UNITED KINGDOM RADIOACTIVE WASTE MANAGEMENT PROGRAM

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ABSTRACT

The organizations responsible for the regulation and implementation of radioactive waste management procedures in the UK are described. Classifications now in use for solid wastes are defined. The quantities of wastes expected to arise over the next 25 years are estimated and plans for their packaging, storage and disposal briefly outlined. The principles upon which the safety of repositories will be based are summarized and current Nirex concepts for repositories are described.

INTRODUCTION

Radioactive wastes are produced in the United Kingdom during operation of nuclear power stations, reprocessing of nuclear fuel, industrial and medical practices and from research laboratories. For over thirty years, the low-level solid wastes have been disposed of as they arose but high- and intermediate-level wastes have in general been stored in unpackaged form at nuclear sites. A new company, UK Nirex Ltd, is now in place to build and operate new underground repositories for packaged intermediate and low-level wastes. Solidified high-level wastes will be stored for at least fifty years at nuclear fuel reprocessing sites and will then be disposed of in a deep underground repository.

ORGANIZATIONAL RESPONSIBILITIES

The Secretary of State for the Environment in England, and the Secretaries of State for Scotland and Wales, have the responsibility, in conjunction with the Minister of Agriculture, Food and Fisheries, for civil radioactive waste management policy in the United Kingdom. They have professional scientists at their service within the Department of the Environment (DoE) in London. In addition, they are advised on the policy and its implementation by an independent Radioactive Waste Management Advisory Committee (RWMAC) currently chaired by Professor Paul T. Matthews, CBE., FRS., of Cambridge University. RWMAC members are drawn from universities, trades unions, local government and the nuclear industry. In recent years, the Department of the Environment has published a "strategy"[1] for radioactive waste management and a set of "principles for the protection of the human environment"[2]. In due course, the Secretary of State for the Environment will consider, and if satisfied, approve applications from the UK Nirex Ltd. for licenses to build and operate waste repositories in England.

The Nuclear Installations Inspectorate (NII), a branch of the Health and Safety Executive in the UK, will also consider, and if satisfied approve, any such application because the NII has responsibility for licensing of nuclear plant in respect of risks to workers and the public during the operational phase of the site.

UK Nirex Ltd., will also need a planning consent from local government, allowing construction of a repository at a specific site. In the case of radioactive waste repositories, the Government has said that a "special development order" will be laid before Parliament to allow UK Nirex Ltd., to conduct geological field measurements at potential sites without the need for planning consent from local government. Moreover, when the planning application is made in due course for construction at a specific site, the Secretary of State for the Environment will require that a Public Inquiry be held and that the outcome be put to him for a decision.

In the UK, the Department of Energy (D.En) is responsible for the development of the nuclear power strategy. Implementation is through the Electricity Generating Boards for power station design, construction and operation and through British Nuclear Fuels plc., for nuclear fuel reprocessing and management of high-level waste.

UK Nirex Ltd. is a private company with shares held by the Electricity Generating Boards (CEGB, SSEB), British Nuclear Fuels plc., and the United Kingdom Atomic Energy Authority (UKAEA). The D.En holds one special share to ensure government power to keep control of repository site ownership and use for as long as required. UK Nirex Ltd., will select sites, secure the necessary licenses and planning consents, and then build and operate repositories for intermediate and low-level solid wastes as a service to waste producers.

Research and development on radioactive waste technology is carried out by the United Kingdom Atomic Energy Authority (UKAEA) and by research laboratories in BNFL, CEGB, other government departments and private industry. The customers who pay for the research are the DoE for regulatory and policy purposes, UK Nirex Ltd., for operational purposes, and the waste producers, who have to package, store and transport wastes.

CLASSIFICATION OF SOLID RADIOACTIVE WASTES

For convenience in discussing solid radioactive wastes, the UKAEA and DoE proposed the following definitions a few years ago. They were endorsed by RWMAC in 1984[3] and are now in general use. It is important to remember, however, that the classification does not imply that each type is destined for a particular design of repository at a particular depth. The isotopes and their concentrations acceptable at any repository will be determined by DoE on a case by case basis.

(1) High-level Waste (HLW) is that in which the temperature may rise significantly as a result of the radioactivity, so that this has to be taken into account in the design of storage or disposal facilities.

(2) Low-level Waste (LLW) is material which is sufficiently radioactive to be subject to detailed control under the Radioactive Substances Act of 1960 but which does not exceed 4GBq/te alpha or 12 GBq/te beta-gamma activity.

(3) Intermediate-level Waste (ILW) is everything in between. A sub-division of ILW into short- and long-lived is often useful; short-lived ILW contains less than 4GBq/te of alpha or other isotopes of greater than 30 years half-life.

PRINCIPLES AND PLANS

Since the beginnings of the nuclear industry in the UK, some thirty-five years ago, solid radioactive wastes corresponding approximately to the current "low-level" classification have been disposed of as they arose in shallow burial trenches at a site owned and operated by British Nuclear Fuels (BNFL) at Drigg in Cumbria. Later another shallow burial site was brought into use by the UKAEA at Dounreay in Scotland. Consequently, there is today little accumulation of low-level waste on nuclear sites. An exception to this are some wastes which met the IAEA guidance on deep ocean disposal and were so disposed until 1982.

It is currently estimated that the quantities of all categories of waste likely to be produced by the year 2010 are approximately as given in Table I[4]. These are "unpackaged" volumes; packaging of the wastes into the solid forms suitable for long term storage and disposal will result in volume changes, generally within a factor or two. Larger volume reductions may result in the case of compaction of some types of LLW.

TABLE I

Radioactive Wastes - Volumes by 2010

Type	Volume(m^3)
High level	5,000
Intermediate level	120,000
Low Level	400,000

In the UK it is government policy to store vitrified HLW at the reprocessing site for at least fifty years; this incurs no significant risk and has the advantage of reducing the thermal power to around 1kW/te so that it may then be disposed of without raising local repository temperature above 100°C. It also allows ample time for site selection and investigation.

Meanwhile it is the function of UK Nirex Ltd. to provide a disposal service for ILW and LLW which, according to Government policy[5], are to be placed in underground repositories as soon as reasonably possible. BNFL will continue to operate the LLW disposal site at Drigg in Cumbria. Nirex plan to open a second LLW repository around 1991 and an ILW repository around 2000.

The principles governing final disposal of all categories are the same and derive from the DoE "disposal principles" document of 1984.

Essentially this requires that an upper limit of $10^{-6}/a$ be taken as the risk to any individual at any time of suffering fatal effects from the disposal of waste and moreover that this risk be as low as reasonably achievable below that limit.

In practice, the risk to man from radioactive waste after final disposal comes from two sources:

(1) external radiation dose or ingestion/ inhalation of radioactive material following inadvertent intrusion into a repository while its' contents are still significantly radioactive,

(2) the movement of contaminated groundwater from the repository to man's environment where it may be ingested either directly or via the good chain; in some cases the inhalation of ^{14}C and CO_2 or CH_4 must also be taken into consideration,

It follows that all the wastes will be disposed of:

(1) at a depth where intrusion risk, after the period of say 200 years during which planning controls may be assumed to prevent intrusion, is below the target limit; for this purpose we define risk as a product of hazard and probability of occurrence of the event,

(2) at a location where the groundwater flow is sufficiently slow, and the flow path sufficiently long, that natural processes of adsorption, delay and decay will, in conjunction with the packaging employed, reduce the risk from contaminated groundwater below the target limit.

Taking the Nirex task, which concerns ILW and LLW, application of the principles spelled out above leads us to seek two kinds of geological site:

(1) for LLW and short-lived ILW, which decay to very low levels within the period over which planning controls will prevent intrusion; a system of surface trenches of depth 3 - 20m will suffice. The preferred geology will be a clay or similar deposit in a region of low hydraulic gradient resulting in a very low groundwater flow rate. This will both ensure a long life for the waste containers and provide a very long time delay for any radioactive species which do manage to enter the groundwater. In practice, political and social factors are more difficult to satisfy than are these geological requirements. Thus a coastal site, for example, may be perceived to be safer, although in reality this is a doubtful assertion since the great majority of radioactive material will decay either inside the container or in its immediate vicinity.

(2) For long-lived ILW, which will outlive any reasonable planning controls on land use, sites at a depth of around 300m are being considered to eliminate the inadvertent intrusion risk. A low groundwater flow rate is again required, to give a very long life to the "near-field" chemical conditions which ensure low solubility of radionuclides in water. The groundwater is likely to have a flow path of tens of thousands of years before reaching the

biosphere, preferably in a region of non-potable water. These criteria could be met by various rock types-such as granite, clay or evaporites-at the appropriate depth and at present NIREX has not chosen any particular formation. Three types of site are being considered-under land, under the sea-bed with access by tunnel from the shore, and under the sea-bed with access from a drilling rig.

In January 1985 DoE asked NIREX to proceed first with selection and development of a site suitable for surface trenches containing LLW and short-lived ILW. The deep repository site, suitable for long-lived ILW is to follow later, allowing plenty of time for the necessary waste packaging developments to be completed. At the present time it seems probable that the trench repository will follow a timetable thus:

1986	-	Announcement of 3 or 4 sites worth of detailed examination.
1986/87	-	Field measurements to check geology and hyrogeology.
1988/89	-	Public Inquiry into a planning application at the best site.
1991	-	Commissioning of the repository.

The deep repository might follow about three years behind, but the much longer construction time in that case would mean a commissioning date beyond 2000.

SITE SELECTION - TRENCH REPOSITORY

The first task was to identify those parts of the UK in which to concentrate the search. It would be impracticable to scan the entire country when much of it is clearly unsuitable. NIREX, therefore, plotted on a map those factors seen as being most likely to influence the choice of sites.

Geology: While containment could be provided by engineered barriers alone, NIREX favors the multi-barrier concept. So with the advice of the British Geological Survey, the clay and marl outcrops across the country were identified (Fig. 1). These would be most suitable, by virture of their low permeability and good sorption characteristics, to enhance the engineered barriers by preventing the migration of radionuclides. A very low groundwater flux is seen as an essential feature of sites for both trench and deep repositories.

Population: The next factor was population. Of course a repository should be engineered to provide containment, with geology acting as a further barrier, so that the local population is not at risk irrespective of the number of people living in the vicinity. However, given a choice of sites equal in other respects it is better to go to an area of lower population. Certainly the public perceive this to be very important. Areas with a population density less than about 5 persons per hectare were, therefore, preferred.

Conservation: There are parts of the country which are designated as being of importance for conservation reasons. These include National Parks, sites of scientific interest (whether for plant or animal habitats, etc.) areas of natural beauty (such as forests or moorlands) and parts of the coastline. Again these were plotted so as to exclude them from our search, although in general, they do not tend to coincide with the clay belts.

Fig. 1. Clay Outcrops in the UK.

Strategic Accessibility: Finally we decided that preferred locations should minimize the transport requirements to get the waste from the sites producing it to the repository. This means reducing the number of miles travelled. So by looking at the geographical distribution of sites producing short-lived ILW and LLW and by examing the network of railways, motorways and major roads through the country it was possible to identify the most favorable areas on accessibility grounds.

When all these factors were combined, we obtained an area of search that could be surveyed for potential sites (Fig. 2). Sites outside this area were not to be excluded if they could be shown to meet these basic requirements, but at least there was an area in which to begin and concentrate the search.

Fig. 2. Preferred Areas for a Trench Repository.

The next stage was to survey this area for sites. Sites owned by the partners of NIREX and by Government departments were listed to see if they might be suitable. Also a few sites known from other sources were considered. In carrying out this search other factors which could not be mapped were also taken into account; for example, land area (a minimum of 50 hectares is required), current use of sites and surrounding land, mineral resources, agricultural quality and other planning issues.

A few hundred sites, identified in this way, then became candidate sites for further investigation.

Existing geological records were then looked at for each site. At the same time inquiries were made as to whether or not the sites might be made available by the owner. This is a very important point since NIREX does not have any powers of compulsory purchase.

During this, exercise sites began to drop out, being unsuitable or unavailable. Then more detailed data were sought and site visits made until only the most promising sites remained.

At this point, each site was assessed by a team of geologists, planning consultants and NIREX staff who gave scores to the sites under headings related to safety, planning and technical factors.

It was recognized that safety factors are more important than either planning or technical factors and so each heading was given a weighting to reflect this relative importance. This was so that a site scoring maximum marks for constructibility for example would score less than a site scoring maximum marks for a very long transit time for radionuclides to leave the site through the clay.

So by giving greatest weight to safety factors, the sites were ranked in order of preference and the few to be examined by detailed field studies were selected. At the present time NIREX is consulting DoE about the sites selected in that way.

SITE SELECTION - DEEP REPOSITORY FOR ILW

A similar approach to that described above will be made by NIREX in searching for a good site for the longer-lived ILW. However, in this case there is a basic choice to be made between underland and undersea options even before we begin to evaluate potential sites. At the present time, therefore, some conceptual engineering designs are being prepared to compare the merits of:

(1) a deep repository on land reached by shaft or tunnel,
(2) a repository under the sea reached by tunnel from the land,
(3) shafts drilled deep under coastal waters from a drilling rig.

When this basic choice has been made, NIREX will apply the same range of safety, technical and planning factors to select favorable areas and then actual candidate sites. We expect to reach that stage around 1989.

WASTE PACKAGING AND REPOSITORY DESIGN - TRENCH REPOSITORY

A useful principle in designing waste packages and their backfill is that the packaged product should be incapable of contaminating groundwater, which in the UK must be assumed to saturate the repository, to the extent that it is signficantly toxic. This principle, in conjunction with the good hydrogeological properties of the site, will provide the convincing double protection of "good near-field and good far-field". It also allows us to specify waste packaging in advance of knowing detailed site characteristics other than depth and water flow rate. Packaging to this standard is a matter of providing a sealed container with a corrosion life sufficient to reduce the soluble species (^{3}H ^{90}Sr and ^{137}Cs) to a low level, and a chemically buffered matrix or grout to ensure low solubility of the small quantities of long-lived species (actinides, ^{59}Ni, ^{14}C, etc) remaining when the container is no longer effective. In practice, much LLW can simply be compacted into 200 l steel drums; the more concentrated materials (short-lived ILW) will need to be cement-grouted inside 500 l steel or stainless steel drums.

The repository will take the form of a series of trenches, of depth between 10 and 20m, lined with concrete and covered with a few metres of impervious rolled clay. Permanent buildings on the site will occupy perhaps 15 hectares and, with trench construction, filling and closure taking about 3 hectares per year, a 160 hectare site would be expected to have an operational life of about 50 years. Thicker clay deposits would allow greater depth of trenches and consequently a smaller area of land usage. The LLW drums will be stacked in the trench and probably grouted into place with clay or concrete. The short-lived ILW drums will be grouted with concrete and a layer of concrete placed over the top. Several metres of rolled clay, perhaps including a 1 metre thick concrete intrusion shield, will be placed on top of the closed trench. Figure 3 gives an impression of trenches for LLW and for the more radioactive short-lived ILW.

It is anticipated that, following closure of the repository, a period of around 200 years would be controlled by planning constraints to ensure that no intrusion into the wastes takes place; in all other respects, the land could be returned to normal use. At longer times, the risks from inadertent intrusion, in the absence of planning constraints, must be below the regulatory limit so this factor is likely to determine the upper limit of specific activity of each long-lived radionuclide which may be disposed of in the trench repository. In the context of groundwater contamination, the site must be safe at all times without the need for human controls such as water sampling and treatment.

WASTE PACKAGING AND REPOSITORY DESIGN - DEEP REPOSITORY

The deep repository will differ from the trench in two important respects. First, it is at a depth and in a geology where the probability of inadvertent intrusion and risk from dust inhalation is extremely small; consequently this repository requires no upper limit on acceptable concentrations of long-lived radionuclides. Secondly, it has an even longer water transit time to the biosphere so the "far-field" is an even more effective barrier than in the case of the trench. The basic principle of waste packaging to restrict the contamination of "near-field" groundwater will, however, still be applied. Much progress has been made during the past year in understanding how the saturation solubilities of actinides can be kept to very low levels indeed by ensuring that an alkaline reducing chemistry is maintained in the "near-field" by incorporation of appropriate grouting and backfill material. Waste packages are likely to be 500 l steel drums, of corrosion life up to 500 years depending on the contents, containing a specially formulated cement

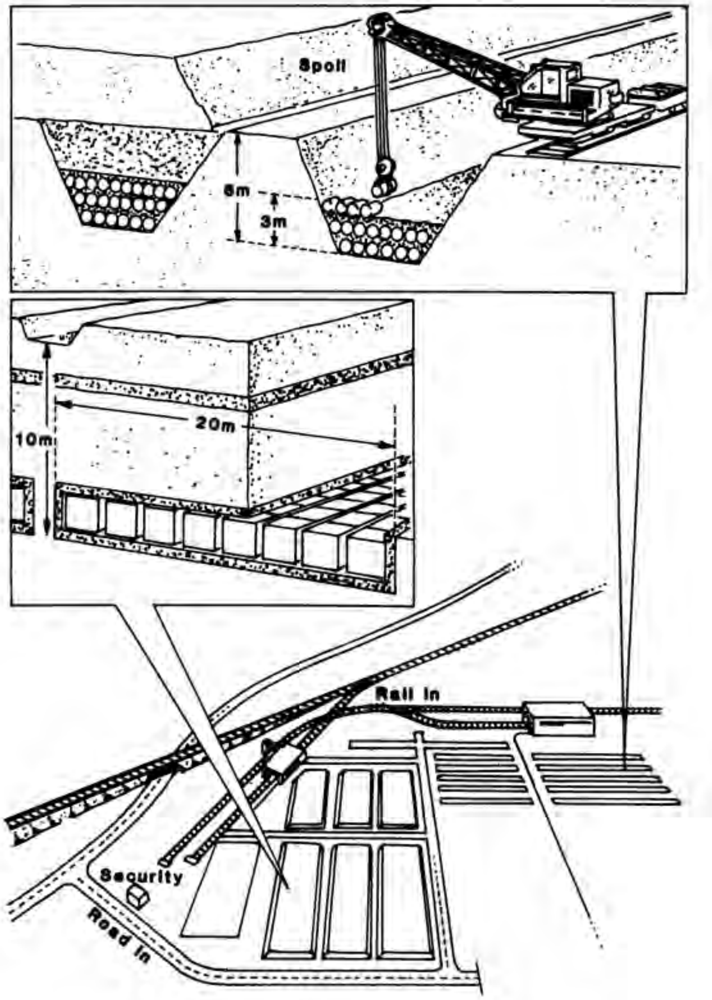

Fig. 3. Artists Impression of Trench Repositories for LLW and Short-Lived ILW.

matrix. The drums will be remotely placed in position in repository galleries and cemented into place.

It will be out intention to provide the first deep repository with at least a fifty year capacity. Surface facilities will occupy about 75 hectares and the capacity for waste will be at least 250,000m^3. After closure, no monitoring nor water sampling would be necessary although in practice it is likely that there would be interest in groundwater behavior, and consequently some sampling.

TRANSPORT OF WASTE

The LLW arising at the BNFL reprocessing plant at Sellafield will be safely disposed of at the Drigg site for the next 20-30 years. This means that the new NIREX trench site will be required to accept about 10,000m^3 per year of LLW and up to 2,000m^3 per year of short-lived ILW. These are small volumes, involving around two trains per week or 25 container lorries per week. At the deep repository, the annual movement of around 5,000m^3 of long-lived ILWs using returnable shielding, will require perhaps 40 lorries or an average of between 2 and 3 trains per week.

It is currently envisaged that drums will be transported in groups of four in reusable containers, shielded if necessary. Figures 4 and 5 give an artist's impression of such containers. The drums will be subjected to acceptance tests upon arrival at the repository site before being moved into position and grouted.

CONCLUSIONS

In the UK, the NIREX company is planning a trench repository for LLW and short-lived ILW to be commissioned about 1991. Site selection is based upon many factors involving technical, planning and social issues. It will be assured by a combination of waste conditioning factors and the choice of a low water-flow site of sufficient depth.

NIREX plans to commission a deep repository for long-lived ILW around the end of the century.

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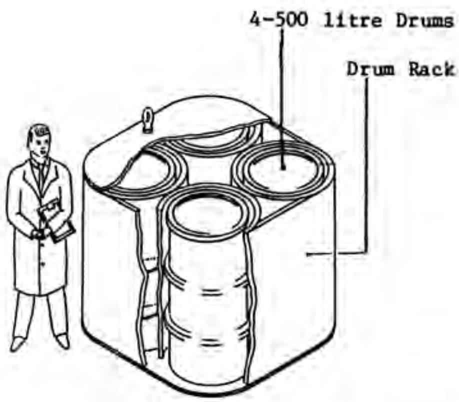

Fig. 4. Artist's Impression of Transport Container for Unshielded 500 l Drums.

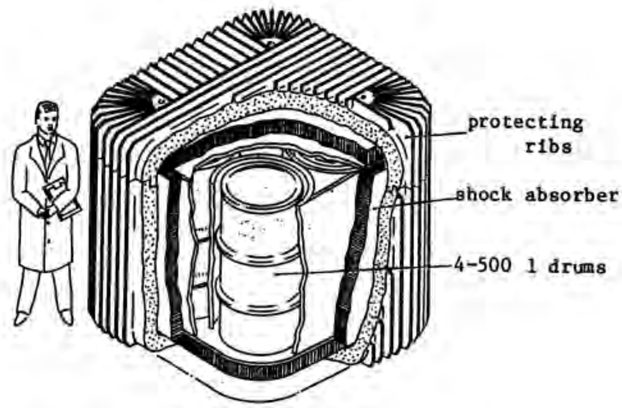

Fig. 5. Artist's Impression of Transport Container for Shielded 500 l Drums.

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