

Review of CoRWM Document No. 625

Sub seabed disposal

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Review of CoRWM Document No: 625

Sub Seabed Disposal

1 SUMMARY

Nirex has performed a review of the NNC Limited report “Sub Seabed Disposal” – CoRWM Document No: 625 Version 5 Issue 2 dated August 2004 [1]. The review is presented against the criteria specified in the CoRWM, *Peer Review Task Specification* [2]. A copy of CoRWM Document No: 625 is included as an Appendix. The CoRWM Peer Review Task Specification requires the report to be reviewed against the following criteria:

- Quality of the work;
- Its transparency,
- Its balance;
- Its auditability;
- Its conclusions;
- Its fitness for purpose;
- Whether it meets the requirements of the work package;
- Whether there are areas of further work, which would be of benefit to CoRWM in fulfilling its key objectives in the area covered by the work package.

The above criteria have been used to guide the review reported herein. Review comments relevant to the specific report sections are given below.

2 OBSERVATIONS AND RECOMMENDATIONS

2.1 Use of Appropriate Terminology

The report needs to make clear and describe upfront the different disposal options that have historically been referred to as ‘sub seabed’ namely:

- i) A repository beneath the seabed:
 - accessed from land, or
 - accessed from an offshore structure;
- ii) Burial of radioactive waste in deep ocean sediments, through the use of:
 - penetrators, or
 - drilling emplacement.

There are key differences in these sub seabed disposal options, e.g. ease of waste retrieval and legal status. This should be made clear in the report.

The report needs to clarify the sub seabed disposal option that it is actually considering – the intended definition of “sub seabed disposal” is currently unclear. Is it disposal from boats to deep ocean basins (water depths of order 4km), with the intent of the waste (which would be packaged in suitably hydrodynamic packages) burying itself at a depth of 10’s of metres in abyssal deposits (oozes) found at the seabed in such environments?

If this is the intended definition, clarification that neither disposal from boats to shallower waters of continental shelf areas nor disposal from boats of packages intended to rest on the seabed itself is being considered would be beneficial.

The report is somewhat confusing in that mention is also made of a Swedish repository facility that is located beneath the seabed, but is accessed from land (the Forsmark facility). From attendance at a CoRWM plenary meeting (Manchester, 15th-16th February 2005), this would actually be an example of a deep geological concept, and therefore should not be mentioned in the current report apart from as a clarifier for the definition of 'sub seabed'.

2.2 Current Status of Technology

The report notes in the Conclusions section that "*the techniques used to bury and retrieve the radioactive waste packages have been used for decades in the oil industry*". This statement is not robust and is very surprising. Whilst offshore drilling techniques are well-developed in the hydrocarbon exploration industry, their application is in water depths much shallower than those of deep ocean basins (noting that abyssal deposits do not hold significant hydrocarbon potential). Furthermore, such oil industry technology is not concerned with down-hole package emplacement, as would be necessary for packaged radioactive waste. It is therefore unclear whether such oil industry experience is of meaningful relevance to sub seabed radioactive waste disposal.

The report quotes references which suggest that wastes emplaced by penetrators or by drilling technology would be retrievable. It may be possible to recover wastes after emplacement, but the operations needed to retrieve wastes from what could be water depths of several thousand metres would not be easy and certainly could not be contemplated on a routine basis. These methods of waste emplacement should be considered as irretrievable. This view is supported by a joint report from The Royal Society and The Royal Academy of Engineering [3], which notes "*disposal to deep seabed sediments*" as being "*a method of irretrievable sea disposal*".

Note that, for repositories constructed beneath the seabed and accessed from land, the ability to retrieve waste is comparable to a repository located on land.

It is stated that "*the radioactive waste is proposed to be packaged in corrosion-resistant containers or glass*". This statement is misleading as radioactive wastes (specifically HLW) are immobilised in glass, not packaged in glass. It is suggested that "*or glass*" is deleted from this statement.

2.3 NIMBY Issues

The report notes "*Disposing radioactive waste in the sub seabed avoids NIMBY*" (Not In My Back Yard), "*as the radioactive waste is disposed of away from human activities*". However, the sea is often viewed as a global resource, and although it may not be near to centres of populations it is something that people protect and believe should not be polluted. Therefore, they care deeply about it, even if they do not live near it. These concerns have been reflected in international laws which limit or ban discharges to the marine environment. It would be helpful if the report reflected these issues.

2.4 Geographical Requirements

Given the above, a key oversight of the report is that the geographical extent of suitable areas for sub seabed disposal (to abyssal deposits) is not clarified. The report needs to address whether the option is available in UK territorial waters, or is an international option only.

2.5 Geological Suitability

The report should provide a more thorough explanation of what would constitute a suitable abyssal deposit, in terms, for example, of its geology, hydrogeology, thickness, lateral extent, rheology and morphology. Given the water depths involved, it is unclear how the suitability of a site could be proved. The report could better emphasise the 'untried, untested' nature of this option – although it might be conceptually very promising

(which can be equated with providing 'good' long term safety with respect to radioactive waste management), how could this be demonstrated in practice? The report could also note key uncertainties affecting this option, for example, the hydrogeology of deep ocean sediments. The report should be careful not to promulgate the idea that safety can be assumed simply on the basis of placing radioactive waste in a very inaccessible environment such as typified by abyssal deposits.

2.6 Cost

The cost comparison (Section 3.8) is poor – it compares an evaluation of the feasibility of sub seabed disposal with land-based site characterisation investigations. It does not appear therefore that the comparison is made on a like-for-like basis with a land-based long term management concept. The report clearly states the status of the understanding of the OECD Seabed Working Group on the economic viability of sub seabed disposal. It needs to be clarified whether this statement applies to all options of sub seabed disposal. The report also presents a comparison of the cost of site evaluation for a sub seabed disposal facility with that of a land-based facility: it is likely that adequate characterisation of the geology and hydrogeology of abyssal deposits at any site of interest would be extremely costly, given the water depth involved. There are also a number of omissions in the discussion of cost issues. Additional to site characterisation, research and development and implementation costs, the cost of, for example, transport by sea would also need to be considered for sub seabed disposal options.

2.7 Legality Issues

The legal status of the sub seabed disposal options needs to be made clear. We would suggest that the report uses the term 'Legality Issues' to discuss this topic rather than 'Regulatory Acceptance'. The report should also cross reference CoRWM Document No: 927 *Sub Seabed Disposal Of Radioactive Waste – Legal Considerations*.

2.8 Key Uncertainties / Disputed Knowledge

The report summarises, in the Conclusion section, areas of key uncertainties and disputed knowledge. It is stated that further research is needed in a range of areas, but it is not explained why. This research would only be needed if it was planned to implement this waste management option; it is not needed in order for CoRWM to make an informed decision on whether this option should be short-listed.

3 CONCLUSIONS

We believe that there is sufficient information available in previously published reports (e.g. by OECD) to enable CoRWM to take an early view on whether or not it foresees the sub seabed disposal option being taken forward. However, the report currently does not clearly describe the practicability of implementing this option for all types of waste.

The key factor that should be considered when deliberating the practicality of implementing sub seabed disposal is its legal status. Whilst sub seabed disposal in a repository accessed from land is legal, sub seabed disposal by emplacement of waste from boats is banned by international treaties. A robust analysis of this issue is currently missing from the report. The report should therefore clearly cross reference CoRWM Document No: 927 *Sub Seabed Disposal Of Radioactive Waste – Legal Considerations*.

The report (CoRWM Document No: 625) would be improved if it took advantage of information presented in [3, 4, 5]. Key points relevant to the report (CoRWM Document No: 625) are:

- The descriptions of sub seabed disposal options are unclear, and need to be clarified;

- The issues that apply to different options of sub seabed disposal need to be carefully differentiated for each option;
- We suggest that the report summarises the status of understanding in this area from published reports, and avoids further analysis that is misleading, e.g. cost comparisons that are not on a like-for-like basis.

4 REFERENCES

- 1 CoRWM, *Sub Seabed Disposal*, CoRWM Document No:625, 2004.
- 2 CoRWM, *Peer Review Task Specification – Task 061*, TS061 / Peer Review Task Specification / v2.
- 3 *Nuclear Energy – the Future Climate*, Joint Report by The Royal Academy of Engineers & The Royal Society, ISBN 0-85403-526-5, 1999.
- 4 *Feasibility of Disposal of High-Level Radioactive Waste into the Seabed, Volume 1, Overview of Research and Conclusions*. NEA/OECD Report, 1988.
- 5 *Assessment of Best Practicable Environmental Options (BPEOs) for Management of Low- and Intermediate-Level Solid Radioactive Wastes*. Radioactive Waste (Professional) Division of the Department of the Environment, 1986.

APPENDIX

A Report by NNC Limited: August 2004

Commissioned by:

**Committee on Radioactive Waste Management
(CoRWM)**

SUB SEABED DISPOSAL

CoRWM Document No: 625

Sub Seabed Disposal

Prepared by: (Name)/Company	Yung Cheung / NNC Limited		
Checked by: (Name)/Company	S Cripps / NNC Limited		
Approved by: (Name)/Company	Sam Usher / NNC Limited		
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Executive Summary

This report provides a description of one of the options considered for the disposal of radioactive waste in the UK, disposal to the sub seabed. This report reviews the disposal to the sub seabed option and provides information on the current status, past applications, operational and long-term safety, physical protection, environmental protection, geographical requirements and cost. The purpose of this report is to provide sufficiently robust information for CoRWM to make an informed decision on the viability of this option for further consideration.

For this option, radioactive packages are transported to the sea by using offshore techniques that have been used in the oil industry. There are two variations of this technique, penetrator and drilling placement method. All countries have discarded this option, as the London Dumping Convention considers disposal to the seabed as sea dumping.

There is also an alternative to this option, which is not prohibited by the London Dumping Convention, where radioactive packages are transported to the seabed by land-based tunnels. This alternative has been implemented in Sweden.

This option has been suggested for LLW, ILW and HLW.

From 1975 to 1986, the Seabed Working Group (SWG), an internationally funded research program, has commissioned the majority of the research carried out to date on the environmental aspects of sub seabed disposal of radioactive waste. The findings from these studies and the relevant conclusions of the UK Royal Society Energy Advisory Group are summarized as follows:

- The stable environment of abyssal clay covers 20% of the earth [2]
- Sub seabed environment offers favourable conditions, such as slow water flow, and low abundance of marine species, in comparison to geological land formations [7]
- Insignificant risk to the deep sea environment and to individual members of the public [2]
- Low risk of terrorist, rebels or criminals retrieving radioactive waste [7]
- Areas of geological perturbations and areas of human activities needs to be avoided [1]
- SWG concluded that HLW and spent fuel could be disposed of economically using this option [7].

There are uncertainties associated with this option, these include:

- If the radioactive waste reach the seabed surface, will the soluble substances be diluted to natural background levels, and at what rate
- The effect of nuclear heat on the clay

- If accidents, such as sinking ships and loss of canister, occur in the process of seabed burial and how will the waste package be recovered
- Study on the transportation of radioactive waste on high seas is required and procedures need to be developed for the recovery of a lost cargo, if a ship carrying radioactive waste sinks or accidentally drops its load [2].
- Radiological consequence to the deep sea environment if radioactive elements are released.

1 Introduction

Radioactive wastes have been accumulated by the nuclear industry for decades. At present, no long-term strategy exists for the management of high-level waste (HLW), intermediate level waste (ILW) and some low level waste (LLW) that is unsuitable for disposal at Drigg.

A new committee on Radioactive Waste Management “CoRWM” was set up by the Government in November 2003 to review the options for managing solid radioactive waste in the UK and to recommend to the government the option or a combination of options that can provide a long-term solution protecting people and the environment.

This report reviews the disposal to the sub seabed option and provides information on the current status, application to UK wastes, operational and long-term safety, physical protection, environmental protection, geographical requirements, and cost.

2 Objective of Study

The purpose of this work package is to provide a clear understanding of the practicality of implementing sub seabed disposal for various types of UK waste so that CoRWM can take an early view on whether or not it foresees this option being taken for further assessment.

3 Review Findings

3.1 Background

In 1973, Charles Hollister suggested the concept of sub seabed disposal during a meeting at the Sandia National Laboratories, New Mexico. Sandia National Laboratories then provided the funding for sub seabed research. This project developed into an OECD (Organisation for Economic Co-operation and Development) project known as the SWG (Seabed Working Group). For bureaucratic reasons, in 1986 the US Department of Energy ceased the funding for the research on sub seabed disposal [1]. A private company, ENSEC Ltd, had also proposed sub seabed disposal for long-lived intermediate level waste [2].

In 1990 a report from the US National Academy of Sciences suggested an alternative to geological repositories, including recommending that disposal to the sub seabed should be explored further [3].

Despite this concept being technically feasible and safe, the legal basis on the method and political implications were far from clear [2]. This option had been considered in the past by a number of countries in the European Union and the applicant countries but was discarded. This was mainly due to International conventions prohibiting the disposal of radioactive waste to the sea and lack of public acceptance, economic considerations and technical limitations [4].

Whilst true sub seabed disposal (from the surface of the sea) has not been adopted by any country, a deep disposal option has been adopted in Sweden, involving the extension of the repository under the seabed [5]

3.2 Current Status of Technology

For this disposal method, the radioactive waste is proposed to be packaged in corrosion-resistant containers or glass. Disposal of long-lived radioactive waste in deep ocean sediments is conceivable in isolated ocean regions under water at least 4,000 m deep [3]. Burial of radioactive waste in deep ocean sediments can be achieved by two different methods, penetrator or drilling placement [6] [7]. The packaged waste can be dropped from a ship or a platform, which would have a drilling facility for the drilling placement method.

1. The penetrator method is where radioactive waste is proposed to be placed at a distance of 50 m into the abyssal clay. The penetrator, which weighs a few tons, would be dropped to the ocean floor, gaining momentum as it approaches the seabed, thus giving it the energy to embed itself up to 50 m into the sediment. In 1986, experiments undertaken at water depth of 250 m in the Mediterranean Sea demonstrates that the entry paths generated by the penetrators can be closed and filled with remoulded sediments of a similar density as the surrounding sediments [6].
2. For the drilling placements method, the radioactive waste is proposed to be buried by using drilling equipment based on techniques from the oil industry that has been in use in the deep sea for about 30 years. For this method, stacks of packaged radioactive waste are placed in holes drilled to a depth of 800 m below the seabed. The uppermost container is placed at about 300 m below the seabed. In the 1980's, the UK investigated the possibility of disposing LLW and ILW beneath the seabed in offshore boreholes drilled in stable areas. The proposed disposal method envisages holes drilled to depths of 2000-3000 m. These holes are then filled with about 900 cubic metres of radioactive waste. A concrete plug of about 300 m long would close off each hole [6].

Figure 1 illustrates the two different techniques for the burial of radioactive waste in the sub seabed [6].

SWG concluded that sub seabed disposal appears to be technically feasible and economically viable for the long-term storage of HLW [5].

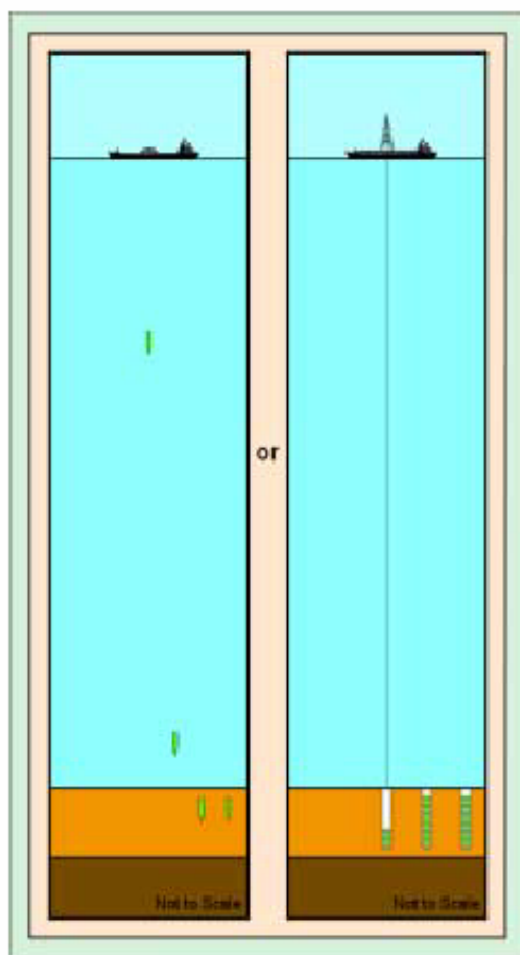


Figure 1: Diagram illustrating both types of method for sub seabed disposal, the left hand side shows the penetrator method and on the right hand side shows the drilling placements method

This option allows the radioactive waste to be retrieved. For the drilling placement method, the radioactive waste packages can be retrieved by using the same type of drilling equipment as the ones used for emplacement. For the penetrator method, the locations of the radioactive waste packages are recorded. For this method, the radioactive waste packages can be retrieved by using recovery equipment within a metre of the radioactive waste packages [5] [8].

Another variation of sub seabed disposal is where radioactive waste is transported to a repository in the seabed by land-based tunnels. This has been implemented in Sweden [5].

The United Nation's Convention on the Law of the Sea states that a coastal state is granted sovereign rights to utilise all resources in water and under the seabed within its EEZ. This zone can extend from the coast line to about 370 km offshore. It is also proposed that the waste packages would be transported through a submarine tunnel connecting land with the sub seabed repository. This would result with a low probability of causing sea pollution during disposal operation. This method is also a variation of geological disposal [8].

Disposing radioactive waste in the sub seabed avoids NIMBY, as the radioactive waste is disposed of away from human activities [5].

3.3 Application to UK Waste

This option has been suggested for LLW, ILW and HLW.

SWG have investigated seabed disposal of SNF (Spent Nuclear Fuel) and HLW (high level waste) including barrier materials, canister and any additional container. The barrier material has to be strong, tough, creep and corrosion resistant. The waste canisters need to be minimised to the same size as the waste packages, which can be achieved by incorporating pressure resistant and corrosion resistant construction [9].

Seabed disposal involves placing waste packages into the clay layer, which covers most of the ocean's seabed. The clay layer has potentially excellent waste-isolation properties.

This option has been discarded by many countries due to international conventions prohibiting the disposal of radioactive waste to the sea, following lack of public acceptance, economic considerations and technical limitations [4]. The London Dumping Convention classifies the disposal of radioactive material below the seabed as 'ocean dumping'. This option is prohibited by International Law

3.4 Safety – Operational and Long Term

From 1975 to 1986 SWG has commissioned several studies into the environmental aspects of the long-term migration of radioactivity from waste disposed under the seabed [3]. The research has been carried out on the sediments collected from the seabed in the Atlantic and Pacific Oceans. The main conclusions of their studies are summarised below.

The slow water flow property of the sub seabed provides a suitable environment for the radioactive waste, as this retards the movement of the radioactive elements, when radioactive elements escape from the package or once the package disintegrates. The contained radioactive elements are subjected to the same processes of dilution, dispersion. Laboratory experiments were conducted to investigate the movement of the radioactive substances in the abyssal clay. The analysis provides evidence of a stable environment for the radioactive waste. The abyssal clay would offer an extra containment to the radioactive material once the waste package has failed through corrosion. This option offers isolation from man biosphere for a period of time that any possible subsequent release of radioactive elements from the waste repository will not result in undue radiation exposure [3].

Sediments collected from the seabed showed an uninterrupted history of geological tranquillity over the past 50 to 100 millions years [8] [3]. Experiments have demonstrated the clays have the property of holding on to several radioactive elements, including plutonium [8]. The studies demonstrate that the rate of migration of these radioactive elements over hundreds of thousands of years would be of the order of a few metres [8]. This suggests that the radioactivity of the package can be reduced to the

background radiation levels or to acceptable limits in accordance with the IAEA [3].

Further research needs to be carried out to investigate the following [8]:

- If the radioactive waste reach the seabed surface, will the soluble substances be diluted to natural background levels, and at what rate
- The effect of nuclear heat on the clay
- If accidents, such as sinking ships and loss of canister, occur in the process of seabed burial and how will the waste package be recovered

3.5 Physical Protection

This option offers good physical protection, as the radioactive waste is buried in the seabed.

A study on the transportation of radioactive waste on high seas is required and procedures needs to be developed for the recovery of a lost cargo, if a ship carrying radioactive waste sinks or accidentally drops its load [3].

3.6 Environmental Protection

If the radioactive elements do migrate out of the seabed, the consequence to the deep sea environment has to be investigated. The release of radioactivity from the radioactive waste packages can cause radiological contamination to the aquatic ecosystem, as illustrated in Figure 2 [2].

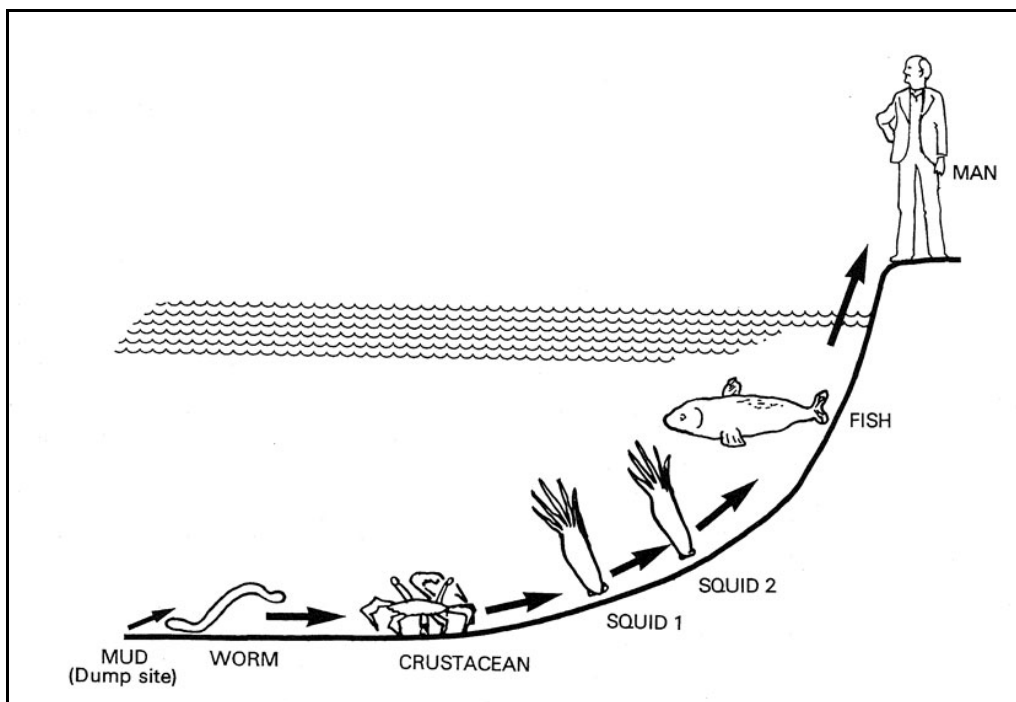


Figure 2: Aquatic food chain

Research shows that mobile, multicellular life forms inhabit at the top metre of the abyssal clay. Below this distance, it appears to have no organism present that is capable of transporting the radioactive substances into ocean [3]. However, further research is required to assess the radiological consequence if radioactive elements are released into the ocean.

3.7 Geographical Requirements

The abyssal clay covers 20% of the earth. Sites in the ocean are chosen on the basis of the characteristics of the seabed sediments. They are free from erosion and are located away from the edges of tectonic plates where seismic or volcanic movements can disrupt a repository and expose the waste packages [3].

Properties of potential disposal sites include thick, weak, and relatively homogeneous sediments of very fine particles. The objective of proper emplacement is to implant waste packages beneath the sea floor in such a way that the barrier properties of sediments can isolate the radioactive elements for thousands of years.

3.8 Cost

The overall cost to evaluate the feasibility of sub seabed disposal can be up to \$250 million [3] [10], which can be considered as a large sum of money for oceanographic research. However, this is modest in comparison to the cost for a land-based repository, so far about \$2 billion has been spent on site evaluation at Yucca Mountain [3] [5].

SWG concluded that HLW and spent fuel could be disposed of economically using this option [5].

4 Conclusion

Scope

- The purpose of this report is to provide sufficiently robust information for CoRWM to make an informed decision on the viability of this option for further consideration.

Applicability

- This option has been suggested for LLW, ILW, and HLW

Cost

- SWG concluded that HLW and spent fuel could be disposed of economically using this option.

Risks

- Abyssal clay offers extra containment to the radioactive material once the waste package has disintegrated.
- The abyssal clay holds on to several radioactive elements, including plutonium

- Abyssal clay showed an uninterrupted history of geological tranquility over the past 50 to 100 million years
- This options offers good security against terrorists once the radioactive waste material is buried in the seabed

Practicability

- The radioactive packages can be transported to the sea bed by penetrators or by using drilling placement method
- Another alternative of this option is transporting the radioactive packages to the seabed by land-based tunnels.
- This option allows the radioactive packages to be retrieved after burial in the seabed
- The techniques used to bury and retrieve the radioactive packages have been used for decades in the oil industry
- The abyssal clay covers 20% of the earth
- SWG concluded that this option is technically feasible and economically viable for the long-term storage of HLW and spent fuel

Regulatory Acceptance

- The London Dumping Convention classifies the disposal of radioactive material below the seabed as 'ocean dumping'. This option is prohibited by International Law
- This option is not prohibited by International Law if the radioactive package is transported to the seabed by land-based tunnels

Overseas experience

- This option has been discarded by many countries due to the London Dumping Convention prohibiting the disposal of radioactive waste to the sea
- Sweden has implemented the variation of this option by transporting the radioactive packages to the seabed by land-based tunnels

Key uncertainties/ Disputed knowledge

- Further research needs to be carried out to investigate the following:
 - if the radioactive waste reaches the seabed surface, will the soluble substances be diluted to natural background levels, and at what rate
 - the effect of nuclear heat on the clay

- accidents, such as sinking ships and loss of canisters, in the process of seabed burial and how will the waste package be recovered
- A study on the transportation of radioactive waste on high seas is required and procedures need to be developed for the recovery of a lost cargo, if a ship carrying radioactive waste sinks or accidentally drops its load [2].

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10. Disposal of Radioactive Waste under the Seabed, E Ash, Royal Society Energy Advisory Group, Feb 2004
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APPENDIX 1: London Dumping Convention

In 1972, the London Dumping Convention [11] was formed as a result of an Inter-Government Conference on the Convention of the Dumping of Wastes at Sea. The purpose of this Convention was to protect the marine environment from unregulated dumped waste. The Convention entered into force in August 1975. In 1997, 77 countries were contracting parties to the London Convention.

The London Convention regulates the disposal of wastes at sea by dumping from vessels, aircrafts or platforms or by incineration. It also regulates the deliberate disposal at sea of the vessels, aircraft and platforms themselves. Other materials can be only dumped subject to the issue of an official permit, which must be granted by the appropriate national authority.

The London Convention Protocol is currently undergoing a process of ratification. The changes will include a total ban on incineration at sea, and measures to encourage technical cooperation between countries in order to prevent or reduce pollution caused by dumping. Also, the Protocol will include a general obligation for contracting parties to apply a precautionary approach to sea dumping wastes, and the polluter pays principle.

Glossary

CoRWM – Committee on Radioactive Waste Management

EEZ – Exclusive Economic Zone

HLW – High Level Waste

IAEA – International Atomic Energy Authority

ICRP – International Commission on Radiological Protection

ILW – Intermediate Level Waste

LLW – Low Level Waste

NIMBY – Not In My Back Yard

OECD – Organisation for Economic Co-operation and Development

SNF – Spent Nuclear Fuel

SWG – Seabed Working Group



United Kingdom Nirex Limited
Curie Avenue
Harwell, Didcot
Oxfordshire
OX11 0RH

t +44 (0)1235 825500
f +44 (0)1235 831239
e info@nirex.co.uk
w www.nirex.co.uk