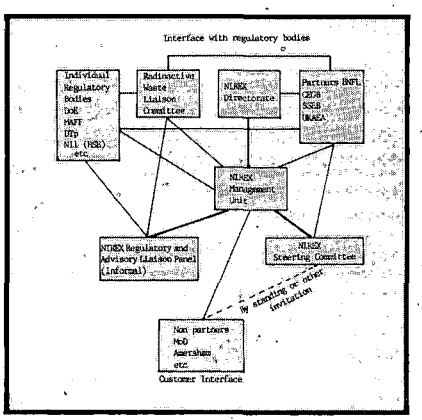
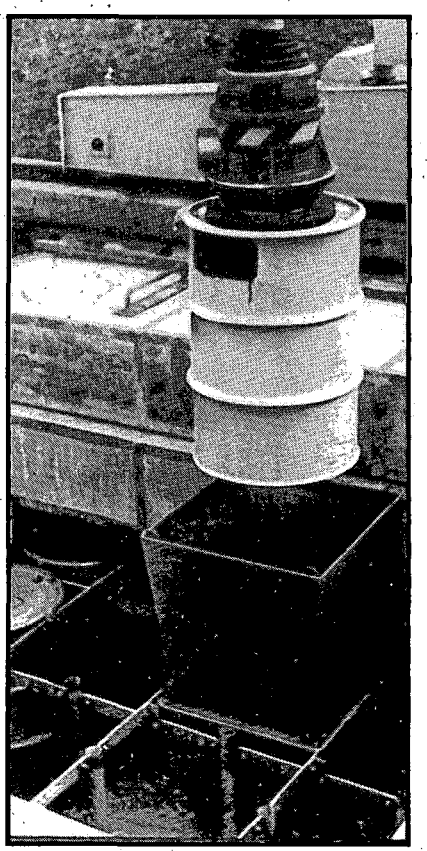
UEG

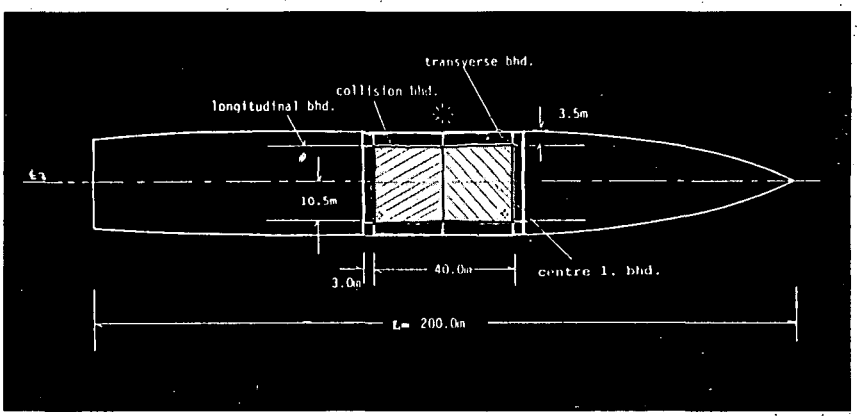
UEG PUBLICATION UR29

# Disposal of nuclear waste at sea —

## a review of development and industrial opportunities





UEG Publication UR29 1986

# DISPOSAL OF NUCLEAR WASTE AT SEA -

# A REVIEW OF DEVELOPMENT AND INDUSTRIAL OPPORTUNITITES

Daniel A Spagni, Hugh M Cameron and Glyn J Ford

---



Price £40 (£8 to UEG Members)

ISBN 0 86017 244 9

ISSN 0268 2303

UEG 6 Storey's Gate Westminster London SW1P 3AU Telephone 01-222 8891

THE RESEARCH AND INFORMATION GROUP FOR THE UNDERWATER AND OFFSHORE ENGINEERING INDUSTRIES
A PART OF CIRIA – THE CONSTRUCTION INDUSTRY RESEARCH AND INFORMATION ASSOCIATION

FOREWORD

This report has been prepared from a study on the subject produced under UEG Project 68, 'Users Group by the PREST Marine Resources Project at the University of Manchester'. The project is being undertaken by members of PREST (Programme of Policy Research in Engineering, Science and Technology) in the Department of Science and Technology Policy at the University of Manchester. It is funded by the Science and Engineering Research Council Marine Technology Directorate (68%), the Department of Trade and Industry (16%) and currently by six industrial organisations (16%), and is managed by UEG.

The project entails the production, over a period of 2 years, of twelve reports outlining the basic technology involved, current R & D, and the industrial opportunities of markets other than oil and gas. The subjects covered in the first year were:

Ocean thermal energy conversion
Disposal of nuclear waste at sea
Artificial islands
Japan and new marine technology
Phosphorite nodules
Satellite remote sensing of the marine environment

The reports are being considered in draft by a project steering group, and published with their support and consent. In the first year of the project the group comprised:

| | |
|---|---|
| UEG | R K Venables (Chairman) |
| British Shipbuilders | C Phipps-Jones |
| John Brown Subsea Ltd | D Smith |
| Sir William Halcrow & Partners | J Simpson |
| Imperial Chemical Industries plc | C N Beard |
| Sir Robert McAlpine & Sons Ltd | D Kerr |
| SERC Marine Technology Directorate | Dr S Mellows |
| Department of Trade and Industry | Dr P L Smith |
| Wimpey Laboratories Ltd | K Kershaw |
| PREST Marine Resources Project Team | Professor M Gibbons |
| | H Cameron |
| | Dr L Georghiou |
| | J Simnett |
| | D Spagni |
| | Dr A Toms |

The report was prepared for the Users Group in the latter part of 1983 and has received only minor updating for this open publication.

CONTENTS


| | | Page |
|---|---|---|
| | FOREWORD | 2 |
| | LIST OF TABLES | 5 |
| | LIST OF FIGURES | 6 |
| | LIST OF ABBREVIATIONS | 8 |
| 1 | INTRODUCTION | 10 |
| 2 | THE NUCLEAR FUEL CYCLE AND THE GENERATION OF RADIOACTIVE WASTE | 11 |
| | 2.1 Radioactivity | 11 |
| | 2.2 Radioactive waste : definitions | 13 |
| | 2.3 Radioactive waste : sources | 14 |
| | 2.4 Radioactive waste : disposal routes | 21 |
| 3 | RADIOACTIVE WASTE MANAGEMENT IN THE UNITED KINGDOM | 26 |
| | 3.1 UK waste inventory | 26 |
| | 3.2 UK radioactive management policy | 26 |
| | 3.3 UK radioactive waste strategy | 33 |
| 4 | SEA DUMPING OF SOLID LOW LEVEL RADIOACTIVE WASTE: PAST AND PRESENT PRACTICES | 39 |
| | 4.1 United States | 39 |
| | 4.2 Japan | 40 |
| | 4.3 South Korea | 40 |
| | 4.4 United Kingdom | 40 |
| | 4.5 OECD/NEA | 40 |
| | 4.6 Dumping in practice | 44 |
| 5 | SEABED DISPOSAL OF HIGH LEVEL RADIOACTIVE WASTE | 49 |
| | 5.1 The Multiple Barrier concept | 49 |
| | 5.2 Seabed disposal options | 49 |
| | 5.3 Investigation and selection of seabed disposal sites | 54 |
| | 5.4 Transport and port facilities | 62 |
| | 5.5 Penetrometers and canisters | 78 |
| 6 | INTERNATIONAL RULES AND REGULATIONS APPLICABLE TO THE SEA DISPOSAL OF RADIOACTIVE WASTE | 80 |
| | 6.1 Dumping | 80 |
| | 6.2 Seabed disposal | 83 |
| 7 | SURVEY OF THE MAIN R & D PROGRAMMES ON THE DISPOSAL OF NUCLEAR WASTE AT SEA | 89 |
| | 7.1 United States | 89 |
| | 7.2 United Kingdom | 89 |
| | 7.3 OECD/NEA | 92 |

Page

8 SUMMARY OF INDUSTRIAL OPPORTUNITIES 97

REFERENCES AND FOOTNOTES 98

LIST OF TABLES


| | | Page |
|---|---|---|
| Table 1 | The various types of radiation | 11 |
| Table 2 | Radioactive waste production in the nuclear fuel cycle: a US example | 15 |
| Table 3 | Projected waste arisings from Stage 1 of the decommissioning of Sizewell 'B' | 18 |
| Table 4 | Projected active waste arisings from Stage 2 of the decommissioning of Sizewell 'B' | 19 |
| Table 5 | Projected active waste arisings from Stage 3 of the decommissioning of Sizewell 'B' | 20 |
| Table 6 | Geological research related to waste disposal | 24 |
| Table 7 | Waste arising from commercial UK power reactors | 27 |
| Table 8 | Waste arising from UK fuel fabrication and reprocessing | 28 |
| Table 9 | Waste arising from nuclear and non-nuclear research, medical and industrial uses in the UK | 29 |
| Table 10 | Estimate of cumulative global and UK arisings of vitrified high-level waste, 1980, 1990 and 2000 | 30 |
| Table 11 | Disposal facilities justifying consideration in the UK | 35 |
| Table 12 | Proportion of radioactive waste disposed at sea by the NEA countries emanating from the UK, 1966-1982 | 41 |
| Table 13 | Amount of waste disposed at sea by the UK, 1966-1982 | 41 |
| Table 14 | Summary of sea disposal operations in the north east Atlantic under OECD/NEA, 1967-1982 | 42 |
| Table 15 | Regulations and codes of practice governing the transport of radioactive material in the UK | 76 |
| Table 16 | UK R & D expenditure on radioactive waste management, 1978-79 to 1982-83 | 90 |
| Table 17 | Main research contracts on the sea disposal of radioactive waste funded by the UK Department of the Environment, 1981-82 | 91 |

LIST OF FIGURES


| | | Page |
|---|---|---|
| Figure 1 | The essential features of uranium fission | 12 |
| Figure 2 | The nuclear fuel cycle | 16 |
| Figure 3 | Disposal of low-level radioactive waste in the former Asse salt mine in the Federal Republic of Germany | 22 |
| Figure 4 | Shallow burial of low activity waste at Cap de la Hague, France | 22 |
| Figure 5 | Low level reactor waste stored at the Muhleberg nuclear power plant in Switzerland | 23 |
| Figure 6 | Relationship between bodies dedicated to NIREX activities and other bodies in the structure for radioactive waste management in the UK | 33 |
| Figure 7 | Responsibility for nuclear health, safety and protection of the environment in the UK | 34 |
| Figure 8 | Outline UK programme for the development of disposal facilities | 36 |
| Figures 9 & 10 | Deep ocean disposal of low-level radioactive waste from nuclear establishments in the United Kingdom. | 37 |
| Figure 11 | Committee structure of the NEA for the Management of radioactive waste | 43 |
| Figure 12 | Map of the OECD/NEA dumping area in the north east Atlantic | 45 |
| Figure 13 | Radioactive residues incorporated homogeneously in a metal container | 46 |
| Figure 14 | Solid waste incorporated into a concrete matrix in a metal container | 46 |
| Figure 15 | Radioactive residues incorporated homogeneously in a metal container closed with a concrete cap | 46 |
| Figure 16 | Solid waste placed, after boiling, in a metal container, lined and filled with concrete | 46 |
| Figure 17 | Drum filled with solid or solidified waste, placed in a metal container with concrete lining and cap | 47 |
| Figure 18 | Solid waste incorporated into a metal drum placed within a concrete container | 47 |

| | | Page |
|---|---|---|
| Figure 19 | Barriers and transport media - sub-seabed disposal | 50 |
| Figure 20 | Possible schema for a reference disposal system | 52 |
| Figure 21 | Sub-seabed Disposal Programme - sediment penetrator emplacement concepts | 53 |
| Figure 22 | Sub-seabed Disposal Programme - drilled-hole emplacement concept | 53 |
| Figure 23 | Platform for an in-situ heat transfer experiment (ISHTE) | 55 |
| Figure 24 | Long core facility - penetrometer | 56 |
| Figure 25 | Long core facility - stages in penetration | 57 |
| Figure 26 | Map of the world showing boundaries of tectonic plates, and abyssal hill and swale regions | 61 |
| Figure 27 | Atlantic research areas for disposal of high level radioactive waste | 63 |
| Figure 28 | Seabed disposal transportation system | 64 |
| Figure 29 | Irradiated fuel being delivered to BNFL Sellafield Works | 64 |
| Figure 30 | Wet flask - Excellox transport flask | 66 |
| Figure 31 | Dry flask - TN12 Mark I transport flask | 66 |
| Figure 32 | Design of a 42 000 DWT chemical/product carrier | 68 |
| Figure 33 | Proposed high-level waste (HLW) disposal ship | 69 |
| Figure 34 | Plan view of the proposed HLW ship | 70 |
| Figure 35 | Midship section of the proposed HLW ship | 70 |
| Figure 36 | Structural member at midships in the proposed HLW ship | 71 |
| Figure 37 | Shipboard storage pool for HLW penetrometers in the proposed HLW ship | 71 |
| Figure 38 | Shipboard handling of HLW canisters in the proposed HLW ship | 72 |
| Figure 39 | Plan view of the HLW ship's hot cell and storage pool | 73 |
| Figure 40 | Penetrator (penetrometer) release mechanism | 74 |
| Figure 41 | Reference waste emplacement package | 79 |

LIST OF ABBREVIATIONS

| | |
|---|---|
| AEC | Atomic Energy Commission (United States) |
| AGR | Advanced Gas-cooled Reactor |
| AVM | Atelier de Vitrification de Marcoule (France) |
| BNFL | British Nuclear Fuels Limited |
| CANDU | Canadian Deuterium Uranium Reactor |
| CEA | Commissariat a l'Energie Atomique (France) |
| CEGB | Central Electricity Generating Board (UK) |
| DoE | Department of the Environment (UK) |
| EEZ | Exclusive Economic Zone |
| EPA | Environmental Protection Agency (United States) |
| EURATOM | European Atomic Energy Community |
| FCO | Foreign and Commonwealth Office (UK) |
| GESAMP | Joint Group of Experts on the Scientific Aspects of Marine Pollution |
| HLW | High Level Waste |
| IAEA | International Atomic Energy Agency |
| ICRP | International Commission on Radiological Protection |
| ILW | Intermediate (or Medium) level waste |
| IMO | International Maritime Organisation (formerly IMCO) |
| INFCE | International Fuel Cycle Evaluation |
| IOS | Institute of Oceanographic Sciences (UK) |
| ISA | International Seabed Authority |
| ISHTE | In-situ Heat Transfer Experiment |
| LCF | Long Core Facility (United States) |
| LDC | London Dumping Convention (Convention on the Prevention of Marine Pollution by dumping of Wastes or other Matter (London, 1972) |
| LLW | Low-Level Waste |
| LWR | Light Water Reactor |

| | |
|---|---|
| MAFF | Ministry of Agriculture, Fisheries and Food (UK) |
| MW | Megawatt |
| NEA | Nuclear Energy Agency of the OECD |
| NERC | Natural Environment Research Council (UK) |
| NIREX | Nuclear Industry Radioactive Waste Executive (UK) |
| NRPB | National Radiological Protection Board (UK) |
| OECD | Organisation for Economic Co-operation and Development |
| PWR | Pressurised Water Reactor |
| RWMAC | Radioactive Waste Management Advisory Committee (UK) |
| SDP | Sub-seabed Disposal Program (United States) |
| SSEB | South of Scotland Electricity Board (UK) |
| SWG | Seabed Working Group of the NEA |
| THORP | Thermal Oxide Reprocessing Plant (UK) |
| UKAEA | United Kingdom Atomic Energy Authority |
| UNCLOS I | First United Nations Conference on the Law of the Sea (Geneva, 1958) |
| UNCLOS III | Third United Nations Conference on the Law of the Sea (1973 - 1982) |
| UNTS | United Nations Treaty Series |

# 1 INTRODUCTION

For many years, waste management received fairly low priority in the nuclear energy programme, but it is now an area which is attracting increasing interest from both government and industry.

The future of nuclear power in many countries hinges on the demonstration by the nuclear industry that the waste generated can be disposed of in an acceptable way. Even those countries which are abandoning nuclear power are faced with a considerable waste problem, as they need to dispose not only of large quantities of contaminated materials and spent fuel, but also of the fabric of their existing power stations.

Solutions to the problem of radioactive waste disposal will have to be found in the near future. Industry has a key role to play in the development and implementation of national strategies for the disposal of radioactive waste.

Those taking an early lead in the field are likely to be assured of a substantial worldwide market. This report has been prepared to review the state of the art, to review current developments and to identify industrial opportunities in the UK in the field of disposal of nuclear waste at sea.