

CONTENTS

EXECUTIVE SUMMARY	1
1. INTRODUCTION	15
1.1. Purpose	15
1.2. Perspective	15
1.3. Structure of the book	21
References	21
2. TYPES AND PROPERTIES OF RADIOACTIVE WASTES	23
2.1. Nature of radioactivity	23
2.2. Radioactive waste definition	23
2.3. Waste classification	24
2.4. Sources and characteristics of radioactive wastes	29
2.4.1. Nuclear fuel cycle	29
2.4.1.1. Mining and milling wastes	33
2.4.1.2. Enrichment and fuel fabrication	36
2.4.1.3. Power reactor wastes	36
2.4.1.4. Spent fuel; high level wastes	37
2.4.2. Research reactors	43
2.4.3. Radionuclide applications	43
2.4.4. Decommissioning wastes	44
2.4.5. Special cases and radioactive mixed wastes	45
References	47
3. RADIOACTIVE WASTE MANAGEMENT, STRATEGIES AND QUALITY ASSURANCE	49
3.1. Systems approach	49
3.1.1. Subsystems of radioactive waste management	51
3.1.2. System optimization	51
3.2. Implications of different industrial and fuel cycle choices	54
3.3. Methodologies	56
3.4. Quality assurance	57
3.5. Conclusions	58

4.	PROTECTION GOALS	59
4.1.	Bases and objectives	60
4.1.1.	The ICRP principles for radiation protection	60
4.1.2.	Protection of the environment	61
4.1.3.	Protection of future generations	61
4.2.	Protection of individual members of the public	62
4.3.	Protection of the general population	63
4.4.	The application of dose limits to rare events	66
4.5.	Alternative protection perspectives	67
4.6.	Protection from toxic chemicals in the wastes	69
	References	70
5.	RADIOACTIVE WASTE MANAGEMENT PRIOR TO DISPOSAL	73
5.1.	Introduction	73
5.2.	Operations preceding treatment or conditioning	74
5.2.1.	Waste generating processes	74
5.2.2.	Segregation at the source	74
5.2.3.	Size reduction	75
5.2.4.	Decontamination	75
5.2.5.	Collection, on-site transport and storage	75
5.3.	Treatment and conditioning	79
5.3.1.	Wastes not requiring treatment or conditioning	79
5.3.2.	Treatment processes	79
5.3.2.1.	Gaseous effluents	80
5.3.2.2.	Aqueous effluents	80
5.3.2.3.	Solid wastes	81
5.3.3.	Conditioning processes	84
5.3.3.1.	Spent fuel	85
5.3.3.2.	High level waste	85
5.3.3.3.	Low and intermediate level and alpha contaminated wastes	90
5.3.4.	Characterization of conditioned waste	94
5.3.5.	Special types of waste	94
5.3.6.	Conclusion on treatment and conditioning	95
5.4.	Transportation	96
5.4.1.	Introduction	96
5.4.2.	The IAEA recommendations	97
5.4.3.	Packaging and package testing	97
5.4.4.	Experience in transport	98

5.5.	Storage	100
5.6.	Decommissioning of nuclear facilities	104
5.6.1.	Safety of decommissioning of large nuclear power plants	108
5.6.2.	Decommissioning operations	110
5.6.3.	Decommissioning costs	111
5.7.	Summary and conclusions	111
	References	112
6.	DISPOSAL	115
6.1.	Introduction	115
6.2.	Shallow land disposal	116
6.2.1.	Near surface burial	116
6.2.1.1.	Near surface non-engineered burial	117
6.2.1.2.	Near surface engineered burial	117
6.3.	Subsurface disposal	119
6.3.1.	Asse, Germany	119
6.3.2.	SFR, Sweden	119
6.3.3.	Konrad, Germany	120
6.3.4.	Others	124
6.4.	Geological disposal	124
6.4.1.	Rock salt: bedded salt or salt domes	127
6.4.2.	Granite and other hard rock formations	129
6.4.3.	Argillaceous sediments	132
6.4.4.	Tuff	135
6.5.	Sea-bed disposal	136
6.6.	Sea dumping	136
6.7.	Long term performance of the 'multibarrier' isolation system for HLW	139
6.7.1.	Waste form	139
6.7.2.	Canister	139
6.7.3.	Buffer and backfill	141
6.7.4.	Host rock	141
6.7.5.	Overlying layers	141
6.8.	Licensing procedures	142
6.9.	Alternative disposal options	144
6.10.	Uranium tailings	145
	References	146

7.	LONG TERM ASSESSMENT OF WASTE DISPOSAL SYSTEMS ..	149
7.1.	Introduction	149
7.2.	Methodology	151
7.3.	Current understanding and data availability	157
7.4.	Validation and demonstration	163
7.5.	Natural analogues and their role in assessments	164
7.6.	Comparison of assessment results with protection goals	165
7.7.	Applicability to other disposal options	169
7.8.	Summary	169
	References	170
	Bibliography	172
8.	INSTITUTIONAL ASPECTS	173
8.1.	Introduction	173
8.2.	Legislative framework	173
8.3.	National authorities	174
8.3.1.	National infrastructure for waste management	174
8.3.1.1.	Laws and regulations	175
8.3.1.2.	Implementing organizations	175
8.3.1.3.	Licensing, regulatory and controlling authorities	176
8.3.1.4.	Funding of waste management	177
8.3.2.	Environmental and natural resource protection	177
8.3.3.	Radiation (public health) protection	178
8.3.4.	Safety of installations	178
8.3.5.	Fissile materials accountability and control	178
8.4.	Post-closure aspects and institutional control	179
8.5.	Radioactive mixed wastes	181
8.6.	International and multilateral co-operation	181
	References	182
9.	SOCIOPOLITICAL AND ETHICAL CONCERNS	183
9.1.	Introduction	183
9.2.	Fundamental concerns	184
9.3.	Conflicting technical and political rationales	185
9.4.	Ethical aspects of disposal	186
9.4.1.	Nature of uncertainties with regard to radioactive wastes	186
9.4.2.	The time perspective	187
9.4.3.	Arriving at ethical assessments	188

9.4.4.	Responsibilities to future generations	189
9.4.4.1.	General considerations	189
9.4.4.2.	Considerations in the timing of the shift from storage to disposal	191
9.5.	Ethical issues in site selection	193
9.6.	Conclusions	194
9.7.	Further reading	195
	References	196
10.	PUBLIC UNDERSTANDING AND ACCEPTANCE	197
10.1.	Introduction	197
10.1.1.	Why is public acceptance necessary?	197
10.1.2.	The major challenges	198
10.2.	Methodology and techniques for communication	200
10.2.1.	Communication based on research, analysis, communication and evaluation (the RACE formula) ...	200
10.2.2.	Research	201
10.2.3.	Analysis	201
10.2.4.	Communication	203
10.2.5.	Evaluation	203
10.3.	Various audiences and their interests	204
10.3.1.	The general public	204
10.3.2.	National and state governments	204
10.3.3.	Regulatory agencies	205
10.3.4.	Local communities	205
10.3.5.	The media	206
10.3.6.	Environmental groups	206
10.3.7.	Special interest groups	207
10.3.8.	Employees in the nuclear industry	207
10.3.9.	Opinion leaders	207
10.4.	Public participation	207
10.4.1.	Judicial and other reviews	210
10.5.	Site selection	211
10.5.1.	Risk perception and the volunteer community method	211
10.5.2.	Economic incentives	212
10.6.	General recommendations and conclusions	214
	References	214

11. ACTIVITIES OF INTERNATIONAL, MULTINATIONAL AND INTERGOVERNMENTAL ORGANIZATIONS AND AGENCIES	217
11.1. Introduction: Responsibilities of international organizations	217
11.2. International Atomic Energy Agency (IAEA)	217
11.2.1. Responding to needs of developing countries	220
11.2.1.1. Technical co-operation (TC)	220
11.2.1.2. Co-ordinated research programmes	221
11.2.1.3. Training courses and study tours	221
11.2.1.4. Standard design concept	221
11.2.1.5. Management of spent radiation sources	221
11.2.1.6. Radioactive Waste Management Advisory Programme (WAMAP)	221
11.2.2. New initiatives	222
11.2.2.1. Waste Management Assessment and Technical Review Programme (WATRP) ...	223
11.2.2.2. Waste Processing and Storage Facility (WPSF)	223
11.2.2.3. Waste Management Database (WMDB)	224
11.3. International Labour Organisation (ILO)	224
11.4. Commission of the European Communities (CEC)	225
11.4.1. Radioactive waste research and technological development	226
11.4.2. Plan of Action in the Field of Radioactive Waste	227
11.4.3. Article 37 of the Euratom Treaty	227
11.4.4. Council Directive on the Assessment of the Effects of Certain Public and Private Projects on the Environment	228
11.4.5. Council Directive on Informing the General Public about Health Protection Measures to be Taken in the Event of a Radiological Emergency	228
11.5. OECD/NEA	229
11.6. United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR)	230
11.7. World Health Organization (WHO)	231
11.8. United Nations Environment Programme (UNEP)	232
References	233
APPENDIX 1. DEFINITION OF TERMS	235
APPENDIX 2. LIST OF IAEA DOCUMENTS ON RADIOACTIVE WASTE MANAGEMENT	249
CONTRIBUTORS TO DRAFTING AND REVIEW	273