoslovakia, Federal Republic of Germany, France, German Democratic Republic and Hungary, and led through all of these countries. The present review covers only one aspect of this Study Tour — radioactive waste management — and is based on lectures given to the tour participants in the various countries and on scientific visits to research centres and nuclear power plants.

RADIOACTIVE WASTE

The development of nuclear power is inevitably dependent on the resolution of two issues: the safety of nuclear facilities and the management of radioactive waste. Let us consider the second of these.

Radioactive waste comprises natural radioactive elements, which arise, for instance, as a result of uranium ore treatment, and artificial radioactive elements produced during the operation of nuclear power plants, research reactors, and accelerators. To ensure that these wastes have insignificant effects on the population and on the environment as a whole, certain measures must be taken to isolate the wastes from the biosphere.

In the practice of radioactive waste management there are two approaches. The first is to collect, process, package and store or bury the waste. The second consists of a controlled release of low-level waste into the environment. These are quite different approaches and are applied to separate categories of waste. Furthermore, since radioactive waste may be in the solid, liquid, or gaseous states, different methods of processing it naturally have to be applied. Waste is also characterized by its radioactivity and radiotoxicity. These parameters determine the conditions under which treatment and transport of the waste is possible (shielding thickness, etc.) and the degree of isolation from the environment that is required.

Depending on its level of radioactivity, waste is conventionally divided into low-, medium- and high-level waste, high-level waste being, in general, that resulting from the reprocessing of spent nuclear fuel. The characteristic features of such waste are its high specific radioactivity and considerable heat release.

After suitable treatment and packaging the waste is transported to storage facilities from which it can be retrieved, if necessary, for retreatment or to disposal sites from which

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it is not intended to retrieve the waste. Of course, no method can guarantee absolute isolation of the waste from the biosphere; what can be ensured is that in the most unfavourable circumstances the spread of the radioactive material from the place of storage or disposal will have an insignificant radiobiological effect, usually only a small fraction of the effect from the Earth's natural background radiation.

FRANCE

In France, nuclear physics has been studied since Becquerel's discovery of the phenomenon of radioactivity in 1896 and the subsequent discovery of radioactive elements and artificial radioactivity through the pioneering research of Pierre Curie, Marie Skladovska-Curie, and Irène and Frédéric Joliot-Curie. The French nuclear power porgramme is characterized by versatile planning and pragmatic implementation. A large number of nuclear power plants using light-water reactors and having an installed capacity of about 40 000 MW(e) are scheduled to be operating by 1985. Since France is building fast reactors and reprocessing nuclear fuel, the management of radioactive waste clearly covers a very wide spectrum in France — from low- to high-level waste.

The main sources of waste in France are the nuclear power plants and the nuclear fuel reprocessing plants. Let us take the modern nuclear power plant at Fessenheim as an example: it has an installed capacity of 900 MW(e) and uses a pressurized-water reactor, the principal reactor type that will be used for future nuclear power plants in France. Such a power plant can be expected to produce, after treatment and packaging, about 500 cubic metres of low- and medium-level waste per annum. This waste is treated by incorporation in concrete, in the case of liquid waste, and by compacting in the case of solid waste. For the future, the possiblity of incorporation in bitumen or in a matrix of heat-resistant plastic are under consideration. After conditioning, the solidified waste is transported to a central storage facility near the nuclear fuel reprocessing plant at La Hague.

Since 1969 about 80 000 cubic metres of waste have been stored at this facility. Storage of the waste on the nuclear power plant site for a protracted period is not permitted.

Reprocessing of nuclear fuel from pressurized-water reactors is to start at La Hague in 1980. The rated capacity — 1600 tonnes per year — will be reached in 1987. One tonne of spent uranium gives rise to up to 500 litres of high-level liquid waste (with activities of up to 10 000 Ci/l). Although high-level waste is being stored at present, this storage involves considerable capital investment for the construction of tanks and requires careful monitoring. For this reason, the problem of solidifying liquid high-level waste was given very close consideration in France at an early date (about 20 years ago). Of all the possible methods of solidifying such waste the most highly developed so far is vitrification. The principal advantages of this method are that it produces a solidified product with low leachability while considerably reducing the volume of waste, and that it can be developed to an industrial-scale process. After the process of vitrification with borosilicate glass had been developed on the PIVER device, therefore, the AVM plant (Atelier de Vitrification à Marcoule) was built at Marcoule for the vitrification of high-level waste. The plant was completed in February 1977, and, after a testing period with inactive solutions, operation with radioactive solutions began in June 1978. In the vitrification plant a continuous process of liquid waste calcination is used followed by melting of the calcinate together with glass-forming additives. The maximum output of the plant is 18 kg of glass per hour with a feed of 40 l of waste solution per hour. The molten glass is poured into metal containers 50 cm in diameter and 1 m long.

These containers are stored at the same facility, in special vaults with forced air cooling.

The AVM plant is designed to treat all the industrial wastes of the Marcoule nuclear centre, including previously accumulated waste.

The projected waste vitrification plant at La Hague, the AVH, is intended for the vitrification of waste produced during the reprocessing of light-water reactor fuel. The vitrified waste from this fuel will give off appreciably more heat, because of the higher fuel burn-up, and will require preliminary cooling in water basins for four years before it can be air-cooled. Since no decisions as to the method of final disposal of high-level waste have as yet been taken, the waste will be retrieved at a later date from the storage facilities for further transport to the disposal site.

The most promising disposal method is considered to be burial of the high-level waste in stable geological formations, in particular in granite rock, which is the most acceptable option under French conditions. However, the study of this possibility is still in the initial stage because it is thought that no urgent need for geological disposal will arise until sometime during the period 1985–90, depending on the rate at which nuclear power develops.

FEDERAL REPUBLIC OF GERMANY

As in France, research is conducted in the Federal Republic of Germany on all parts of the nuclear fuel cycle, from uranium enrichment and nuclear fuel reprocessing to the problems of final disposal of waste in deep geological formations. Particular features of the Federal Republic's programme are the development of a thorium fuel cycle and the practical implementation of disposal in geological formations.

Until recently, the principle adopted in the Federal Republic was to use a single site for the centralized disposal of waste from nuclear power plants and nuclear research centres and waste arising from the applications of radioisotopes in industry, medicine, etc. The old salt mines of Asse were used as such a disposal site. However, in autumn 1978 this site was closed because its licence had expired, and further waste will not be accepted until a new licence is issued.

The principal requirements that have been in force until recently for waste disposal are: (a) the waste must be homogeneously solidified in a material of low leachability; (b) the containers for transporting the waste must limit the dose rate to not more than 200 mrem/h on the container surface and 10 mrem/h at a distance of 1 m; (c) the maximum permissible activity must not exceed 25 Ci for a container holding waste incorporated in concrete.

After the Asse salt mines were closed it became necessary to arrange for temporary waste storage on the sites of the nuclear power plants; this storage period may be quite long – of the orders of several years.

Liquid radioactive wastes make up a large part of the waste produced in nuclear power plants, and this waste is treated using mechanical filtration, evaporation and ion exchange.

Solid radioactive waste is compacted in 200-litre steel drums.

Only one method of waste solidification is actually used at the nuclear power plants — incorporation in concrete. Other methods that might be used at power plant sites, such as incorporation in bitumen or solidification by means of plastics, are still in the development stage. Their introduction has been delayed largely by the fire hazard involved in the bituminization process and the comparatively high cost of plastic.

There is an interesting tendency in the practice of nuclear power plant waste treatment in the Federal Republic of Germany. Since there are no definitive regulations on waste disposal and on the properties of the treated waste sent for disposal, it is impossible, because of the high capital expenditure involved, to develop stationary systems for final waste treatment at the power plant sites. Intensive development work has therefore been done on mobile waste solidification systems which can be transported from one power plant to another. The process used by these systems is usually incorporation in concrete; only in one device is plastic used for the solidification of medium-level waste, such as ion-exchange resins.

There are plans to build a large nuclear fuel reprocessing facility, with a capacity of 1400 tonnes of fuel per year, at Gorleben, where there are favourable conditions for waste disposal in deep salt formations. Several processes for solidifying high-level waste are under development in the Federal Republic. One of them was developed in Karlsruhe for the solidification of high-level waste from the Purex process. The system uses a spray calciner with a ceramic crucible. The pilot device uses a fairly high input of 30 litres of waste solution per hour. Research on the vitrification process for inactive solutions continues.

In another nuclear centre, Julich, the FIPS process was developed; this is suitable for the vitrification of waste from the reprocessing not only of light-water reactor fuel, but also of high-temperature reactor fuel containing thorium. Tests with radioactive solutions have been carried out at this pilot facility. These two facilities are designed for the production of borosilicate glass.

A third process, PAMELA, is designed for the production of phosphate glass beads and their incorporation into a metal matrix. This process is intended for the vitrification of high-level waste stored at the fuel reprocessing facility at Mol (Belgium).

As already indicated, the concept of centralized waste disposal is accepted in the Federal Republic of Germany. The successful disposal of waste in the Asse salt mines for over ten years demonstrates the feasibility of such an approach. A further possibility for deep geological formations is to bury waste in iron ore mines. Research on the possibility of using such formations is being conducted here.

CZECHOSLOVAKIA

Czechoslovakia not only possesses a uranium-mining industry, but is also conducting extensive research in the fundamental and applied nuclear sciences, and is implementing a large-scale nuclear power programme. In the next 30 years a number of nuclear power plants with a total installed capacity of 45 000—50 000 MW(e) are to be built in Czechoslovakia.

Radioactive waste in Czechoslovakia can be divided into two categories: waste from the nuclear power facilities, and waste from research on radioisotopes in medicine and other branches of the national economy.

Waste management in Czechoslovakia is affected by the following factors: (a) the limited capacity of the environment for absorbing radioactive releases, due to the fact that Czechoslovakia is a small land-locked country with unfavourable geological and hydrological conditions and a high population density; (b) the lack of uninhabited places suitable for final disposal of waste; (c) the proposed use of all water resources as drinking water or for irrigation; (d) the strong public opposition to any radioactive contamination of the environment.

For this reason, all activities in the country connected with waste management are regulated by decrees of the Ministry of Public Health and supervised by a number of inspectorates: the Inspectorate of Health, the Inspectorate of Atmospheric Protection and the Inspectorate of Water Resources.

The waste from the uranium mining industry is treated mainly by ion exchange and coprecipitation methods to remove the uranium and radium. The tailings are covered with a layer of earth and planted with trees and greenery.

Liquid radioactive waste from the 150 MW(e) A-1 and the 440 MW(e) V-1 power plants is treated by filtration, ion exchange and evaporation. Current practice consists of temporary storage of concentrates, slag, bottoms and spent ion-exchange resins in tanks at the power plant sites.

For example, the V-1 power plants are to be equipped with five underground tanks, each having a capacity of 470 cubic metres, for the storage of liquid concentrates with a salt content of up to 400 g/l. These vessels should allow 5–7 years of uninterrupted operation of the power plant. Spent ion-exchange resins are to be stored for 15 years in two 400 cubic metre tanks.

This type of waste will be solidified either by vacuum cementation or by bituminization. The former process applies pressure and vacuum sequentially to a mixture of concrete and waste. The blocks obtained are very strong and have a low water content. Leaching from such solidified waste does not exceed 10^{-4} g/cm^2/day.

The bituminization process involves the use of a thin-film evaporator operating at a temperature of 150°C and into which the liquid waste and a bitumen emulsion are charged. Extensive research on the properties of the end product have shown that wastes with activities of up to 10 Ci/kg can be incorporated in bitumen.

Solid waste will be kept in concrete storage bins and later, after sorting and size reduction, it will be compacted in 200-litre metal drums. Burning of combustible waste will not be carried out until central waste treatment plants are available at the sites of nuclear power centres.

One such plant will be built in Jaslowské Bohunice.

Low-level radioactive waste from nuclear power plants will be disposed of in watertight concrete chambers buried in the ground at depths up to 5 metres. According to plans, the construction of two disposal areas will be started in 1980 – one in Moravia, the other in Slovakia.

Radioactive waste from nuclear research centres, medical institutions and industrial enterprises is buried in disused limestone mine shafts near Litoměřice. If necessary, this waste is solified at the Řež Nuclear Research Institute. There is also a disposal site for waste from the uranium mining industry in the old uranium mines at Jachymov.

HUNGARY

Radioisotopes are widely used in medicine, industry and agriculture in Hungary and the country has now embanked on a nuclear power programme. In developing systems for the treatment, storage and disposal of radioactive waste, the Hungarian authorities proceed on the assumption that it will consist only of low- and medium-level waste. This is because there are no plans for the reprocessing of spent nuclear fuel under the nuclear power development programme. The country's first nuclear power plant, PAKS, will go into operation in the early 1980s.

The liquid and solid radioactive wastes that will arise from the operation of Hungarian nuclear power plants are to be stored temporarily on the plant site, with concentrates, bottoms and spent ion-exchange resins being held in tanks, and solid waste in suitable containers. It is believed that the planned volume of the storage facilities will be sufficient to allow the power plants to operate for 5–10 years. A decision concerning final treatment and disposal of the PAKS waste has not yet been taken. The options being considered for the solidification of liquid waste include: incorporation in concrete, bituminization, and evaporation using an evaporator-crystallizer. Solid waste is to be compacted.

The evaporation-crystallization process is based on the use of hot air to evaporate the liquid waste. In this process the temperature of the liquid does not reach the boiling point, and a high condensate decontamination factor can be achieved as a result of reduced transport of radioactivity by entrained droplets. In model tests a decontamination factor of the order of 10^4–10^5 was achieved for various radioactive elements. The tank in which evaporation takes place is used subsequently as a container for burying the waste. The significant reduction in waste volume that is achieved appreciably reduces the cost of waste transport.

No site for final disposal of nuclear power plant waste has been selected so far.

At present Hungary has one central facility for the disposal of waste originating from the medical and industrial uses of radioisotopes. It is situated 50 km from Budapest. At this centre, the sludge and concentrates obtained after treatment of the liquid waste are solidified by incorporation in concrete in the containers of the storage facility. These containers are concrete vessels set in the ground at depths of up to 6 metres. Besides the treatment and disposal of liquid waste the centre is also used for the disposal of solid waste, liquid organic and biological waste and sealed radiation sources of high activity.

GERMAN DEMOCRATIC REPUBLIC

In the German Democratic Republic, as in Czechoslovakia, a nuclear power programme is being implemented systematically. At present, four nuclear power plants with a total installed capacity of 1390 MW(e) are in operation in the country.

The supervision of nuclear safety, including questions of radioactive waste management, is carried out by the Nuclear Safety and Radiation Protection Council, an independent Government body. The radioactive waste management programme is based on the following principle: temporary storage of waste at the place where it is produced (nuclear research centres and nuclear power plants) followed by disposal in deep geological formations (salt formations).

Under the Nuclear Safety and Radiation Protection Council there is a Waste Disposal Service, the functions of which include the transport, treatment and disposal in disused mines of low-level waste from nuclear research centres and medical and industrial enterprises.

A research programme is being conducted on the development and testing of container designs for the transport of radioactive waste and materials, including spent nuclear fuel.

CONCLUSION

The examples given above do not exhaust the subject of radioactive waste management but they do suggest a number of conclusions.

The treatment and storage of low- and medium-level waste does not at present raise any particular problems. This does not mean, of course, that the technology for treating such waste will not be developed further, but it does mean that the safe utilization of atomic energy is limited by our ability to treat and dispose of low- and medium-level wastes.

Nuclear power plants, as major producers of low- und medium-level waste, are equipped with systems by means of which waste can be treated in accordance with the applicable safety standards. So far the most widespread method has been incorporation of the waste in concrete. However, research continues on the possiblity of using such processes as bituminization, burning, evaporation-crystallization, etc. for the treatment of waste at the site of the nuclear power plant.

There is reason to expect that waste treatment which can considerably reduce the waste volume will come into ever wider use. This is true both in countries where long-term storage of waste at the nuclear power plant sites is practiced and in countries where the waste is transported to a central storage facility.

The reprocessing of spent nuclear fuel is directly related to the problem of high-level waste. The most promising method of treating high-level waste at present is considered to be vitrification. Final disposal of such waste will probably proceed in two stages: initial storage of the vitrified waste in engineered structures where it will be cooled for the necessary length of time, and then transfer of the waste to a final disposal site, e.g. in deep geological formations.

Data on the prospects of such a course of action are available even now. Experiments conducted at the Chalk River Nuclear Laboratories (Canada) on vitrified waste placed in the ground for 20 years have shown that the leaching of radioisotopes from the glass and the rate of their migration through the soil are very much lower than expected. A more impressive experiment performed by Nature in Gabon — the Oklo phenomenon — has also shown that practically all the radioactive elements which were formed during the operation of a natural reactor have remained at their place of formation. All this gives us the assurance that the problem of disposing of high-level waste will be successfully overcome.